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Recommended data exchange conceptual model for Europe

D5.1

EU-SysFlex

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ABBREVIATIONS AND ACRONYMS

ACSE	Association Control Service Element
AI	Artificial Intelligence
AIS	Account Information Service
AISP	Account Information Service Provider
API	Application Programming Interface
ASPSP	Account Servicing Payment Service Providers
AU	Italian: Acquirente Unico
BACnet	Building Automation and Control network
BRP	Balance Responsible Party
BSP	Balancing Service Provider
BUC	Business Use Case
CAF	Confirmation of the Availability of Funds
CCPA	California Consumer Privacy Act
CEN	French: French: Comité Européen de Normalisation; English: European Committee for Standardisation
CENELEC	French: Comité Européen de Normalisation Électrotechnique; English: European Committee for Electrotechnical Standardisation
CGMES	Common Grid Model Exchange Standard
CIM	Common Information Model
CMS	Central Market System
CSV	Comma Separated Values
DEP	Data Exchange Platform
DER	Distributed Energy Resources
DPO	Data Platform Operator
DRMS	Demand Response Management System
DSO	Distribution System Operator
DSR	Demand Side Response
ebIX	European forum for energy Business Information eXchange
EC	European Commission
ECCo SP	ENTSO-E Communication & Connectivity Service Platform
EDSN	Dutch: Energie Data Services Nederland
EFET	European Federation of Energy Traders
EMC/EMI	Electromagnetic interference (EMI) and electromagnetic compatibility (EMC)
EMM	Energy Market Management
EMS	Energy Management System
ENTSO-E	European Network of Transmission System Operators for Electricity
ERRP	ENTSO-E Reserve Resource Process
ESCO	Energy Service Company
ESMP	European Style Market Profile
ETSI	European Telecommunications Standards Institute
EU	European Union
EU-SYSFLEX	Pan-European System with an efficient coordinated use of flexibilities for the integration of a large share of Renewable Energy Sources (RES)
EV	Electrical Vehicle
FinTech	Financial Technology

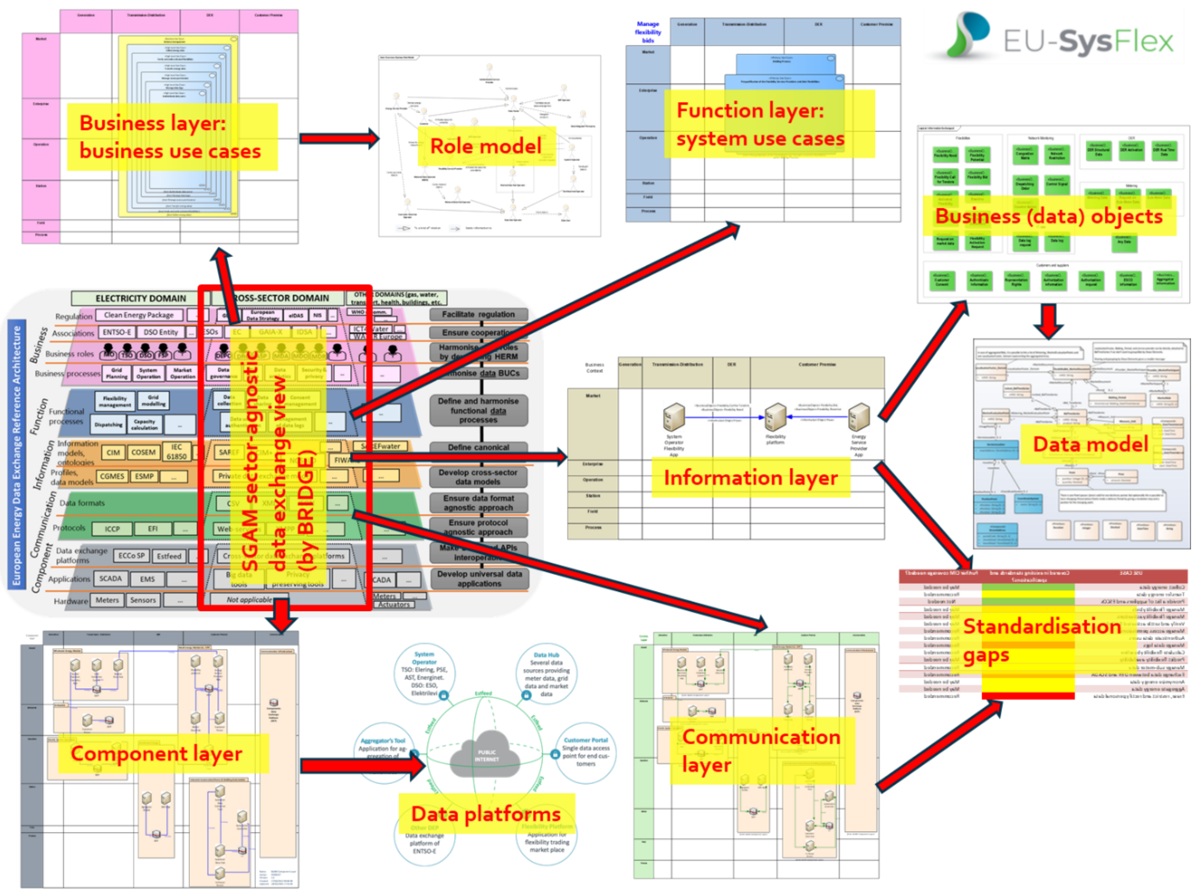
FSP	Flexibility Service Provider
GA	Grant Agreement
GB	Green Button
GDPR	General Data Protection Regulation
HEMRM	Harmonized Electricity Market Role Model
HLUC	High Level Use Case
HTTP	Hypertext Transfer Protocol
ICCP	Inter-Control Center Communications Protocol
ICT	Information and Communication Technology
IEC	International Electrotechnical Commission
IEM	Internal Electricity Market
IoT	Internet of Things
IP	Internet Protocol
IT	Information Technology
KNF	Polish: Komisja Nadzoru Finansowego (Polish Financial Supervision Authority)
MAC	Medium access control layer of the Open Systems Interconnection
MDMS	Meter Data Management System
mDNS	Multicast Domain Name Service
MO	Market Operator
NAESB	The North American Energy Standards Board
N/A	Not Applicable
NBS	Nordic Balance Settlement (eSett)
n.d.	no date
OGD	Open Government Data
OECD	Organisation for Economic Co-operation and Development
OFDM	frequency division multiplexing
OO	Optimisation Operator
OPC	Open Platform Communications
OPC UA	OPC Unified Architecture
PHY	Physical layer
PIS	Payment Initiation Service
PISP	Payment Initiation Service Provider
PMB	Project Management Board
PRIME	PoweRline Intelligent Metering Evolution
PSD2	Revised Payment Services Directive
PSI Directive	Directive on Re-Use of Public Sector Information
PUC	Primary Use Case
RES	Renewable Energy Sources
RSC	Regional Security Coordinator
SCA	Strong Customer Authentication
SCADA	Supervisory Control and Data Acquisition
SGAM	Smart Grid Architecture Model
SGU	Significant Grid User
SHIP	Smart Home IP
SMTP	Simple Mail Transfer Protocol,
SO	System Operator

SOAP	Simple Object Access Protocol
SPI	Small Payment Institutions
SPINE	Smart Premises Interoperable Neutral Message Exchange
SSL	Secure Sockets Layer
SUC	System Use Case
TBD	To Be Defined
TPP	Third Party Providers
TSO	Transmission System Operator
UMIG	Utility Market Implementation Guidelines
UML	Unified Modelling Language
UNCTAD	United Nations Conference on Trade and Development
VPP	Virtual Power Plant
WP	Work Package
XML	Extensible Markup Language

EXECUTIVE SUMMARY

In its specific meaning, a data model explicitly determines the structure of data, "organizes elements of data and standardizes how they relate to one another and to the properties of real-world entities"[1]. However, in the context of this report more conceptual approach for data model is applied to address different layers of interoperable data exchange. This is based on SGAM (Smart Grid Architecture Model) and its five interoperability layers – Business Layer, Function Layer, Information Layer, Communication Layer, Component Layer. This report mainly builds on the data exchange business use cases (Business Layer) and data exchange system use cases (Function Layer) described in other EU-SysFlex documents[2], it proceeds to provide further insights into data (semantic) models (Information Layer), models' translation into formats and protocols (Communication Layer), data platforms (Component Layer), regulatory requirements (Business Layer) as well as data exchange business roles (Business Layer) and system roles (Function Layer).

The data exchange conceptual model to be recommended to Europe combines the concepts described in this deliverable and in other associated EU-SysFlex data exchange deliverables with the data exchange reference architecture proposed by BRIDGE Initiative:



[1] https://en.wikipedia.org/wiki/Data_model
[2] See here in WP5 section: https://eu-sysflex.com/documents/.

The need for such European level approach comes from the fact that (energy) data still does not flow without major obstacles across country borders (and across sectors). It has been recognised widely (for example by European Commission's Smart Grid Task Force) that a way to address this issue would be through the interoperability requirements. In this report EU-SysFlex proposes a generic model in order to address the interoperability at any level and start agreeing the common approach. European approach is the precondition to complete single energy market as well as to contribute to single digital market.

Data exchange conceptual model for Europe recommended by EU-SysFlex indicates the needs and specific solutions to extend and adjust the already well-known concepts like Smart Grid Architecture Model, Harmonised Role Model, Common Information Model. Crucial elements of the model are reliance on well-defined data exchange system use cases and data exchange platforms. But it all starts by agreeing the high-level methodological approach and common vocabulary. Details cannot be discussed, i.e. full interoperability ensured, while speaking different languages.

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First, the **legal context** is reviewed to understand the legal requirements regarding data access and data exchange in more general which might be facilitated inter alia by Data Exchange Platforms (DEPs). It serves as background information for developing European data exchange model. Also, more specifically the attempt has been made to link these legal requirements to EU-SysFlex use cases and demonstrators.

Ten EU legal texts for energy sector were reviewed and 74 articles in total were identified relevant for data exchange and where DEP can support to fulfil respective legal requirement. Out of these cases 66 are covered by EU-SysFlex – either through data exchange system use cases or data exchange business use cases.

DEP can ensure easy and non-discriminatory access to data and via DEP to different energy services, including flexibility services. DEP can enable consent management (access permissions), secure data exchange and access. DEP can provide in compliance to GDPR (General Data Protection Regulation) different types of data easily and simultaneously to different types of stakeholders, incl. final customers themselves. Different DEPs should be able to communicate with each other, it makes possible cross-border data exchange respecting different countries legal restrictions. DEP can facilitate TSO (transmission system operator) and DSO (distribution system operator) tasks on data management and digitalization, as well as TSO-DSO cooperation.

Beside energy legislation there are several 'generic' European legal acts for data management. The *personal information* protection regulation and technologies are to ensure data processing and sharing while maintaining security. DEP is a communication platform for secure data exchange and the area of data protection and privacy for individual citizens is included in EU-SysFlex data exchange requirements and use cases. *Open data* regulation is relevant for some EU-SysFlex data exchange use cases like 'Transfer energy data', 'Aggregate energy data', 'Anonymize energy data'. Also, DEP can comply with the requirements contained in regulation on a framework for the free flow of *non-personal data*.

Energy could learn from banking. Banking industry is undergoing profound changes: digitization, service integration and, most importantly, the emergence of FinTechs (Financial Technologies). Despite competition, new networks of connections emerge that can create new services. However, the pace of changes is still determined by banks – FinTechs have not yet reached the appropriate critical mass. For energy industry, there are the following conclusions: need to educate, encourage, and support new service providers; building a partnership ecosystem requiring several coordinated actions. However, in the area of standardisation of technical solutions, energy sector is more mature and able to develop a consistent set of standards based among others on single and common information model like CIM (Common Information Model).

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EU has declared that validated historical consumption data shall be made available to final customers on request, easily and securely and at no additional cost (Directive 2019/944). To comply with this, several countries are currently implementing solutions for access to and exchange of meter data, incl. central national data hubs but there are also several countries that already have implemented similar solutions earlier. Beside central solutions also more decentralized options exist (e.g. in Austria) for meter data access and exchange, but were not interviewed for this study. The intention of this report is not to evaluate the benefits on central solutions compared to decentral solutions (and vice versa). As this comparison is beyond the scope no evaluation and no recommendation towards a central or decentral solution are given. It rather evaluates the benefits of easy data access and exchange as such. Regardless of the level of (de)centralisation all solutions need to be interoperable inside the given country as well as across borders in coming years.

The aim with the report is to investigate the key characteristics of some European '**data access&exchange platforms'** today and in the future with an emphasis on how they are governed and which markets and stakeholders they support. To comply with the aim, several interviews have been performed with data platform operators (DPOs) with additional questionnaire for them to fill in regarding their status quo and future plans. The information from DPOs has been supplemented with information from relevant reports to provide a complete picture. The term 'data (access&exchange) platform' captures the concepts of both 'data hub'[3] and 'data exchange platform' (DEP)[4], in most cases data hub acting also as DEP.

The results show that the data platforms are owned and operated by TSOs and DSOs mainly today where the aim to large extent is to be an independent party providing secure, reliable and qualitative data for different

[3] 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. Data Hubs are not necessarily centralized in a country or in a region. (EU-SysFlex D5.2, 2020)

[4] Data exchange platform (DEP) is a communication platform the basic functionality of which is to secure data transfer (routing) from data providers (e.g. data hubs, flexibility service providers, TSOs, DSOs) to the data users (e.g. TSOs, DSOs, consumers, suppliers, energy service providers). DEP stores data related to its services (e.g. cryptographic hash of the data requested). The DEP does not store core energy data (e.g. meter data, grid data, market data) while these data can be stored by data hubs. Several DEPs may exist in different countries and inside one country. (EU-SysFlex D5.2, 2020)

stakeholders. The limited answers from the DPOs in terms of which business use cases (BUCs) and system use cases (SUCs) are managed in respective data platforms also confirm that the core business for data platforms (i.e. data hubs in most cases) is to provide *access to data for different stakeholders*.

There is also a distinction between the data platforms that integrate smaller customers to use and benefit from the services and data platforms that mainly provide benefits to larger stakeholders. The data platforms in the Nordic countries, Estonia and the Netherlands are examples of more electricity end-customer (consumers, prosumers) oriented solutions whereas the Belgium and the Italian data platforms are more focused on suppliers and balance responsible parties (BRPs) to facilitate their business processes.

The future of the data platforms according to the DPOs lies in a mix between the focus on today's business but also to enable a more market-oriented business where all kinds of consumers and generators can benefit from the data platforms. There is also a focus to include more and other types of data and/or allow third party applications to connect to the data platform, *inter alia*, to be part of the flexibility market for the energy system. The interviewed data platforms have in general a focus on national data access and exchange, but the Nordic countries and the Data Bridge Alliance initiative are two examples where data platforms in different countries work together (or plan to work together) for a cross-border data exchange collaboration.

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Beside data platforms, various existing **data exchange models** used in the energy domain are described from the technical perspective. Both data models and data protocols are captured. A list of selected models consists of the main standards that are used in the industry.

State of the art is the Common Information Model, supported by ENTSO-E and standardised by IEC. IEC 61850 is another standard that defines the communication between devices in the substation and related systems requirements. DLMS/COSEM standard, developed by IEC and DLMS Association, has been established for meter data exchange. Green Button is a specification used in the US and introduced in Canada to allow utility companies to present in a standardised form.

Estfeed solution created by Elering and Cybernetica is to securely and verifiably exchange data between the parties interconnected to the DEP. German industry initiative called EEBUS specification enables developing a future-proof, maintainable, and simple device interface, whether for connection to local energy management or the world of numerous platforms in Smart Home & Building.

As an outcome of this work, the report contains the technical aspects of data exchange models to help decision-makers to navigate various standards that enable interoperability. All the described standards are mapped against the SGAM model, a state-of-art framework for Smart Grid architecture.

Throughout this work, 14 standards and protocols were analysed. Compared to CIM, other standards provide a rather narrow, case-specific view on data models. Nevertheless, described data models share some general commonalities: most data models are maintained in UML and have XML as the preferred serialisation format, sometimes different models reflect the same aspects of the power system, mostly equipment and measurements.

Most widely used data models by EU-SysFlex demonstrators are CIM CGMES (Common Grid Model Exchange Standard), CIM ESMP (European Style Market Profile), IEC 60870 (101 or 104 or TASE.2 ICCP), IEC 61850 and OPC UA (Open Platform Communications Unified Architecture).

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The data exchange **role model** based on EU-SysFlex data exchange SUCs has been elaborated describing how Business Roles interact with one another and which data they exchange. The objective of this data exchange role model is to relate Business Roles with the already existing roles from the HEMRM – Harmonised Electricity Market Role Model (ENTSO-E, EFET and ebIX®, 2020)[5] and to identify new Business Roles motivated by business/market or IT/data needs.

The analysis led to the definition of a data exchange role model built on the scenarios of data exchange SUCs and the Business Roles who operate the involved systems or interact with them. It is called data exchange role model because the focus was on data exchange and many new roles identified are about 'data exchange roles' which are agnostic to specific market processes. However, in this process also 'market roles' could not be ignored and some new were proposed.

Most of the identified Business Roles can be mapped, fully or mostly, to the HEMRM. The other ones reflect the new business and IT needs. The new roles proposed include Authentication Service Provider, Customer Portal Operator, Data Delegated Third Party, Data Owner, Data User, DEP Operator, Flexibility Service Provider (FSP), Foreign Customer Portal Operator and Optimization Operator (OO).

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Finally, the data exchange SUCs are modelled according to SGAM using a dedicated SGAM Toolbox. Each layer of the **SGAM framework** has been modelled although the SUCs lacked some information related to physical components, data model and communication protocols. The model could be further completed, especially with information about data model standards and communication protocols.

The business layer identifies the Business Actors, their Business Goals and the corresponding Business Cases which are the ways Business Actors reach their goals. In function layer, the main objective is to decompose High Level Use Cases into several Primary Use Cases (PUCs). PUC identifies the Logical Actors and offers also a dynamic view of the

[5] https://www.entsoe.eu/digital/cim/role-models/

use case through activity and sequence diagrams. Each PUC offers a link to the EU-SysFlex data exchange SUCs' activity diagrams.

The component layer presents two kinds of information: a mapping of the logical actors to physical (real) components; and electrical and ICT (Information and Communication Technology) links between the components. To identify the links between the components, it is checked if the equivalent system actors in the SUCs are exchanging information. This can be derived from the activity diagrams, for example. ICT links between components were identified only, and not electrical links. However, this is fully acceptable and even desirable as the purpose of this modelling exercise is to propose data exchange model.

In information layer, two kinds of information can be found: Business context view; and standard and information object mapping. The data exchange SUCs identify the business objects exchanged between the actors. The data exchange SUCs don't refer explicitly to any standards. The (canonical) data model standards that are mentioned in this layer are the ones used by the EU-SysFlex demonstrators. The communication layer provides information on the communication links between the components and the (standardised) communication protocols on which they rely. Since no communication protocol information is clearly provided in the data exchange SUCs, only the communication links between components is modelled and communication protocol are not referenced.

1. INTRODUCTION

According to the Description of Action (DoA) the outcome of task 5.1 is conceptual data exchange model for the pan-European system with descriptions, including functionalities, processes, roles and services. The model does not imply a single data exchange platform but rather allows for interoperability of different platforms across Europe.

Data regarding electricity consumption has never before been as abundantly generated as it is now in the era of Big Data and therefore can be a valuable source of information to balance supply with demand or manage network congestions. While the topic of metering data processing has been addressed and regulated, this is not the case with access and sharing (including across the borders) of end user electricity consumption data. The situation regarding collecting and processing consumption data varies across states in terms of regulation and across energy providers in terms of advancement in adoption of information technology. It is a challenge to develop a single homogenous model or a set of rules to fit all. Requirements of network codes and new market design legislation need to be considered when developing data exchange model.

Elaboration of data exchange model is based on data exchange SUCs as identified and described in EU-SysFlex D5.2 (2020). The model is closely linked with the concepts and results of other data management deliverables: proposals for standardisation and CIM modelling (EU-SysFlex D5.5, 2021), data privacy and security considerations (EU-SysFlex D5.4, 2021), big data analysis and case studies (EU-SysFlex D5.3, 2020). The core of all these reports considers data exchange platform as the facilitator of any data exchange. However, while these platforms support distributed data exchange, most of the results are equally applicable to other types of data exchange (i.e. centralised and bilateral).

DEP is a communication platform the basic functionality of which is to secure data transfer (routing) from data providers (e.g. data hubs, FSPs, TSOs, DSOs) to the data users (e.g. TSOs, DSOs, consumers, suppliers, energy service providers). DEP stores data related to its services (e.g. information about data logs, cryptographic hash of the data requested). The DEP does not store core energy data (e.g. meter data, grid data, market data) while these data can be stored by data hubs. Several DEPs may exist in different countries and inside one country.

Structure of the report:

- Chapter 2 reviews European level legal requirements to energy data exchange.
- Chapter 3 analyses the market and governance of several existing European data platforms.
- Chapter 4 provides synthesis of some data exchange models, incl. overview of data models used by EU-SysFlex demonstrators.
- Chapter 5 presents a data exchange role model.
- Chapter 6 summarises the work done in EU-SysFlex data management work packages by providing a comprehensive SGAM based data exchange model.

2. REGULATORY REQUIREMENTS OF ENERGY DATA EXCHANGE

The objective of this chapter is to understand the legal requirements regarding data access and data exchange in more general which might be facilitated inter alia by DEPs. Therefore, relevant legal aspects related to data management have been identified. It serves as background information for developing European data exchange model. Also, more specifically the attempt has been made to link these legal requirements to EU-SysFlex use cases and demonstrators.

Annex I presents in a summarized way the articles associated to data management (referring to specific paragraphs). Focus is on key EU directives and regulations, including network codes and taking into account the amended texts resulting from Clean Energy Package.

Further information cyber security and data protection are addressed in EU-SysFlex D5.4 (2021).

2.1 DATA MANAGEMENT IN EU ENERGY LEGISLATION

Ten EU legal texts for energy sector were reviewed and 74 articles in total were identified relevant for data exchange and where DEP can support to fulfil respective legal requirement. Out of these cases 66 are covered by EU-SysFlex – either through data exchange system use cases or data exchange business use cases.

Legal texts reviewed:

- Directive on Common Rules for the Internal Market in Electricity, http://data.europa.eu/eli/dir/2019/944/oj
- Regulation on the Internal Market for Electricity, http://data.europa.eu/eli/reg/2019/943/oj
- Directive on Energy Efficiency, https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1565862934624&uri=CELEX:02012L0027-20190612
- Guideline on Electricity Balancing, http://data.europa.eu/eli/reg/2017/2195/oj
- Guideline on System Operation, http://data.europa.eu/eli/reg/2017/1485/oj
- Network Code on Demand Connection, http://data.europa.eu/eli/reg/2016/1388/oj
- Network Code on Requirements for Grid Connection of Generators, http://data.europa.eu/eli/reg/2016/631/oj
- Network Code on Electricity Emergency and Restoration, http://data.europa.eu/eli/reg/2017/2196/2017-11-28
- Guideline on Capacity Allocation and Congestion Management, http://data.europa.eu/eli/reg/2015/1222/oj
- Regulation on Submission and Publication of Data in Electricity Markets, http://data.europa.eu/eli/reg/2013/543/oj

While the major content is provided in a way of a table (see Annex I) here is some guidance how to read it:

- The title of the article is exact text from the regulation but occasionally extensions in parenthesis have been added for better understanding of the scope of the respective article.
- The content provided is not always the full quote in order to simplify the reading by leaving out less relevant parts of the text (like references to other articles or paragraphs not focusing on data management).
- Second column of the table answers to question whether the requirements in respective article could be supported by a DEP.
- Third column includes references to EU-SysFlex data exchange SUCs identified and described in deliverable 5.2 (2020) and data exchange BUCs as demonstrated in Work Package 9. It refers to the BUC only if the respective article would be at least partially demonstrated.

Summary of DEP potential to address European legal requirements:

- DEP can ensure easy access to data and via DEP to different energy services
- DEP if properly managed can ensure non-discriminatory access to data
- DEP can enable consent management (access permissions), secure data exchange and access
- DEP can provide in compliance to GDPR different types of data easily and simultaneously to different types of stakeholders, incl. final customers themselves
- Comparison tools can be connected with DEP thereby providing them necessary data and enabling consumers to find and choose between tools
- DEP can link 'consumer energy management systems' to data from certified meters
- Different DEPs should be able to communicate with each other, it makes possible cross-border data exchange respecting different countries legal restrictions
- DEP can be used for transferring data for publication
- DEP can facilitate TSO and DSO tasks on data management and digitalization
- DEP can facilitate TSO-DSO cooperation
- DEP can facilitate access to meter data from both certified meters and sub-meters necessary for demand response
- DEP can facilitate easy access to flexibility market
- DEP can facilitate data exchange between FSP, market operator and system operator (SO)
- Through DEP all technologies providing flexibility can provide and receive data necessary to participate in the flexibility market
- DEP can be used to integrate different market platforms
- DEP can be used for exchanging flexibility bids, flexibility needs, activation requests, data necessary for prequalification of flexibility providers, data necessary for verification of flexibility activations, flexibility availability
- DEP can be used to exchange data necessary for identifying congestions in the grid and setting limits
- DEP can be used for data exchanges necessary for system operation between TSOs, DSOs and SGUs
- DEP could be used for some data exchanges in emergency, blackout or restoration states

2.2 GENERIC EU DATA LEGISLATION

2.2.1 PRIVATE DATA

The EU's GDPR emphasises the importance of privacy protection and has a global impact. Similar activities are undertaken in other parts of the world. According to the data[6] provided by United Nations Conference on Trade and Development, 66% of the countries have legislation on data privacy, 10% have draft legislation, 19% have no legislation, and no data for the rest.

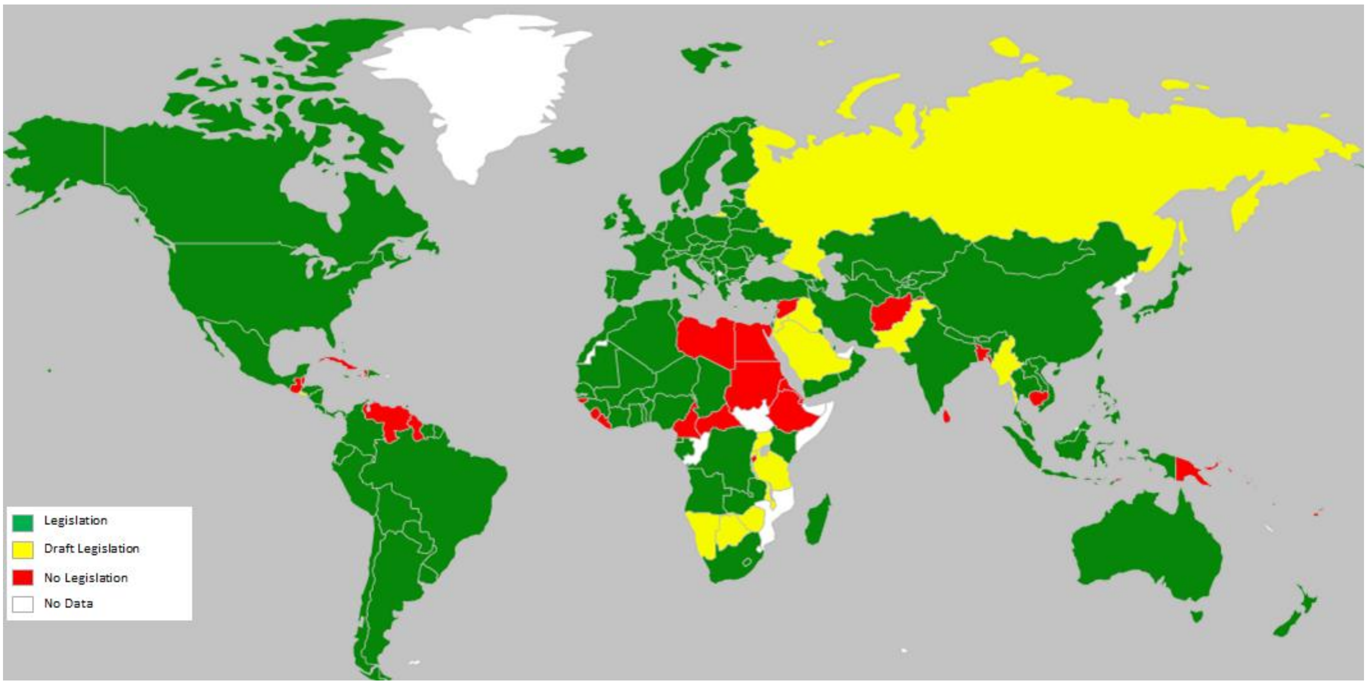

FIGURE 1: DATA PROTECTION AND PRIVACY LEGISLATION WORLDWIDE (REDRAWN FROM UNCTAD, 2020)[6]

This creates a global set of privacy laws, which are not always consistent. For example: California Consumer Privacy Act (CCPA), like GDPR, specifies civil remedies for individuals in the case of privacy violation, however it is only allowed when: "nonencrypted and nonredacted personal information was stolen in a data breach as a result of the business's failure to maintain reasonable security procedures and practices to protect it". [7] According to the EU data privacy regulation each data subject has the right to claim, without additional conditions, after any violation of the law[8].

Adapting to the regulations in force is a challenge for organizations that process personal data of citizens, clients, and employees. The consequence of the violation of law may be not only the penalties specified in the regulation but also the loss of reputation and loss of customers.

[6] https://unctad.org/page/data-protection-and-privacy-legislation-worldwide
[7] https://oag.ca.gov/privacy/ccpa
[8] https://eur-lex.europa.eu/eli/reg/2016/679/oj

The need for compliant processing of private data has created a demand for privacy-enhancing computation. Gartner identifies three types of technologies that protect personal information data (Smith et al., 2021):

- Trusted environments in which sensitive data can be processed or analysed.
- Decentralized processing and analytics (also with the use of machine learning).
- Transformation of data and algorithms before processing or analytics.

2.2.2 THE NEXT GENERATION CLOUD FOR EUROPE

Cloud and edge computing services are becoming critical infrastructure underpinning the digital transformation of European economy and society. That is why the Commission put particular emphasis on the development of EU next generation cloud computing technologies[9].

EC's 'Digital Decade' Communication (2021)[9] specifies that the absorption of cloud computing services should increase to 75% of European enterprises in 2030 (2020 baseline is 26%).

One of the actions to achieve the above-mentioned objective is the establishment of the European Alliance for Industrial Data, Edge and Cloud[10]. The Alliance aims to foster technologies that are highly secure, distributed, fully interoperable, resource-efficient and trusted by cloud users from society, businesses and public administrations.

Also Gartner predicts the empowering of cloud, especially, distributed cloud (Smith et al., 2021). The distributed cloud means that public cloud providers manage services in different physical locations (also in customer sites or data centres). The source of this trend are the needs of:

- Low latency in data transfer.
- Reduction of cost of transferring large data sets.
- Processing data in a specific location to comply with regulations.

The first two needs are met by edge computing where information is processing closer to the information sources (for example: smart meters, IoT (Internet of Things) devices or high-speed trading) and does not flow to central processing nodes. Data processing in a specific physical place is possible using hybrid or private cloud computing forms.

Distributed cloud combines public, private, hybrid clouds and edge computing. The hybrid IT environment created in this way allows the use of existing resources, also on-premises, along with new technologies and services.

Several cases of using the cloud computing have been described in the EU-SysFlex D5.3 (2020). Some of them e.g., aggregator considered 100 000 devices located in the same region, directly fit into the edge computing model. This

[9] https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:52021DC0118
[10] https://digital-strategy.ec.europa.eu/en/policies/cloud-alliance

means that the needs exist, but there is no technology available to meet them – migration of a solution built based on a public cloud to the distributed cloud edge computing model should be easy.

2.2.3 OPEN DATA

Open data is data that anyone can access, use, and share. Governments, businesses, and individuals can use open data to bring about social, economic, and environmental benefits. Open data becomes usable when made available in a common, machine-readable format. Open data must be licensed. Its license must permit people to use the data in any way they want, including transforming, combining, and sharing it with others, even commercially.

Open government data is data collected by public sector. According to the Organisation for Economic Co-operation and Development (OECD)[11]: "Open Government Data (OGD) is a philosophy – and increasingly a set of policies – that promotes transparency, accountability and value creation by making government data available to all. Public bodies produce and commission huge quantities of data and information. By making their datasets available, public institutions become more transparent and accountable to citizens. By encouraging the use, reuse and free distribution of datasets, governments promote business creation and innovative, citizen-centric services".

OECD conducts OGD maturity studies. It comprises three Pillars: Data availability (open by default policy, stakeholder engagement, increasing availability), Data accessibility (unrestricted access, quality, real implementation), Government support to the re-use (promotion initiatives and partnerships, data literacy programmes, monitoring impact).

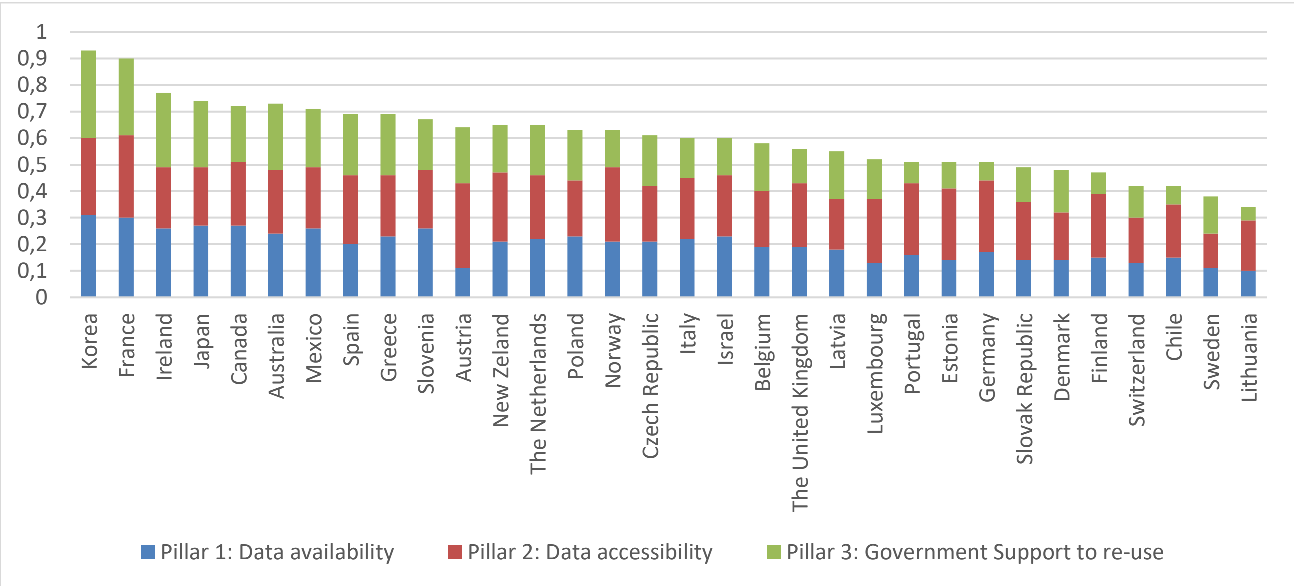

FIGURE 2: OECD OURDDATA INDEX FOR 2019 (DATA FROM OECD, 2020)[12]

[11] https://www.oecd.org/gov/digital-government/open-government-data.htm#:~:text=Open%20Government%20Data%20(OGD)%20is,government%20data%20available%20to%20all.&text=By%20making%20their%20datasets%20available,transparent%20and%20accountable%20to%20citizens

[12] https://www.oecd.org/gov/digital-government/policy-paper-ourdata-index-2019.htm. Note: Data for 2019 are not available for Hungary, Iceland, Turkey, and the United States.

Compared to 2017 the OECD average index increased from 0.54 to 0.60. In the Pillar 1 (data availability) 19 of 32 countries have made progress, in the Pillar 2 (data accessibility) 17 of 32 countries and in the Pillar 3 (Government support to the re-use) 20 of 32.

OECD in its study[13] writes that: "The strategic sharing of OGD, combined with digital technologies, can support good governance and improve public trust. Examples include enabling better public service delivery, improving citizen engagement, enhancing government openness, and providing a data-driven basis for stronger government accountability and public sector integrity".

EU has started to open the public sector data through Directive on Re-Use of Public Sector Information[14]. It caused a change of attitude Public Sector Bodies towards data stored in their IT systems. Data began to be seen as a good that could be made available to the public[15]. In 2013 PSI Directive was modified to adapt to the current needs. The principle "Re-usability of data by default" has been introduced. Rules have been added for:

- Marginal cost charging
- Extension of the Directive to cultural data
- Machine readable format

In 2019, a completely new directive was adopted, Directive on open data and the re-use of public sector information[16]. Member States should implement it by 16 July 2021. New regulation introduces high-value datasets. These are the datasets associated with important socio-economic benefits having a particular high value for the economy and society. High-value datasets, as a rule, shall be available free of charge, machine readable, provided via Application Programming Interfaces (APIs), and provided as a bulk download.

"Energy consumption" was mentioned as an example; however, the catalogue of high-value datasets is open and could be expanded in the future.

As a result of this process is the stimulation of the creation of a Data Market in EU. "The Data Market is the marketplace where digital data is exchanged as "products" or "services" as a result of the elaboration of raw data" (Cattaneo et al., 2020)[17]. According to this European Data Market Monitoring Tool report: "The value of the Data Economy, which measures the overall impacts of the Data Market on the economy, exceeded the threshold of 400 Billion Euro in 2019 for the EU27 plus the United Kingdom, with a growth of 7.6% over the previous year. The positive trend in the growth of the Data Economy is confirmed by the Data Market value in 2019 for the EU27 plus the U.K., which is displaying a growth rate above the one exhibited by the total IT spending, at 4.9% year-on-year, reaching 75 Billion Euro".

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13 https://www.oecd.org/gov/open-government-data-report-9789264305847-en.htm
14 https://eur-lex.europa.eu/eli/dir/2003/98/oj
15 https://op.europa.eu/et/publication-detail/-/publication/45328d2e-4834-11e8-be1d-01aa75ed71a1/language-en
16 https://eur-lex.europa.eu/eli/dir/2019/1024/oj

Despite the high growth rate, EU market lags the U.S. The value of their Data Market in 2019 was almost 185 billion euros. The further development of the Data Market reducing the distance to U.S. is one of the goals of implementing European Digital Strategy.

Table 1 presents three development scenarios for the Data Market (EU27 until 2025) from The European Data Market Monitoring Tool report (Cattaneo et al., 2020)[17].

TABLE 1: EU27 2025 DATA MARKET GROWTH SCENARIOS (DATA FROM CATTANEO ET AL., 2020)

SCENARIO	DATA MARKET	DATA ECONOMY	DATA ECONOMY AS A PART OF EU GDP
Baseline (most likely with healthy growth)	82.5B EUR	550B EUR	4%
High Growth (acceleration in Artificial Intelligence, advanced robotics, automation)	107B EUR	827B EUR	5.9%
Challenge (low level of data innovation)	72B EUR	432B EUR	3.3%

It's been 15 years since the famous thesis that "Data is new oil"[17] was made. Everyone is now aware of the importance of data for the economy and society. EU has acted on open data even earlier. This has led to the creation of a current Union data market with value 75 Billion Euro.

2.2.4 FREE FLOW OF NON-PERSONAL DATA

To ensure the free flow of non-personal data, allowing organizations to process non-personal data wherever in the Union, the EU has adopted a dedicated regulation[18]. The law is to help remove the following barriers along with examples of problems and solutions (EC, 2017)[19].

Introduce a general rule that prohibits location restrictions: paragraph 1 of Article 4.

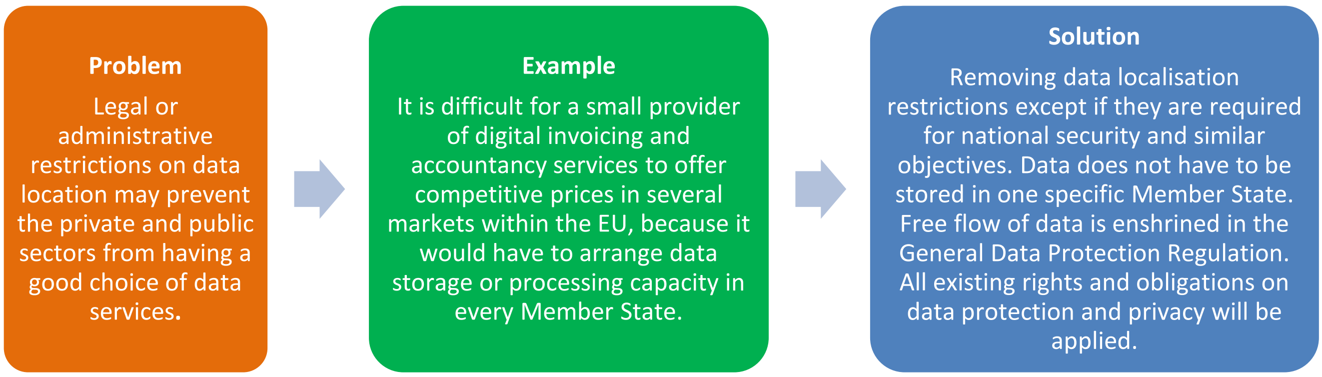

FIGURE 3: REMOVING DATA LOCALISATION RESTRICTIONS (REDRAWN, TEXT FROM EC, 2017)

[17] https://www.theguardian.com/technology/2013/aug/23/ tech-giants-data
[18] https://eur-lex.europa.eu/eli/reg/2018/1807/oj
[19] https://ec.europa.eu/commission/presscorner/api/files/attachment/ 493181/Data_Economy_Factsheet.pdf

Encourage self-regulation by creating 'codes of conduct' at Union level: paragraph 1 of Article 6.

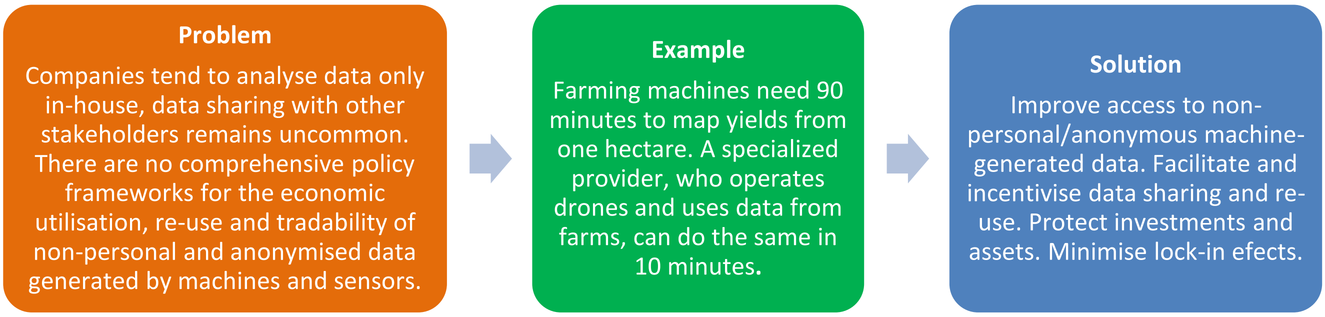

FIGURE 4: REMOVING DATA ACCESS AND TRANSFER BARRIERS (REDRAWN, TEXT FROM EC, 2017)

Encourage self-regulation by creating 'codes of conduct' at Union level: paragraph 1 of Article 6.

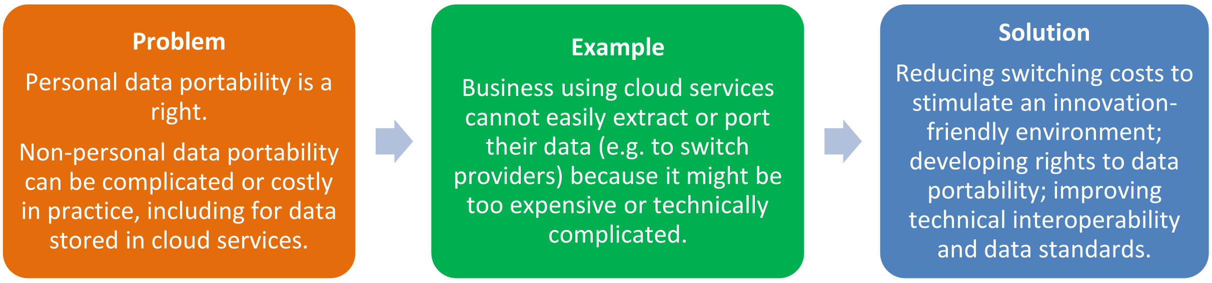

FIGURE 5: REMOVING DATA PORTABILITY AND INTEROPERABILITY BARRIERS (REDRAWN, TEXT FROM EC, 2017)

2.2.5 ARTIFICIAL INTELLIGENCE

Artificial Intelligence (AI) is one of the main pillars of EU digital transformation (EU, 2021)[20]. Closely related to the Data Market, it is to ensure benefits to people and businesses. The Union is to become the leading global AI centre while preserving safety and fundamental rights of its citizens.

Proposal for AI regulation defines Artificial Intelligence System as: "software that is developed with one or more of the techniques and approaches listed in Annex I[21] and can, for a given set of human-defined objectives, generate outputs such as content, predictions, recommendations, or decisions influencing the environments they interact with".

To ensure respect to EU rules and values the proposed act introduces risk-based approach. The areas of AI use are divided into categories as presented in Table 2.

[20] https://ec.europa.eu/newsroom/dae/redirection/document/75788

[21] https://ec.europa.eu/newsroom/dae/redirection/_document/75789. Currently, these are: (a) Machine learning approaches, including supervised, unsupervised and reinforcement learning, using a wide variety of methods including deep learning; (b) Logic- and knowledge-based approaches, including knowledge representation, inductive (logic) programming, knowledge bases, inference and deductive engines, (symbolic) reasoning and expert systems; (c) Statistical approaches, Bayesian estimation, search and optimization methods.

TABLE 2: ARTIFICIAL INTELLIGENCE RISK CATEGORIES (TEXT FROM EU, 2021)

RISK CATEGORY	DESCRIPTION	STATUS
Unacceptable (TITLE II of AI regulation)	Contravening Union values, e.g., manipulate persons through subliminal techniques beyond their consciousness, exploits any of the vulnerabilities of a specific group of persons due to their age, physical or mental disability, social scoring of natural persons for general purposes done by public authorities	Prohibited
High (TITLE III of AI regulation)	High risk to the health and safety or fundamental rights of natural persons, e.g., critical infrastructure (34), safety component of a product, remote biometric identification (TITLE II of AI regulation), education or vocational training (35), employment and workers management (36), essential private and public services and benefits (37), law enforcement (38), migration, asylum and border control management (39), administration of justice and democratic processes (40)	Permitted with certain mandatory requirements (risk management system, data and data governance, technical documentation, record-keeping, transparency and provision of information to users, human oversight, accuracy, robustness and cybersecurity) and an ex-ante conformity assessment
Low or minimal	Other	Permitted with the specific transparency obligations for low risk and free use for minimal risk

The implementation of the new law is to be supervised by the European Artificial Intelligence Board at the Union level. Additionally, it is supposed to stimulate development of standards and best practices for AI. At the national level, local competent market surveillance authorities are supposed to be responsible for supervision.

Proposed regulation specifies a set of requirements for high-risk AI systems. Pursuant to Article 6, this is how systems affecting the safety may be classified. ANNEX III HIGH-RISK AI SYSTEMS REFERRED TO IN ARTICLE 6[22] contains the following area: “Management and operation of critical infrastructure: (a) AI systems intended to be used as safety components in the management and operation of road traffic and the supply of water, gas, heating and electricity”. The table in Annex I-12 lists some articles with the assumption that the DEP will be subject to proposed AI regulation.

2.3 EXPERIENCE FROM BANKING INDUSTRY – OPEN BANKING

Gartner defines the concept of open bank[23] as: “one that shares or consumes business services (for example, data, transactions and algorithms) with business ecosystem partners (for example, other banks, partners [such as

[22] https://ec.europa.eu/newsroom/dae/redirection/document/75789

[23] S. Cohen, P. Malinverno, *Industry Vision: Bank CIOs, Identify Your Readiness to Embark on Open Banking*, Gartner, 2019-06-25.

insurance], employees, customers, FinTechs and developers). Open banking technologies facilitate this sharing and consumption of data, transactions and algorithms. A digital business model is a plan that enables people, businesses and things to give, take and multiply value creation for a bank through sharing assets like algorithms and data (…). To execute a digital business model, banks will need a digital business platform, on which new products can be built. A digital business platform is an architectural innovation that transacts and shares assets like algorithms and data with ecosystems of people, businesses and things. Digital business models, digital business platforms and open banking technologies are enablers for a strategy for banks to become more like a platform company and an open bank".

Key element in the digital business platform is group of APIs through which authenticated entities have access to data and services. Digital business platforms provide access to functions for defined business use cases. On the other hand, rich set of APIs can enable various types of integration supporting newly invented business scenarios.

In EU, the impulse for the development of Open Banking has been Revised Payment Services Directive (PSD")[24]. The new law is to facilitate the modernisation of Europe's payment services, inter alia, by promotion of the development of online and mobile payments, while ensuring consumer protection. At the same time, PSD2 Directive, it is to ensure equal payment market conditions for the new players e.g., FinTechs. Requirements for secure communication standards, among others, in the field of interfaces, are specified in supplementing Commission Delegated Regulation (EU) 2018/389[25].

Standardisation work with goal to create open, common, and harmonised API was carried out by both international and national organizations. One of pan-European standards is *NextGen PSD2* created by The Berlin Group (https://berlin-group.org/).

National standards were also created, among others in United Kingdom: *Open Banking UK*[26] (https://www.openbanking.org.uk/), Czechia: *Czech Open Banking Standard* (https://cbaonline.cz/cesky-standard-pro-open-banking) or Poland: *PolishAPI Standard* (https://polishapi.org/en/).

From 14 September 2019, actors of the payment market provided the following services:

- Account Information Service (AIS) – service which provides consolidated information on payment accounts held by a payment service user with payment service providers,
- Payment Initiation Service (PIS) – service which accesses a user's payment account to initiate the transfer of funds on their behalf with the user's consent and authentication,
- Confirmation of the Availability of Funds (CAF) – service that accesses a user's payment account to confirm availability of funds.

[24] https://eur-lex.europa.eu/eli/dir/2015/2366/oj
[25] https://eur-lex.europa.eu/eli/reg_del/2018/389/oj
[26] Open banking in UK was initiated in 2016 by the Competition and Markets Authority (CMA) report, which found that larger banks are blocking market development. CMA together with nine largest banks set up Open Banking Implementation Entity, which is responsible for managing the standard.

Those services can provide interactions between:

- Account Servicing Payment Service Providers (ASPSP) – they are currently almost 100% banks,
- Third Party Providers (TPP) – an external company (e.g., FinTechs) authorized by the service user to make payments (Payment Initiation Service Provider – PISP), check funds availability and access account information (Account Information Service Provider – AISP) on its behalf.

The launch of the above services is associated with the introduction of Strong Customer Authentication (SCA)[27] for payment service users. Due to the complexity of the SCA, the date of its implementation was postponed by European Banking Authority in EU to 31 December 2020 and by Financial Conduct Authority in UK to 14 March 2022[28].

KPMG Poland (2019)[29] predicted that: "The implementation of the PSD2 Directive in banks and the road towards Open Banking will take place in four stages, possibly mutually overlapping. At the first stage, which is currently underway, most banks focus on the implementation of APIs and on compliance issues. At the second stage, banks will look for ways to monetise the opportunities offered by the PSD2, including the provision of the so-called premium services. The third stage involves banks taking an active role as an AISP/PISP player by creating new products and services based on their own products and those offered by third parties, to provide personalised services to customers. The fourth stage is based on the analytics of bank-as-a-service data. Each stage will require banks to change their business models and operational models, which means that the digital transformation of banks has only just begun".

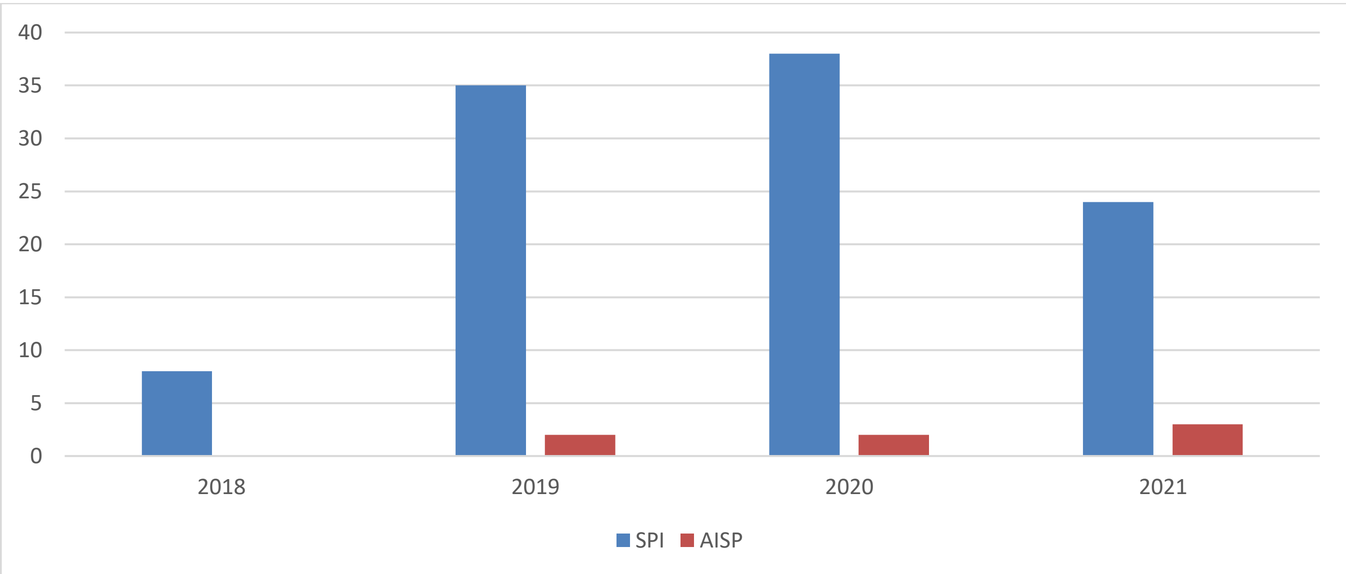

FIGURE 6: ANNUAL NUMBER OF REGISTERED SPI AND AISP (KNF'S ELECTRONIC REGISTER, MAY 2021[31])

[27] This type of authentication shall be based on two or more elements which are categorised as knowledge, possession, and inherence.
[28] https://www.fca.org.uk/news/statements/deadline-extension-strong-customer-authentication
[29] https://home.kpmg/pl/en/home/insights/ 2019/04/report-psd2-and-open-banking-revolution-or-evolution.html

The report (2020)[30] prepared by Polish Bank Association confirms the above predictions – generally banks use Open Banking in Poland. However, the data on the number of registered[31] yearly Small Payment Institutions – SPIs (the legal entity created, inter alia, for the FinTech start-ups), allows to assume that this will change. The number of AISP domestic service providers (operating FinTechs) is also increasing but is only few.

Open Banking implementation is progressing although there are some delays. Currently, it mainly takes place in old entities e.g., banks but new players appear too. A clear obstacle in providing Union wide payment services is the existence of several API standards, however, they should be consolidated soon (the less popular ones will disappear).

Banking industry is undergoing profound changes: digitalisation, service integration and, most importantly, the emergence of FinTechs. Despite competition, new networks of connections emerge that can create new services. However, the pace of changes is still determined by banks – FinTechs have not yet reached the appropriate critical mass.

For energy industry, there are the following conclusions: need to educate, encourage, and support new service providers; building a partnership ecosystem requiring several coordinated actions. In the area of standardisation of technical solutions, energy sector is more mature, and able to develop a consistent set of standards based among others on single and common information model like CIM "CIMification" (EU-SysFlex D5.5, 2021).

[30] https://alebank.pl/wp-content/uploads/2020/11/Raport-open-banking-otwarta-bankowosc.pdf
[31] https://e-rup.knf.gov.pl/

3. MARKET AND GOVERNANCE OF EXISTING DATA ACCESS&EXCHANGE PLATFORMS

3.1 BACKGROUND OF DATA PLATFORMS

Data management has become important in today's society and the electricity sector is not an exception. Countries, both within and outside Europe, are working on new solutions to increase the usage and efficiency of energy data management and how this could be implemented. National data platforms to store and process energy data is seen as one key player to coordinate this work. Several European countries have already implemented national data platforms (data hubs, DEPs) with shifting focuses. The experience from these implementations could bring valuable information for the EU-SysFlex project in its aim for interoperability of different platforms across Europe as an enabler for increased share of renewable energy in the electricity system.

The aim of this chapter is to investigate the key characteristics of some European data hubs and DEPs today and in the future with an emphasis of how they are governed and which markets and stakeholders they support. In the following it will be referred to 'data (access & exchange) platform' capturing concepts of both 'data hubs' and 'data exchange platforms'.

Based on the Electricity Market Directive (2019/944), validated historical consumption data shall be made available to final customers on request, easily and securely and at no additional cost[32]. Final customers should be able to retrieve their own metering data and to give another party access, acting on their behalf. In order to promote competition in the retail market and to avoid excessive administrative costs for the eligible market participants, Member States must facilitate interoperability and non-discriminatory and transparent procedures for data access. The Electricity Market Directive does not require the implementation of data hubs or other platforms *per se*, but there is no coincidence why the data hubs and DEPs are high on the agenda in many European countries today.

The vision of the data platform as a means is to structure electricity market data on national level, and to harmonise markets and management systems to enable cross-border competition within these platforms in Europe. Markets could be opened up to new players and make the consumer more active in the market. Existing data platform solutions are currently not homogenously structured, and this report focuses on the differences and similarities in governance and their relation to the markets they operate in.

Within the EU-SysFlex project, interviews with five different data platform operators (DPOs) have been performed which form the basis for this report. The answers from the DPOs are then compiled with relevant reports in the subject in order to understand the current status of data platforms today, what services they provide, and how they might develop in the future.

[32] Currently, Implementing act on interoperability and access to metering and consumption data is under development as mandated in article 24 of the directive.

The five DPOs that were interviewed represent the Danish hub, the Dutch hub, the Italian hub, the Belgian hub and the Estonian hub+DEP. To provide a broader understanding of the current status on data platforms, information from the Nordic data hubs (Sweden, Finland, Norway and Denmark) is included. The interviewed and presented data platforms represent rather central approaches. For a full picture decentralised approaches need to be equally analysed additionally. As this analysis would go beyond the scope of this document, the selection represents a first step to evaluate the benefits of easy data access and exchange as such, but does not intent to give recommendations about the approach.

Table 3 and Table 4 provide brief understanding of the characteristics of the data platforms in focus in this herein.

TABLE 3: SUMMARY OF THE STUDIED DATA PLATFORMS' OWNERSHIP, OPERATION AND CONNECTION POINTS (DATA FROM THEMA CONSULTING GROUP, 2017; NORDREG, 2018)

Country (name)	Data platform ownership	Data platform operator	Operational since (planned)	Connection points 2017
Netherlands (EDSN)	TSO and 7 DSOs	Private company owned by grid operators	2013/2018	15.7 Mil (incl. gas)
Estonia (Estfeed)	TSO	TSO	2012	0.75 Mil
Italy (SII)	The State	Third party	2016	37 Mil
Belgium (Atrias)	5 DSOs	Atrias*	2018	-
Denmark (DataHub)	TSO	TSO	2013/2016	3.3 Mil
Sweden (Data hub)	TSO	TSO	(2023)	5,3 Mil**
Finland (Datahub Oy)	TSO	TSO	(2021)	3.6 Mil**
Norway (ElHub)	TSO	Subsidiary of TSO	2019	3 Mil**

*Atrias is private company

**Estimation of connection points when online

TABLE 4: SUMMARY OF THE CONCERNED MARKETS, MARKET PARTICIPANTS AND ACCESS TO DATA FOR THE STUDIED DATA PLATFORMS (DATA FROM THEMA CONSULTING GROUP, 2017; NORDREG, 2018)

COUNTRY (NAME)	RETAIL OR WHOLESALE DATA?	DATA PLATFORM FACILITATES MARKET DATA?	ALLOWS APPLICATIONS OR ESCOs?*	CUSTOMERS HAVE ACCESS TO DATA?
Netherland (EDSN)	Retail	No	No, external	No
Estonia (Estfeed)	Both	Yes	Yes	Yes
Italy (SII)	Both	No	No	No
Belgium (Atrias)	Retail	planned: flexibility	No	Planned
Denmark (DataHub)	Retail	No	Yes	Yes
Sweden (Data hub)	Retail	No	Yes	Yes
Finland (Datahub Oy)	Retail	No	Yes?	Yes
Norway (ElHub)	Retail	No	No	Yes

*Energy service company

3.2 STATUS OF DATA PLATFORMS IN EUROPE

A presentation follows about the current status of a few data platforms already implemented or with imminent implementation expected. The description is especially focussing on the Danish hub, the Dutch hub, the Italian hub, the Belgian hub and the Estonian hub+DEP as they have been approached and interviewed by the EU-SysFlex team. For the interviewed data platforms, the answers from the interviews form the foundation of text where the focus is on:

- Governance of the data platforms
- Prioritised principles for energy data exchange
- Data access and stakeholder related/benefiting from the data platform
- Future plans

3.2.1 THE NORDICS

Sweden, Norway, Finland and Denmark, from now on called "the Nordics", share a common aim to harmonise the electricity retail markets. Already today, the Nordics have common wholesale and balancing markets organised by Nord Pool and imbalance settlement provided by eSett. Denmark and Norway have already implemented data hubs, Sweden and Finland will launch their data hubs in 2023 and 2021 respectively. With the introduction of the supplier-centric data hubs, the Nordics have the possibility to also harmonise the retail market. In the Nordics, all data hubs are owned and operated by respective TSO (or a subsidiary thereof) in the country. Especially the Norwegian, the Swedish and the Finnish data hubs feature a similar interface and structure. Table 5 shows a comparison between the functions of the data hubs in the Nordics.

TABLE 5: FUNCTIONS OF THE DATA HUBS IN THE NORDICS TODAY (DATA FROM NORDREG, 2018)

FUNCTION	DENMARK	NORWAY	FINLAND	SWEDEN
Metering point management	Yes	Yes	Yes	Yes
Customer data management	Yes	Yes	Yes	Yes
Customer moving and switching	Yes	Yes	Yes	Yes
Contract management	Yes	Yes	Yes	Yes
Forwarding service requests from supplier to DSO	Yes	Yes	Yes	Yes
Meter value management	Yes	Yes	Yes	Yes
Third party access to metering data	Yes	Yes	Yes	Yes
Provides settlement data to NBS**	No*	Yes	Yes	Yes
Market monitoring	Yes	Yes	Yes	Yes
Correction settlement	Yes	Yes	Yes	Yes
Compiling statistics	Yes	Yes	Yes	Yes
Combined billing	Yes	Yes	No	Yes

*Denmark is planning to join

**Nordic Balance Settlement (eSett)

3.2.2 DENMARK

The first version of the Danish data hub (DataHub) went online 2013 and the second version 2016 which made them to be the frontrunner in the Nordics in the area. The data hub was developed as a result of a law, is owned and operated by the Danish TSO Energinet and is paid by customers via TSO tariff (asset, 2018). The goal of DataHub is to make all meter data from generation and demand at all levels centrally accessible and make the customer more active by providing them secure and reliable data. DataHub does not contain any market data but allows applications and energy service companies on the platform (THEMA Consulting Group, 2017).

The most prioritized principles for energy data exchange according to the Danish DPO are:

- Data hub operator to be neutral to ensure independence and fairness of treatment of different actors
- Provide secure data access to suppliers, BRPs and to enable technical unbundling of grid operators
- Also, easy access to data enabling customer to become active is considered to be prioritized

Data access and stakeholder related/benefiting from the data hub

The DSOs own, operate and collect data from the meters and are responsible for the data quality and the meter master data to be sent to the data hub. Suppliers are responsible for the customers' master data and its delivery to the data hub.

TSO, DSOs, BRPs, suppliers, third parties and customers are benefiting and/or are related to the data hub. In 2017 there were in total 160 third parties consisting of suppliers, groups of customers represented by third parties to procure energy, monitoring service providers, which accessed the data hub. Another feature of the Danish data hub is that the customers have the possibility to access their own data by authenticating themselves using national digital signature. The data hub also works as a consent data base and a register of service providers by giving unique codes where a stakeholder can give consent to application through the data hub portal.

Future perspectives

The following future steps for DataHub were presented by Energinet:

- Not only DSO-collected metering data should be accessible via DataHub but also e.g. Electric Vehicle (EV) charging and other possible flexibility providers' data. The granularity of the data is not clear yet.
- Data potentially to be used for network planning.

3.2.3 NETHERLANDS

The Dutch DEP was original commissioned 2013 with major upgrades 2018 and is owned and operated by a consortium of several DSOs called EDSN (Energie Data Services Nederland). About 15.7 million metering points, gas and electricity, were connected 2017 (THEMA Consulting Group, 2017).

The most prioritized principles for energy data exchange according to the EDSN are:

- Data hub operator to be neutral to ensure independence and fairness of treatment of different actors
- Fair and equal access to data and/or information
- Easy access to data enabling customer to become active
- Enable supplier switching
- Imbalance settlement
- Also, data quality (data integrity, ability to handle massive flows of data, timely uploading, etc.) is considered to be prioritized

The business model of the platform is to administer all electricity and gas metering points and register parties like BRPs, suppliers and metering companies. The data hub is currently paid by the DSOs and TSO which could potentially hinder innovative developments of new functionalities (e.g. customer access).

Data access and stakeholder related/benefiting from the data hub

TSO, DSOs, BRPs, suppliers and metering companies are benefiting and/or are related to the data hub. For big consumers, above 3x80A, metering companies collect and validate data. For smaller consumers, the DSO or the supplier, performs the validation instead. The metering companies, DSOs and suppliers then send their data to the platform and directly to the TSO for imbalance settlement. For big end users, metering is a free market where metering company owns and operates meters.

Future perspectives

The aim for the platform in the future is to be operated by an independent party and that data should be available to interested parties immediately, driven by the customer.

3.2.4 BELGIUM

On behalf of the Belgian DSOs, Atrias is developing a central market platform with a new single CMS (Central Market System). The CMS will replace the existing platforms of the DSOs and facilitate migration and transition to the new system. Atrias will then both deliver system operation services as well as manage the maintenance of the CMS. The CMS is a technical platform to gather, structure and exchange data between different market parties where all the market transactions are treated centrally in a uniform way. The CMS executes operations and calculations on the behalf of the DSOs and facilitates the access for newcomers to the energy market.

Atrias will act as a neutral, objective consultation platform for the energy SOs, suppliers and regional regulators and offer a technical platform for structuring and exchanging data between the Belgian energy sector players. Atrias develops the normalization and standardisation of procedures (Utility Market Implementation Guidelines (UMIG)) for the exchange of information.

Business model of the data hub and Atrias as market facilitator:

- Organize a consultation platform for:
  - DSOs and TSO
  - Suppliers, BRPs, Third Parties, Energy Service Companies (ESCOs), BSPs, FSPs
  - Regional regulators
- Develop the standards for the exchange of information between market parties active in the distribution system

Data access and stakeholder related/benefiting from the data hub

TSO, DSOs, Brussels Airport, BRPs, third parties – ESCOs and a few retailers benefiting and/or are related to the data hub. Also, BSPs and FSPs have the possibility to use the data hub. Access for consumers is not in the scope. Consumer can access their data directly from DSO / Data Manager or communicate directly with supplier regarding supplier switching. The DSOs are responsible for the collection, validation, retention and provision of meter data, which are used in the regulated market.

Future perspectives

According to Atrias, a new society is evolving where every consumer is also a potential generator, decentralized and renewable generation increases, electrification of building heating and transportation occurs and political "governance" concerning the above needs to be addressed. This will lead to the appearance of new roles and services, which will drive even more data and information flows to deliver these services. Atrias aims to develop an adapted market model, processes and data hub to comply with this. Another important step is to link an external flexibility platform to Atrias to enable more flexibility in the grid.

3.2.5 ITALY

The Italian data hub named SII is operated by Acquirente Unico (AU) which is a public company wholly owned by the GSE (Energy Services Manager), a company of the Ministry of Economy. It cannot generate revenue to cover its operating costs, so all SII's users (energy operators) pay a little fee to cover operating costs. Every year AU submits to the authority an annual budget for the management and development of new functionalities.

The Integrated information system was established in 2010 by the law and the platform has been operational since 2014.

The most prioritized principles, in ranked order, for energy data exchange according to AU are:

1. Data hub to be neutral to ensure independence and fairness of treatment of different actors
2. Guarantee data privacy, data security, and communication security
3. Fair and equal access to data and/or information
4. Data quality (data integrity, ability to handle massive flows of data, timely uploading, etc.)
5. Support market competition

Data access and stakeholder related/benefiting from the data hub

Every month SII manages over 2 million performances (switching, customer change, activation, deactivation, etc.) and every month, the DSOs transfer the consumption measurements via the SII to suppliers. This means that every day, suppliers, DSOs and the TSO are working with the SII producing data and information. This data and information are stored in the SII's database and provided by the DSOs, but it is the DSO that assure the data quality.

Specific role per stakeholder:

- TSO, DSOs and suppliers
    - SII is a central point to information for suppliers, generators and aggregators about grid congestions and the impact they may have on their ability to participate in energy or reserve markets. Also, third parties can potentially take advantage of the data hub in the future.
- Authority
    - Authority can monitor and control the market in cooperation with the SII and contribute to the regulation development or punish those who commit unfair business practices.
- Customers
    - Correct billing and correct information about own consumption of energy and profiling to choose the best supplier for your needs. Direct access to SII since 2019.

Future perspectives

The evolution in the future is vast and has the opportunity for plenty of new functionalities. Below are a few examples presented by AU:

- Web portal for consultation of consumption and supply for customers
- Web portal to enable comparability of energy offers
- Energy footprint analysis
- Provision and monitoring of incentives for renewable sources
- Monitoring of energy efficiency measures.

3.2.6 ESTONIA

Estonia has a central data access and exchange platform for electricity and gas meter data called Estfeed which is owned and operated by the Estonian TSO Elering. Estfeed was started as R&D project which was partly financed through network tariffs, foreign grants and TSO's own profit. Stand-alone part of Estfeed is data hub which was established few years before and it was mainly commissioned because of the reason that it would be more cost efficient to develop a single data hub than for every DSO, mainly smaller DSOs, to develop their own. Estfeed consents access to all the market actors (DSOs, suppliers, customers and third-party applications) once provided the required authorization by the consumer. The consumers can then give access right to their data to third parties through the platform. Discussions about possibilities for commercial revenues are ongoing.

The most prioritized principles, in ranked order, for energy data exchange according to Elering are:

1. Easy access to data enabling customer to become active
2. DEP operator to be neutral to ensure independence and fairness of treatment of different actors
3. Guarantee data privacy, data security, and communication security
4. Fair and equal access to data and/or information
5. Facilitating innovation by opening, as much as possible and legally allowed, the access to the data
6. Ability to communicate with other DEPs for completing internal energy market
7. Support to competition

Data access and stakeholder related/benefiting from the data hub

- Today Estfeed provides historical values for electricity and gas in terms of consumption and generation data with an hourly resolution. Connections to other data sources have been piloted like heat meter data, weather data and the spot price data.

It is the DSOs' responsibility to transmit data to the data hub but any data source (e.g. meter data, public data base for public market data) and application receiving the data (supplier, energy service provider) can be integrated with Estfeed and thereby also benefit from the services.

Future perspectives

Estfeed is working on integrating data where near-real-time (i.e. higher resolution, quickly available) data can be exchanged, behind the meter data exchange will be possible, where flexibility services will be possible more widely and where all that will enhance customer-centric approach and the collaboration between DSOs and TSOs and other stakeholders. Estfeed declares that any energy use case in need for data exchange will be possible to manage through the platform in the future.

Examples of new types of data:

- Behind the meter data
    - Both generation and consumption data from sub-meters with down to second-level resolution that will be available near real time.
- Data needed for flexibility services
    - By introducing other data such as reactive power, voltage and frequency together with price signals of flexibility services and flexibility offers, Estfeed plans to enable a growing flexibility market for a diversity of stakeholders.

Another aspect for the future is increased cross-border and cross-sector data exchange. Elering together with several other grid operators is part of the Data Bridge Alliance which aim is to facilitate and standardise data exchange between data hubs, incl. cross-border (Pöyry, 2019).

3.2.7 SUMMARY OF BUSINESS USE CASES AND SYSTEM USE CASES FROM INTERVIEWS

To understand which, and how many, SUCs are needed for any BUC to work, and to understand which are the most common SUCs for each respective data platform, a matrix was prepared for the DPOs to fill in, see exemplified matrix in Table 6. The matrix included in total 12 BUCs and 34 SUCs, most of them defined in EU-SysFlex D5.2 (2020).

TABLE 6: EXEMPLIFIED MATRIX TEMPLATE OF BUCs AND SUCs FOR ONE DATA PLATFORM

	BUC 1	BUC X	BUC 12	TOTAL
SUC 1	X	X		2
SUC X		X		1
SUC Y		X		1
SUC Z				0
SUC 34		X		1
Total	1	4	0	

In the example illustrated in Table 6, BUC 1 only needs SUC 1 to run, BUC X is the most complex BUC which needs 4 SUCs to work and BUC 12 is not used at all in this specific data platform. According to Table 6, SUC 1 is the most common SUC for this data platform and SUC Z is not used. The same method was used to quantify and analyse the answers from the DPOs. The DPOs from the Netherlands, Estonia and Italy filled in the matrix and the result together with an average number for the three data platforms is illustrated in Table 7 and Table 8. The original answers are found in Annex 2.

The results give an interesting view of the data platforms, but it should be noted that with such a limited number of answers, a quite subjective selection of use cases and inhomogeneous answer structure the results provide an incomplete picture and rather constitute a starting point for discussion then a final answer.

TABLE 7: THE NUMBER OF SUCs TO RUN THE EACH OF THE BUC IN RANKED ORDER

BUC	NL	EE	IT	AVERAGE
ACCESS TO DATA	13	14	13	13
SERVICES RELATED TO END CUSTOMER	19	15	0	11
BALANCE MANAGEMENT	15	11	0	9
OPERATIONAL PLANNING AND FORECASTING	11	0	14	8
MARKET FOR FLEXIBILITIES	16	3	0	6
ENERGY TRADING	15	0	3	6
CONNECTING TO THE NETWORK	15	0	0	5
RES ADMINISTRATION	7	8	0	5
REPORTING	10	4	0	5
SERVICES OF RSCs	11	0	0	4
LONG-TERM NETWORK PLANNING	2	0	0	1
CAPACITY ALLOCATION	0	0	1	0

As mentioned above, the limited number of answers means that the results should be used as an indication rather than a complete answer but according to Table 7 and Table 8, the three different data platforms are used for different purposes.

TABLE 8: THE NUMBER OF BUCs THAT NEED A SPECIFIC SUC TO RUN

SUC	NL	EE	IT	AVERAGE
Management of user's requests	10	4	2	5
Management of authorizations	10	4	2	5
Authentication of data users	10	4	2	5
Aggregation of data	9	4	2	5
Data transfer	6	6	2	5
Retrospective corrections of data	8	4	2	5
Change of data format inside DEP	11	0	2	4
Data collection	6	3	3	4
Quality check of data	10	0	2	4
Customer notifications	9	0	2	4
Assignment of EIC codes	5	5	0	3
Massive data processing	6	0	1	2
Device level (sub-meter) metering	5	0	2	2
Erasure, restriction and rectification of personal data	1	3	2	2
Data storage	0	3	2	2
Management of network agreement	3	2	0	2
List of suppliers and service providers	2	3	0	2
Verification of activated flexibilities	4	0	1	2
Anonymisation of data	5	0	0	2
Management of supply agreement	2	2	0	1
Management of portfolio agreement	3	1	0	1
Integrating new application	0	3	1	1
Maintaining list of platform services	1	2	1	1
Management of flexibility bids	2	0	0	1
Management of flexibility activations	2	0	0	1
Peer-to-peer trading	2	0	0	1
Integrating new data source	0	2	0	1
Management of bids and offers in DA, ID and forward markets	1	0	0	0
Baseline calculation	1	0	0	0
Data exchange between DER and SCADA	0	0	0	0
Detect data breaches	0	0	0	0
Manage security logs	0	0	0	0
Predict flexibility availability	0	0	0	0

BUCs

Common for the data platforms are the purpose of providing access to data. EDSN and Estfeed have more focus on services related to the end customer and for balancing settlement compared to SII which is more focused on operational planning and forecasting. For several of the BUCs to be utilized, at least 10 SUCs needs to be used which can facilitate the implementation of respective BUCs. According to the answers from the DPOs, EDSN facilitates more BUCs with the data hub than both Estfeed and SII and also more SUCs per BUC. A certain conclusion could not be drawn from just these answers because of the very limited response from the DPOs and also the fact that the personal interpretation for each of the DPO could impact the result. One interpretation of the results is that EDSN is more diverged than Estfeed and SII which are more focused on fewer BUCs currently.

SUCs

According to Table 8, management of user's requests, management of authorizations (consent management), authentication of data users, aggregation of data, data transfer and retrospective corrections of data are the most used SUCs for these three data platforms. Data exchange between DER and Supervisory Control and Data Acquisition (SCADA), detection of data breaches, management of security logs and prediction of flexibility availability are not used by any of these data platforms today. Just as for the BUCs, a certain conclusion could not be drawn from just these answers because of the very limited response from the DPOs.

3.3 EVOLUTION OF DATA PLATFORMS FROM STATUS QUO TO FUTURE VISION

The interviews together with the available literature in the area provide several interesting thoughts on how the data platforms can evolve in the foreseeable future and what is not in scope. The main takeaways are listed below:

- Continuation of settlement data dominance
- No operational or real time aspects described this far
- Integrating the consumer/prosumer to the data hub
- Integrating types of data (e.g. sub-meter data for renewable energy and EV-charging, market data like prices, etc.)
- The data platforms are heading in the direction to be market driven and independent
- Increased focus to provide and/or be part of the flexibility solution for the electricity sector

The above-mentioned takeaways do not apply to every each of the data platforms and some of the stated future plans are already implemented in few of the data platforms, but the list provides an interesting snapshot on where this sector is heading. Most of the data platforms have come online during last several years, therefore it is essential to work with the core business and then take small new steps rather than leapfrogging. This is for example shown by the fact that the data platforms today look to integrate more data and users to the data platforms as well as enable a market driven focus rather than to plan for integrating real time data and/or cross-border exchange with other data platforms. The Nordics is one example where cross-border data exchange between the data hubs has been implemented though.

The intermediate and long-term development of European data platforms are more uncertain and will be dependent on how the current data platforms will evolve within the next few years, but it is of great interest to understand where this specific area is heading. The list below highlights some of the direction for the long-term focus:

- Data platform as an enabler for the transformational shift in the European energy market. From conventional generation and passive consumption to variable renewable generation and demand side response (DSR).
- Shift from settlement focus to use cases enabling and supporting cross-border trades at operational time scale.
- Vision of distributed computation and operational support close to real time as well as higher level coordination / co-optimisation of bids and proof of service functions on minute to quarterly scale.
- Integration and interoperability with market driven applications for new services.

The number of countries with national data platform solutions has increased over the past years and several will come online within the next few years. Interviews have been performed with five different DPOs to understand how the data platforms are operated today and what they see as their next steps. The interviewed DPOs were also asked to fill in a matrix of which BUCs and SUCs that were currently used in respective data platform. Relevant reports were also reviewed to get more complete picture of the market and governance of existing data platform solutions today.

Out of the interviewed DPOs, only the Italian (named SII), the Dutch (named EDSN), and the Estonian (named Estfeed), operator filled in the matrix of which BUCs and SUCs that are implemented by the respective data platform. A certain conclusion could not be made based on these answers alone because of the very limited response from the DPOs and also because of the fact that the personal interpretation for each of the DPO representatives could impact the result. With the limited answers in mind, a preliminary conclusion of the BUC-and-SUC-matrix is that the core business for the three data platforms is to provide access to data for different stakeholders. EDSN and Estfeed have more focus on services related to the end customer and balancing settlement compared to SII which is more focused on operational planning and forecasting. The most utilised SUCs for the three data platforms were to a large extent similar. Management of user's requests, management of authorizations, authentication of data users, aggregation of data, data transfer and retrospective corrections of data where the five most utilized.

The data platforms are mainly owned and operated by TSOs and DSOs today where the aim to a large extent is to be an independent party providing secure, reliable and qualitative data for different stakeholders and to handle imbalance settlement. There is also a distinction between the data platforms that integrate smaller customers to use, and benefit from the services and data hubs that mainly provide benefits for larger stakeholders like DSOs/TSOs and energy suppliers. The data hubs in the Nordic countries, Estfeed and EDSN are examples of more customer-oriented platforms whereas the Atrias and SII are more focused on suppliers and BRPs to facilitate their business processes.

The future of the data platforms according to the DPOs lies in a mix between the focus on today's business but also to run a more market-oriented business where all kinds of consumers and generators can benefit from the data platforms. There is also a focus to include other data and/or allow third party applications on the data platform to be part of the flexibility solution for the energy system. The general focus for the future is still on services which only requires low resolution data like imbalance settlement, rather than real time or close to real time applications which require high resolution data. Services relying on high resolution data could instead by carried out by distributed applications connected to the data platforms where these could be used for data storage and invoicing only. Estfeed is one exception to this where they plan to integrate close to real time data exchange and new types of services and market data which will enable flexibility services through the data platform.

There is also a vision to implement cross-border data exchange between data platforms, but that will require a unified way of handling data, providing similar functions and a common interface for the end user. The Nordic countries and a collaboration between several system operators under the name of Data Bridge Alliance constitute examples of a unified vision for their data platforms where cross-border data exchange will be made possible for coordination of services.

This report has shown that there are several different models of how existing European data platforms are governed and which markets and stakeholders they are aiming to cover. It has also shown the trend of more European countries to introduce national data platforms and new collaborations between DPOs to standardise the data exchange. With more investments and increased policy maturity in the energy data exchange field, we will see more applications, both national and cross-border, additional market integration and possible decreased cost for the end user if stakeholders can standardise the data exchange on a European level.

4. SYNTHESIS OF EXISTING DATA EXCHANGE MODELS

This chapter aims to describe existing data exchange models used in the energy domain from a technical perspective. Specifically, this work focuses on how data is organised within selected standards, i.e. data model, and how this data is communicated between systems, i.e. data protocols.

A list of selected data models and protocols consists of the main standards that are used in the industry. State of the art is the CIM, supported by ENTSO-E and standardised by IEC. CIM has flexibility for accurate data sharing, merging, and transformation into reusable information. IEC 61850 is another standard that defines the communication between devices in the substation and related systems requirements. This work also describes DLMS/COSEM standard, developed by IEC and DLMS Association, for meter data exchange. It also describes a standard that exists outside Europe, such as Green Button (GB). GB is a specification used in the US and introduced in Canada to allow utility companies to present in a standardised form. It is based on the Blue Button data exchange model used in the US to give patients access to their medical data. It also includes parts about the global standard for smart energy metering, control, and management.

Estfeed solution created by Elering and Cybernetica is to securely and verifiably exchange data between the parties interconnected to the data exchange platform – between the data sources that store or provide the data and data consumers that are energy services interested in using the data. German industry initiative called EEBUS specifications enables developing a future-proof, maintainable, and simple device interface, whether for connection to local energy management or the world of numerous platforms in Smart Home & Building. PoweRline Intelligent Metering Evolution (PRIME) touches on medium-low voltage networks data communication protocols. This open telecommunications architecture includes a forum for defining, maintaining, and supporting open and comprehensive solutions for Smart Grid communications.

As an outcome of this review, the report contains the technical aspects of data exchange models and communication protocols to help decision-makers to navigate various standards that enable interoperability. All the described standards are mapped against the SGAM model (see Chapter 6.1 for SGAM framework description), a state-of-art framework for smart grid architecture.

4.1 DEFINITION OF DATA MODELS

The concept of semantic data models with generic properties was introduced by Peckham et al. (1988). Generation data models lacked direct support for relationships, data abstraction, inheritance, constraints, unstructured objects, and the dynamic properties of an application. Although the need for data models with richer semantics is widely recognized, no single approach has won general acceptance. According to Fowler, a data model *"is an abstract model that organises data elements and standardises how they relate to one another and the properties of real-world entities".* For instance, an EV data model may define a data element representing a car. In turn, those elements represent an owner, engine or how data flows from a sensor to sensor (Fowler et el., 2004). Data Models are defined at a lower level of abstraction and include many details. They are intended for implementers, protocol-specific constructs for implementation. Data models are often represented informal data definition languages specific to the management protocol being used (Schonwalder, 2017).

The term data model can refer to two distinct but closely related concepts:

- Abstract formalisation of the objects and relationships found in a particular application domain: EV, sensors, devices.
- Set of concepts used in defining abstract formalisations or data structure: entities, attributes, relations, or tables. For example, a sensor with ID 42 *(attribute)* measures *(entity)* energy consumption data.

A data model consists of 4 parts: Data, Data relationship, Data semantics, and Data constraint (Watt et al., 2014). A data model provides the details of information to be stored and is of primary use when the final product is the generation of computer software code for an application or the preparation of a functional specification to aid a computer software make-or-buy decision. A data model explicitly determines the structure of the data. Data models are specified in a data modelling notation, which is often graphical in form.

A data model can sometimes be referred to as a data structure. Data models are often complemented by function models, especially in the context of enterprise models.

A data model instance may be one of three kinds (Steel et al., 1975):

- **Conceptual data model:** describes the semantics of a domain, being the scope of the model. For example, it may be a model of the interest area of an organisation or industry consisting of entity classes, representing kinds of things of significance in the domain, and relationship assertions about associations between pairs of entity classes.
- **Logical data model:** describes the semantics, as represented by a particular data manipulation technology. This consists of descriptions of tables and columns, object-oriented classes, and XML tags, among other things.
- **Physical data model:** describes the physical means by which data are stored.

Steel et al. (1975) claim that such an approach allows the three perspectives to be relatively independent. Storage technology can change without affecting either the logical or the conceptual model. The table/column structure can change without (necessarily) affecting the conceptual model. In each case, of course, the structures must remain consistent with the other model. The table/column structure may be different from a direct translation of the entity classes and attributes. However, it must ultimately carry out the objectives of the conceptual entity class structure. The early phases of many software development projects emphasise the design of a conceptual data model. Such a design can be detailed into a logical data model. In later stages, this model may be translated into a physical data model.

4.2 DATA EXCHANGE MODELS

4.2.1 COMMON INFORMATION MODEL

Common Information Model CIM is an open standard model to define the relationships of the objects in an IT environment (CIM DMTF, 2003). The CIM model defines a common concept to control information for systems, applications, networks and services. The CIM standard covers the three main elements: the **CIM Schema,** the **CIM Infrastructure Specification,** and **CIM Metamodel.**

CIM Schema:
The CIM Schema defines a common concept to represent various elements and relationships (CIM DMTF, 2003). The CIM Schema is defined for the elements such as operating systems, computer systems, middleware, networks, services and storage. Classes can be defined as: *CIM_ComputerSystem*, *CIM_OperatingSystem*, *CIM_Process*, *CIM_DataFile*. CIM Schema is extensible because it allows producers to create their specific features considering the common base functionality.

CIM Infrastructure Specification: The CIM Infrastructure Specification defines the architecture of CIM and details to map with other management models (CIM DMTF, 2003). The CIM architecture is built on a UML structure, which means the organisation of the model is designed on an object-oriented concept - the managed elements are represented as CIM classes. The functionalities as inheritance, abstraction and encapsulation enhance the quality and consistency of management data.

Object-Oriented Modelling: The relationships and associations between management data are built based on object-oriented rules (CIM DMTF, 2003).

Abstraction and classification: The management data is built as classes, the features as properties, behaviour as methods, relationships are defined as associations. The abstraction approach allows to increase the system's quality and reduce its complexity.

Inheritance: The fundamental objects are built as main classes, subclasses (lower level objects) that might have the same functionalities inherit all the information from superclasses (higher-level objects).

Associations: Association is a relationship where all objects have their lifecycle, and there is no ownership concept. There are associations and inheritance between classes and properties.

CIM Metamodel: The semantics to build the *new* conformant models and the descriptive schema for those models are defined by the CIM Metamodel (CIM DMTF, 2019). Requirements of modelling are different and change depending on the modelling sector. As extending of model elements is possible, the metamodel can be enhanced through qualifications.

The electric power industry developed CIM to define power transmission and distribution standards in application software (Simmins, 2011). CIM describes the aspects of the electric power industry as a common vocabulary in dedicated IEC standards (IEC 61970 for electricity transmission, IEC 61968 for electricity, IEC 62325 for energy market communications). The CIM builds the network model by describing the components to transmit electricity. The measurements of power support the controlling of power flow at the transmission level and the modelling of power on the distribution system. CIM provides a common framework for energy market communications. The European style market profile is derived from the CIM to manage the energy market data exchanges in Europe.

CIM standard designs the elements such as electric transportation and electrical distribution. The related applications to electricity transportation include energy management systems, planning, optimisation. The related applications to electricity distribution include outage management system, distribution management system, planning, work management, metering, geographic information system, customer information systems and enterprise resource planning (Simmins, 2011).

CIM Model use cases

Example IBM use case:
Common Information Model standards are used for designing a message and service definition integration strategy (IBM, 2012) Some services require extensions to the CIM model to cover all the features. CIM extensions developed by IBM are added to Rational Software Architect. These extensions provide an easier procedure to control the processes. While developing the model strategy, three principles should be followed:

- The built-in architecture of the CIM model, which CIM User Group shares, should not be changed.
- The business process requirements should be fully understood, and the extension to the model itself probably be required. The extensions should be well-explained and well-understood and sent to the CIM User Group to release the new extended model.
- A strategy should be designed using the newly released version of the CIM model.

Recommended track while working with CIM by IBM:

- Copy the last version of the CIM model shared by the CIM User Group
- Check the original model and understand the architectural solutions
- If there is a lack of functionality, extend the model without altering the built-in structure of the model
- Document the extensions to the CIM model
- Could send the additions to the CIM User Group to publish a new updated version of the CIM model

EPRI CIM for Planning and CIM for Dynamic Models (Saxton, 2008):
The EPRI project aims to build a common power system network model to provide the network model data once for both operations and planning groups. The purpose of the project is to enhance the reliability of the transmission grid by planning efforts. Based on the information exchange among the planning and operations groups, some new classes such as BranchGroup, Ownership, Planning Area were added to the original CIM model.

4.2.1.1 MADES (IEC 62325-03)

MADES (Market data exchange standard) is a specific part of CIM and a standard for decentralised common communication of TSOs. According to ENTSO-E, “The purpose of MADES is to create a data exchange standard comprised of standard protocols and utilising IT best practices to create a mechanism for exchanging data over any TCP/IP communication network in order to facilitate business-to-business information exchanges.” In general, MADES can be used for any non-real-time data exchange purpose. A MADES network transports objects with sender document is securely repackaged a header containing all the necessary information for tracking, transportation and delivery.” (ENTSO-E, 2014)

MADES provides TSOs with a standardised communication access point to securely exchange documents with other parties involved in the European electricity market. These documents are mainly used in the energy market and described in IEC 62325-351 and the IEC 62325-451 series. Such parties include TSOs, DSOs, BRPs, capacity traders, MOs, producers, transmission capacity allocators (ENTSO-E, 2014).

MADES can support any business process, whatever the document types being transmitted (e.g. XML, binary) and the sequence for the exchanges. MADES is independent of the physical underlying communication Infrastructure, any IP (Internet Protocol) network, such as the Internet, a physical private infrastructure, or a multi access-point virtual private network (VPN). MADES relies upon open IT standards for communication protocols, data integrity, signing and confidentiality (encryption), peer access point authentication, peer party authentication, parties' directory (e.g. HTTPS, SOAP, X.509) (ENTSO-E, 2014).

This design has two main benefits:

1. The recipient may be offline for a given duration without losing any information. So, parties not involved in frequent or critical business processes can turn off their access points installed on a non-permanently network-connected computer.
2. The security level for the architecture is higher than other methods since access points are not required to accept incoming connections, i.e. all connections are initiated by the client. No exception to firewall rules is required.

4.2.2 IEC 61850

IEC 61850 is an object-oriented standard that describes a network or system of power utility automation for data transmission and data communication. It uses Ethernet for data transmission as Ethernet has higher EMC & EMI performance and is safer and quicker than the wires. In addition, it describes the abstract model of information exchange (Figure 7, yellow part) and defines communication profiles using existing standards protocol like TCP/IP or ISO 9506. Standards define methods (GOOSE messages or SV streams).

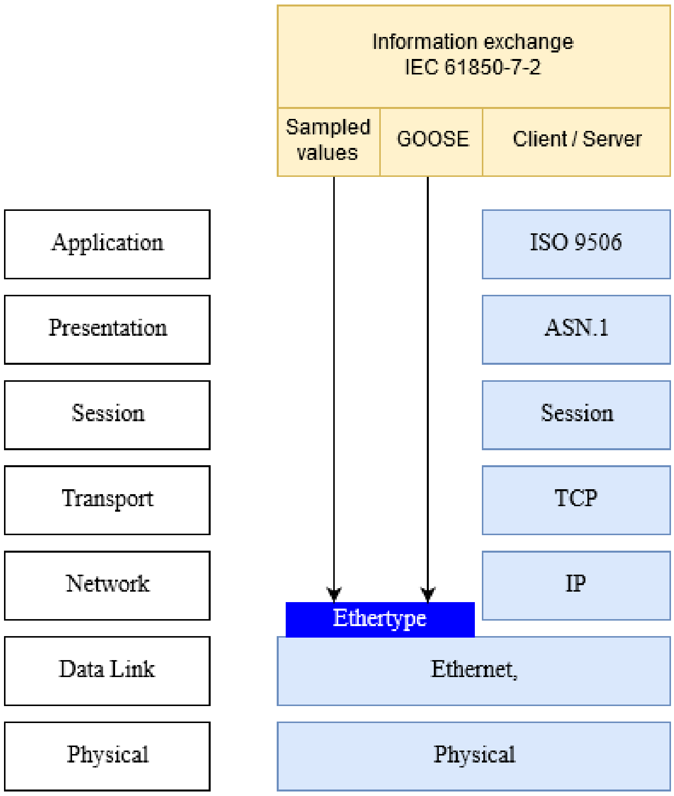

FIGURE 7: IEC 61850 STANDARD GENERAL STRUCTURE

The IEC 61850 has three main elements:

1. **Semantic Data Models.** IEC 61850 defines functional elements, logical nodes with data objects. A logical node is a container that contains the data object with a lot of data classes. Every object can have data attribute/-s. Examples: XCBR - a model of the circuit breaker - process interface. Secondary logical nodes produced by software algorithm in an automation system. For example, PDIS.
2. **Communication.** IEC 61850 provides a mechanism of P2P exchange information via a high-speed communication network without hard-wired connections. Includes Generic Object Oriented Substation Event (GOOSE). Manufacturing Message Specification – IEC 61850-8-1, Extensible Messaging and Presence Protocol – IEC 61850-8-2, Sampled Measured Values, TCP/IP, Ethernet protocols.
3. **System communication language,** which provides a set of files with configuration information. The data is contained within a virtual model—for example, Substation Configuration Description file.

Architecture of IEC 61850 consists of 3 main blocks:

1. **Station level.** The Center monitoring and control system of a substation is at this level. Uses MMS protocol for reports transmission.
2. **Bay level.** At this level, there are a lot of IEDs. These IEDs can be relay protections, fault recorders, monitoring devices, control devices. (Uses GOOSE)
3. **Process level.** Primary devices are located at this level and use SV streams. Examples: current transformer, potential transformer, circuit breaker, switchgear.

Data communication:

1. Client-server. A client sends a request to the server. The server receives the request, and it gives a response to the client. (MMS). Used for reports and not time-critical messages.
2. Publisher - subscriber (multicast). A publisher sends to Subscribers GOOSE/SV message to all subscribers. Time-critical (status positions of primary devices)
3. SLC file contains all the information and the data about the models of the substation.

GOOSE Messages:

- transfer Object-Oriented messages from a substation
- Message transfer by the publisher-subscriber model (just like SV streams)
- Fast and reliable transfer of information to multiple devices simultaneously

4.2.3 DLMS/COSEM

DLMS/COSEM specification is used for smart energy management, consumption data metering and facilities control. It consists of 3 parts:

- Companion Specification for Energy Metering (COSEM), the object-oriented data model, helps to describe any application virtually.
- Object Identification System is a naming system of the COSEM objects. OBIS codes are specified for every type of consumption data (e.g., electricity, gas, water data) and thermal energy metering. It also defined abstract data non-energy related measures. Data characteristics are organised hierarchically. For example, "electrical energy – active power – integration – tariff – billing period".
- DLMS is a device language message specification

As COSEM takes an object-oriented approach, each object consists of data attributes and methods to work with these attributes. Objects can be used in combination to model uses cases like "*register reading* or *tariff and billing schemes* or *load management*". (DLMS User Association, n.d.) It defines standards to model metering equipment as logical devices hosted in a single physical device. Each logical device models a subset of the functionality of the metering equipment in terms of attributes and methods and is called COSEM objects. Various COSEM objects that have same structure are covered under a common COSEM interface class. OBIS naming is used to identify COSEM objects to make them self-describing. A full list of standard OBIS codes and valid combinations of standard values in each group is maintained by the DLMS User Association. (DLMS User Association, n.d.) The hierarchical structure defined by COSEM helps combine standardised building blocks to model any complex metering system and is independent of utility type and communication media. (Vyas et al., 2012)

One part of DLMS/COSEM standard is DLMS that converts objects holding data into message format. It is based on OSI (Open System Interconnection); however, seven layers of OSI are primarily collapsed into four layer structures: physical, data link, transport, and application. The physical layer defines the transfer method and a communication parameter to transfer information with the meter. The data link layer provides the communication with the meter and the messaging method to change data. The transport layer enables data transfer using IPv4 network. The application layer defines the energy meter functions as objects so that the application program can access them.

DLMS/COSEM is based on a client-server paradigm where metering equipment plays the role of the server and data collection system such as Central system plays the role of a client. In cases of events or alarms, a server can also execute an unsolicited service to notify clients. (Kmethy, 2008) The communication protocol stack, called a communication profile, is completely independent of the application layer, so servers and clients may independently support one or more communication profiles to communicate over various media. Usually, meters are end devices, and clients are Head End Systems (concentrators). The application layer handles the connection of clients and servers by granting ACSE services. It also provides xDLMS services for adding new objects to the existing model without any consequences and accessing the data within COSEM objects. The application layer also builds the messages (APDUs, Application Protocol Data Units), applies, check and removes cryptographic protection as needed and manages to transfer long messages in blocks. (DLMS User Association, n.d.)

4.2.4 EDIEL

EDIEL is the data exchange model based EDIFACT standard used by Nordic countries (Norway, Sweden, Denmark, Finland) to enable information transfer (EDIEL, 2015). The model is derived from ENTSO-E (CIM electricity) and ebIX. The business rules are defined using XML format. There are common rules defined for this model:

- According to the winter/summertime, using the same time format by countries;
- Setting the common business rules to establish the energy flow direction;
- Rounding signed rules of the exchanged data.

General Principles:

- All Nordic projects use the latest available EDIEL schemas.
- EDIEL schema is updated in case of any additional code.
- By updating the schema, the release number is updated.

As in CIM and ebIX, EDIEL also uses UML modelling approach to design the business services. UMM consists of three views (EDIEL, 2015)

- Business Requirements in the "Business Requirement View"
- Modelled processes in the "Business Choreography View"
- Modelled Information in the "Business Information View"

Nordic TSO Market model uses only the first view, and the other two views are substituted by ENTSO-E implementation guides (EDIEL, 2015).

Communication:

- SMTP: in case of usage SMTP, the message format should be in the Multipurpose Internet Mail Extensions.

- Web Services: SOAP over HTTP is used.
- The size of the message should not be over 50 MB; time synchronisation should be considered; in the case of the compressed message, the zip format is preferred, security mechanism should be considered as well.

4.2.5 EBIX©

ebIX® is a cooperation platform whose main purpose is to standardise electronic data exchange between energy providers and users in Europe (ebIX®, 2015). ebIX information models are based on Harmonised Role Model. As the CIM model, ebIX is built based on UML. ebIX model consists of three main parts (ebIX®, 2015):

- Business Requirements in the "Business Requirement View"
- Modelled processes in the "Business Choreography View"
- Modelled Information in the "Business Information View"

Business Requirements View

The business requirements are determined by business user groups that follow the ebIX® methodology rules.

- **Business process use case**: It defines various activities happening between business partners. Business process use case might happen between the business partners or internally inside one business partner.
- **Business process:** It defines the behaviour of business process use cases among partners. The business process helps to determine the business requirements for the partners to cooperate. The exchange data process between two partners is described in Figure 8.
- **Business data view:** It is designed to contain all elements described by a business entity shared between two or more business partners in a business process.

Business Choreography View

Business Choreography View defines the global choreography for the business partners. The choreography means modelling the start of the transactions and combining the transaction in the collaborations.

- **Business Transactions:** It defines the business information flow between partners. The transaction might happen one way or two ways where the transaction happens from initiator to responder or vice versa
- **Business Collaboration:** It describes the details of the transactions between collaborators.
- **Business Realisation:** Once the business collaboration is defined, the business realisation is modelled for the executions.

Business Information View: The business information view describes the information that should be exchanged between partners.

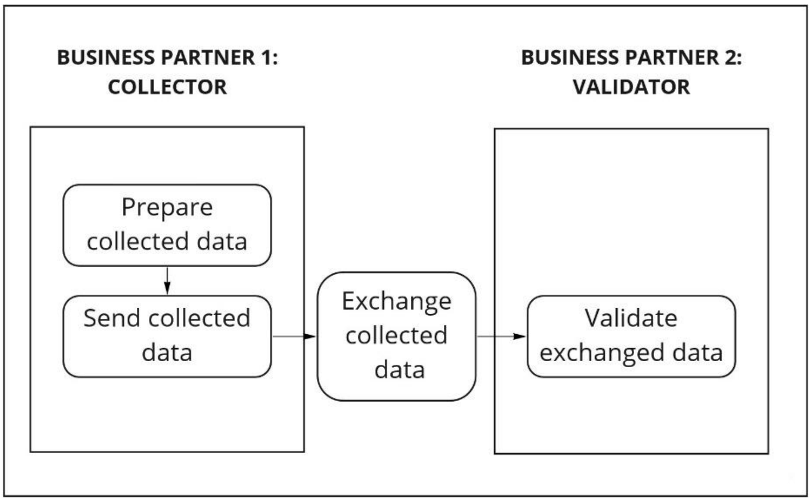

FIGURE 8: EXAMPLE OF BUSINESS PROCESS – EXCHANGE COLLECTED DATA BETWEEN PARTNERS (REDRAWN FROM EBIX®, 2015)

4.2.6 GREEN BUTTON

GB is a standard that helps utility companies provide consumption time-series data (such as electricity, gas, water data) to the customer directly from the utility website (in CSV or XML format) or indirectly (via sharing data with third-party applications). GB standard works with the existing utility system. It does not require installing extra hardware inside the homes. GB framework is employed in the US and Canada. The OpenADE group and PAP 10 carried out the NAESB ESPI standard. It communicates information securely and defines a common energy usage data model. GB falls under international standards and works at different scales (industrial and residential). (OpenEI, 2018) However, GB is not involved with distribution, transmission, and energy generation. There are two scenarios from a consumer perspective:

1. **Download My Data** scenario (Figure 9);
2. **Connect/Share My Data** scenario (Figure 10).

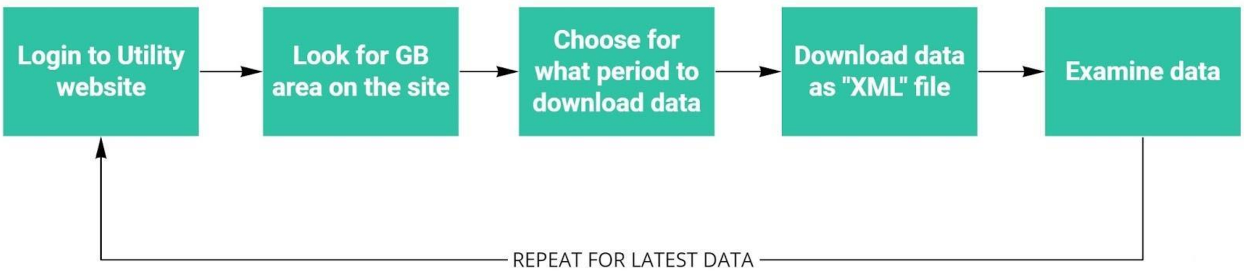

FIGURE 9: GREEN BUTTON "DOWNLOAD MY DATA" USE CASE

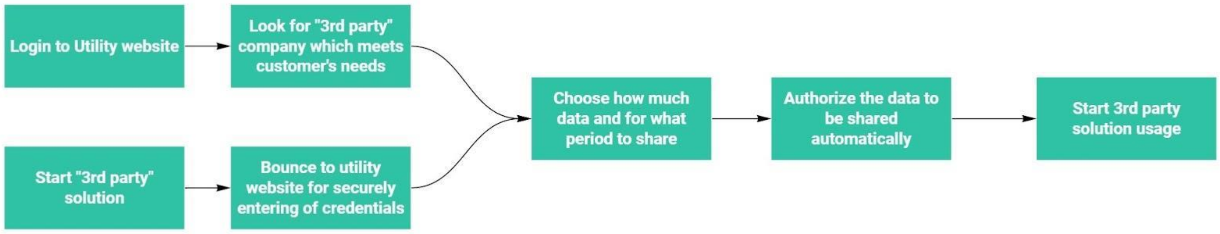

FIGURE 10: GREEN BUTTON "SHARE MY DATA" USE CASE

Connecting my data allows third parties to securely subscribe to GB consumers' data streams with consumer authorisation. OAuth 2.0 Authorization Framework guarantees access to consumer's data without revealing/receiving user ID & password (Green Button Learn, 2015).

Utility perspective

The company has an operational data store or meter management system where metering data is stored. Utility company creates systems that reformat their current data into GB formats and make it available through the GB APIs. Developed by utility platform applies standardised data structures and anonymising data (privacy by design). After that, data becomes available through APIs. 3rd party apps can connect through APIs, test GB capabilities, work with data, and demonstrate results. They will be added to the list of apps and be promoted to customers. GB converted information on the fly when requested (no need for a different database). The flexibility of technical data storage implementations depends on the back-end utility systems managing customer and metering data at a utility company. Atom Syndication Format Standard applied in GB to structure energy consumption data in an XML format.

The data structure consists of 3 parts:

- **XML schema.** XSD file contains a description of the rules of file format.
- **XML file.** The file itself holds energy usage information in standardised file format and references to XSD and XSLT files.
- **XSLT.** It helps to represent data in a human-friendly format.

UsagePoints referencing every meter reading that is contained within the GB data, and all resources are measured. UsagePoints contain *ServiceCategory,* which defines the type of resource is measured (electricity, gas, or water). For example, Utility Smart Meter. A MeterReading is a container for measured *IntervalBlocks* within the GB data.
A *ReadingType* offers details on the specifics of the information being obtained for reading. *IntervalBlock*s are GB data carriers of IntervalBlocks and *IntervalReading,* containing data about each interval (start and end). The *LocalTimeParameters* is used to provide Energy Usage Information with local time without using Personal information. (Green Button Developers, 2015).

Example of Southern California Edison (Green Button Alliance – Overview, 2018):

SCE started its GB program in 2013 with "Download My Data", giving customers the ability to download their interval usage data from SCE's website. The data was available on-demand within the last 13 months in (.csv) or

(.xml) formats. In 2015, SCE launched "*Connect my Data*", which helps customers analyse and optimise their consumption by allowing registered third parties ongoing and automatic access to their data. In 2016, SCE enhanced "*Connect my data*" to include Billing, meter and Program Participation related data so that: Data is available within 1-5 business days. Daily, monthly, and yearly automated data feeds are available based on customer selection.

4.2.7 EEBUS (SPINE)

EEBUS provides a standardised way of exchanging messages between different building blocks within the smart home, building or vehicle. EEBUS is a German driven initiative that created a standard for IoT networks and energy efficiency applications that is open, freely accessible and internationally standardised (CENELEC, EIC, ETSI). EEBUS consists of 3 types of blocks (EEBus Website, 2019)

1. Use cases. For example, generally, there are three use case scenarios for energy management (optimisation and coordination), operation (configurations) and display (monitoring) devices.
2. SPINE (Smart Premises Interoperable Neutral Message Exchange) specification offers message exchange and enables semantic interoperability. SPINE data types can be implemented for several use scenarios (e.g., heating, air conditioning).
3. SHIP (Smart Home IP) specification based on mDNS for identifying and discovering devices is TLS secured.

According to the EEBUS website, SPINE Resources *"describes the device model and the message content itself as data models (class descriptions) and application rules."* In contrast, SPINE Protocol "describes the format of a SPINE datagram as well as rules and descriptions for connecting SPINE devices such as identification of supported use cases or determination of the address of a function." (EEBus Website, 2019) A datagram is a class that describes SPINE message and consists of header and payload. XML Schema Definition (XSD) files describe the SPINE data model. (EEBus, 2018)

4.2.8 FIWARE

FIWARE is an open-source components framework and set of API (FIWARE NGSI) for context data management. It facilitates Smart Solutions' development for different domains such as Smart Cities, Smart Industry, and Smart Energy. FIWARE framework enables the development of a system that allows to capture data from multiple sources besides IoT and analyse that information to implement desired outcomes and behaviour without limiting to specific standards (FIWARE Alliance – Main Website, n.d.)

“FIWARE smart data model includes three elements: the schema, or technical representation of the model defining the technical data types and structure, the specification of a written document for human readers, and the examples of the payloads for NGSIv2 and NGSI-LD versions.” (FIWARE Alliance – Smart Data Models, n.d.) Data models are grouped into subjects. Currently, FIWARE energy domain compiles four data models for batteries energy, energyCIM, Green Energy. Energy data model is the adaptation of IEC standards (CIM). (FIWARE Alliance - Github, n.d.) It contains three data models with the following entity types:

- **ACMeasurement.** Data Model measures the electrical energies consumed by an electrical system that uses an Alternating Current (AC) for a three-phase (L1, L2, L3) or single-phase (L) and neutral (N).
- **InverterDevice.** Data model describes the mechanical, electrical characteristics of an Inverter according to DC - Direct Current Information supplied as input and AC - Alternating Current Information returned as output.
- **ThreePhaseAcMeasurement.** An electrical measurement from a system that uses a three-phase alternating current.

4.2.9 ESTFEED

Estfeed is defined as "a data access platform that connects energy data hubs and enables energy companies, demand response aggregators and other service providers to access data from one place" (Smart Grid Development, n.d.) It connects different market participants and data sources as well as grants secure access to consumption data. Estfeed protocol is compliant with any domain-oriented data model (e.g. energy, bank, transport).

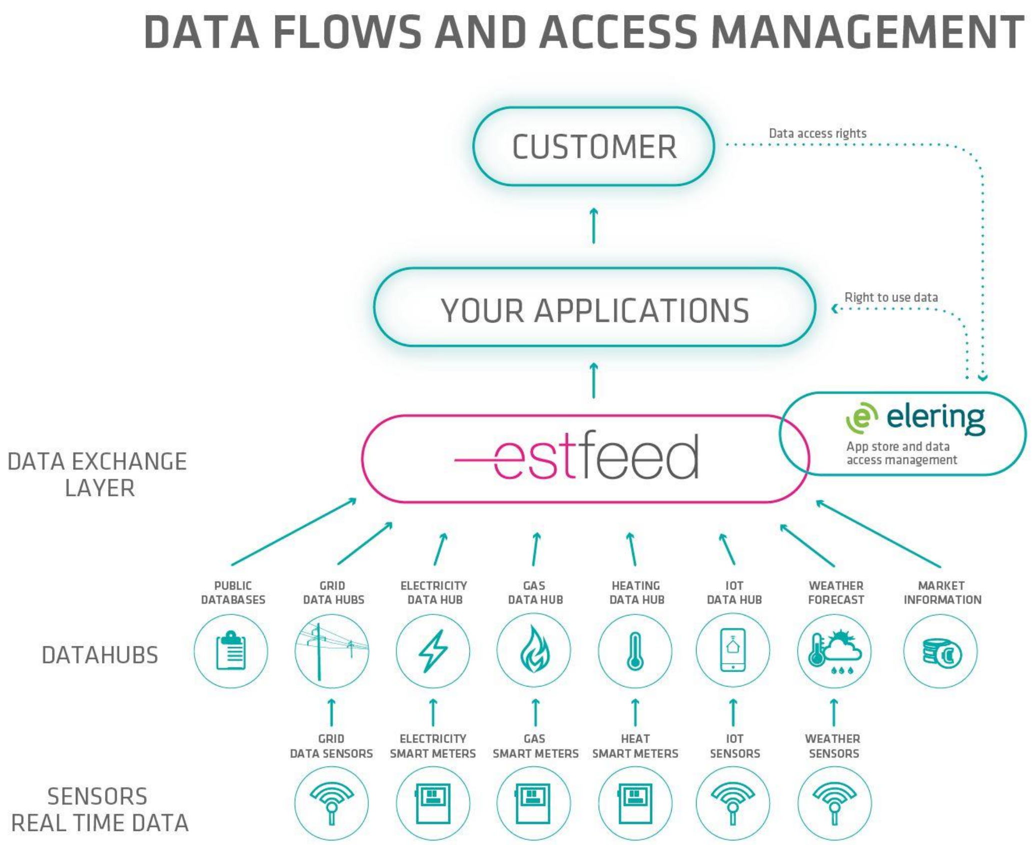

FIGURE 11: ESTFEED DATA FLOWS OVERVIEW (REPRINTED, WITH PERMISSION FROM ELERING WEBSITE)[33]

[33] https://elering.ee/en/smart-grid-development

The data exchange process involves three actors:

1. **Application information system.** Consumer of data and services. Communicates with the Estfeed (application adapter) system using Estfeed protocol.
2. **Data Source information system.** Provider of the data and services. Communicates with the Estfeed system (source adapter) using Estfeed protocol.
3. **Estfeed system.** It is a mediator of data and services between applications and data sources.

Both application information systems and source information systems use HTTP POST over mutually authenticated TLS (HTTPS) connections to exchange data with the Estfeed system.

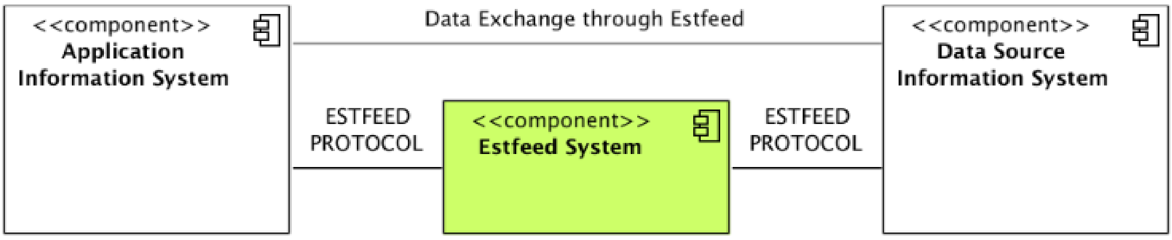

FIGURE 12: ESTFEED PROTOCOL EXCHANGE OVERVIEW (REPRINTED WITH PERMISSION, FROM ESTFEED SPECIFICATION, 2018)

For the end-to-end data exchange, an encoded multipart MIME messages format is used. A MIME message consists of 2 parts: metadata in XML format and optional service-specific data payloads. Between individual systems, HTTP is used for the transfer of messages. (Estfeed Specification, 2018)

4.2.10 G3-PLC

G3-PLC is an open, international standard published by ITU[34] G.9903 that facilitates high-speed, highly reliable, long-range communication over the existing powerline grid. G3-PLC provides “a mesh routing protocol to determine the best path between remote network nodes, a "robust" mode to improve communication under noisy channel conditions and channel estimation to select the optimal modulation scheme between neighbouring nodes” (G3-PLC Alliance User Guidelines, 2020). It covers the PHY and Data Link layers of the OSI model for powerline communication. It has been designed to be used with IPv6 at layer three and UDP at layer 4.

Two-way communications networks based on G3-PLC will provide electricity network operators with intelligent monitoring and control capabilities. Operators will monitor electricity consumption throughout the grid in real-time, implement variable tariff schedules, and set limits on electricity consumption to manage peak loads better.
G3-PLC-based two-way communications networks provide intelligent monitoring and control capabilities for electricity network operators. In order to better manage peak loads, operators will be able to monitor electricity consumption throughout the grid in real-time, implement variable tariff schedules and set limits for electricity consumption. (G3-PLC Alliance User Guidelines, 2020)

[34] https://www.itu.int/rec/T-REC-G.9903

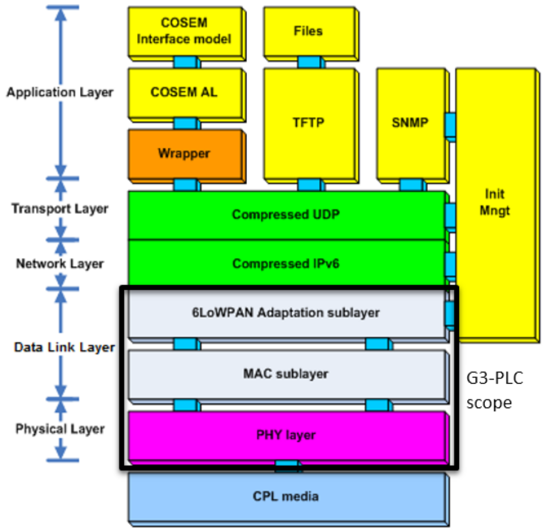

FIGURE 13: G3-PLC PROTOCOL OVERVIEW (REPRINTED, WITH PERMISSION, FROM TRIALOG, 2017)

Intelligent network management approaches from G3-PLS provide the world with a smarter solution. Network operators will use existing resources better rather than constructing additional power plants to accommodate worst-case scenarios. Simultaneously, demand-side management should act as a form of indirect generation by better managing the load distribution.

4.2.11 MODBUS

Modbus is an application layer request-response communication protocol developed with the master-slave relationship approach. In a master-slave relationship, communication always occurs in pairs—one device must initiate a request and then wait for a response. The initiating device (the master) is responsible for initiating every interaction. Typically, the master is a human-machine interface or SCADA system, and the slave is a sensor, programmable logic controller, or programmable automation controller. The content of requests, responses, and the network layers across which these messages are sent, are defined by the different layers of the protocol (MODBUS Application Protocol, 2012)[35].

Every device (e.g., Control Panel, Driver, Motion control) can use MODBUS protocol to initiate a remote operation. The same communication can be done on serial lines as on Ethernet TCP/IP networks. Gateways allow communication between several types of buses or networks using the MODBUS protocol. To do that, MODBUS protocol "defines a simple protocol data unit independent of the underlying communication layers. The mapping of MODBUS protocol on specific buses or networks can introduce some additional fields on the ADU. The MODBUS application data unit is built by the client that initiates a MODBUS transaction. The function indicates to the server what kind of action to perform. The MODBUS application protocol establishes the format of a request initiated by

[35] https://modbus.org/docs/Modbus_Application_Protocol_V1_1b3.pdf

a client. For example, a client can read the ON / OFF states of a group of discrete outputs or inputs or read/write the data contents of a group of registers. When the server responds to the client, it uses the function code field to indicate either a normal (error-free) response or that some error occurred (called an exception response). For a normal response, the server simply echoes to the request the original function code MODBUS bases its data model on a series of tables that have distinguishing characteristics.” (MODBUS Application Protocol, 2012).

The distinctions between inputs and outputs and bit-addressable and word-addressable data items do not imply application behaviour. It is acceptable and common to regard all four tables as overlaying if this is the most natural interpretation of the target machine in question (MODBUS Application Protocol, 2012).

For each of the primary tables, the protocol allows individual selection of 65536 data items. Reading or writing operations are designed to span multiple consecutive data items up to a data size limit dependent on the transaction function code.

All the data handled via MODBUS (bits, registers) must be located in device application memory. However, physical address in memory should not be confused with data reference. The only requirement is to link data references with physical addresses. MODBUS logical reference numbers used in MODBUS functions are unsigned integer indices starting at zero (MODBUS Application Protocol, 2012).

4.2.12 OSGP

OSGP is an open specification that defines the data interface model, security system, and management functionalities for the data exchange of smart-grid devices. OSGP is interoperable with other standards & specifications. OSGP is compatible with DLMS/COSEM. OSGP is a REST-style protocol meaning that it contains methods to interact with attributes organised in a structured manner.

"Data exchange with smart grid devices enables service providers to obtain client usage information such as data billing and loading profiles, track and control grid usage, schedule tariff provision, detect theft and tampers, and issue disconnects. The OSGP data interface uses a representation-oriented model (tables (rows, columns) and procedures). The device data structures are presented and used in tabular form and include binary encoded information elements." (OSGP Technical Specification, 2019) The exchange of information (e.g., device status, data logs) is done via tables.

TABLE 9: PROTOCOL STACK ACCORDING TO OSI (OSGP TECHNICAL SPECIFICATION, 2019)

OSI Layers	Standards/Protocols	Description
Application layer	ETSI Group spec GS OSG 001	Allows to define devices a set of data (attributes), methods (procedures) and events
Layer 2-6	ISO/IEC 14908.1 Control Networking	Provides reliable and multicast messaging.
Physical layer	ETSI Technical spec TS 103 908	Used for control power line channel for control networking in the smart grid.

The frequency range of devices is between 9kHz and 95 kHz. Defines an independent media layer for secure messaging of meters and control nodes.

4.2.13 OPC UA

OPC is a Client/Server-based communication, which means one or more servers wait for several Clients to make requests. Once the server gets a request, it answers that and then goes back into a wait state. Nevertheless, the client can also instruct the server to send updates when such comes into the server. In OPC, the client decides when and what data the server will fetch from the underlying systems. That is also true if the client subscribes to updates where the client decides how often the server should quire the systems. (OPC UA Overview, 2015)

The different classical OPC protocols are completely self-sustained and have nothing in common. That means that the quality field in DA has no connection to the same field in HAD.

Currently in the classic OPC model has the following protocols:

- **DA** (Data access)
- **A.E.** (Alarm & Events)
- **HDA** (Historical Data Access)
- **XML DA** (XML Data Access)
- **DX** (Data eXchange)

Each of these protocols has its read/write commands that only affect one protocol at a time. That is true even if one OPC server supports several of the protocols. The most commonly used and oldest protocol is the data access (DA), and in the following section, the others will be more explained.

“The difference between classical OPC and OPC UA is that it does not rely on OLE or DCOM technology making it possible to implement it on any platform, such as Apple, Linux (JAVA) or Windows**.** The other very important part of UA is the possibility to use structures or models. This means that the data tags or points can be grouped and given context, making governance and maintenance easier. These models can be identified in runtime, making it possible for a client to explore the connection possible by asking the server" (Novotek Website, n.d.).

The information modelling is very modern in OPC UA. Manufacturers or protocols like BACNet can define these models. However, it can also contain more of a MESH structure where very complex relations and connections between points and nodes can be defined. The possibility also exists to have data structures so that certain data always are grouped and handled as one piece. This is important in many applications where it is important to be sure that the data set is taken simultaneously.

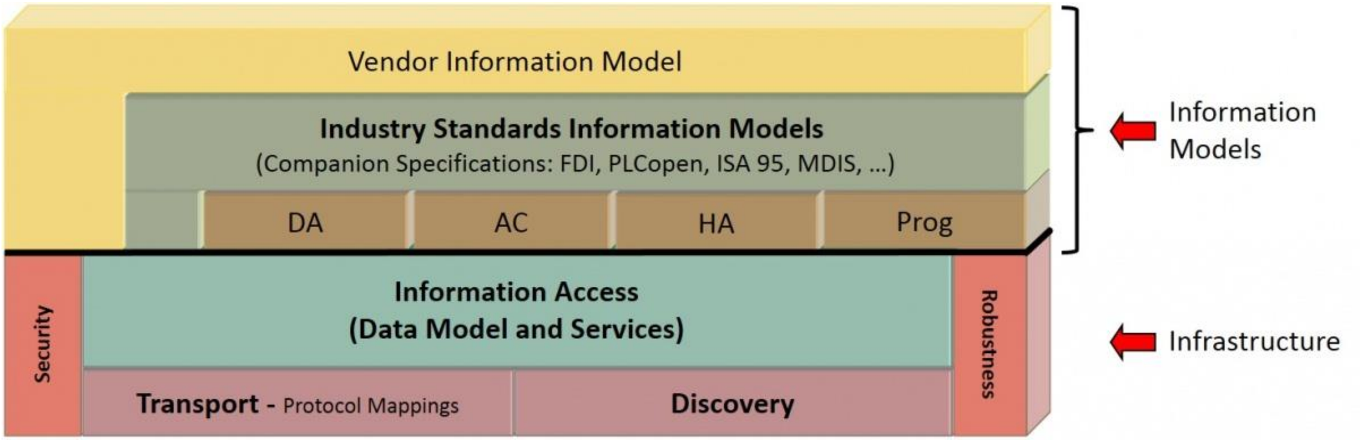

FIGURE 14: OPC UA OVERVIEW (REPRINTED WITH PERMISSION, FROM OPC UA OVERVIEW, 2015)

OPC UA communication layer

OPC UA communication layer is built into layers on top of the standard TCP/IP stack so that OPC UA can be platform-independent. Two layers handle the session and establish a secure channel between the client and server. The transport layer comprises TCP/IP and, on top of that, SSL, HTTP or HTTPS. The Communication layer secures the communication channel and the authentication so that the endpoints cannot be infiltrated and changed. This is based on X.509 certificates with three parts to them, and the first peer to peer trust needs to be manually done, but after that, the rest is taken care of securely (OPC UA Overview, 2015).

4.2.14 PRIME

PRIME initially defines lower OSI layers of a narrowband PLC data transmission system over the electricity grid. The whole architecture has been designed to be low-cost but high-performance**.** It uses Orthogonal Frequency Division Multiplexing (OFDM) in narrowband frequency ranges. OFDM PRIME technology-specific a narrowband data transmission system based on OFDM modulations scheme for providing mainly core utility services. Detailed communication layers are described in PRIME specification[36]. This specification focuses mainly on the data, control and management plane. According to PRIME Specification, the reference model of protocol layers contains a convergence layer that "classifies traffic, associating it with its proper MAC connection; this layer performs the

[36] https://www.prime-alliance.org/wp-content/uploads/2020/04/PRIME-Spec_v1.4-20141031.pdf

mapping of any kind of traffic to be properly included in MAC service data units. It may also include header compression functions. Several service-specific convergence sublayers are defined to accommodate different kinds of traffic into MSDUs. The MAC layer provides core MAC functionalities of system access, bandwidth allocation, connection establishment/maintenance and topology resolution. The PHY data rates can be adapted to channel and noise conditions by the MAC. The PHY layer transmits and receives MAC Protocol Data Units between *NeighborNodes* using OFDM" (PRIME Alliance, 2020). OFDM is chosen as the modulation technique because of:

- its inherent adaptability in the presence of frequency selective channels (which are common but unpredictable, due to narrowband interference or unintentional jamming);
- its robustness to impulsive noise, resulting from the extended symbol duration and use of FEC;
- its capability for achieving high spectral efficiencies with simple transceiver implementations.

4.3 SUMMARY OF THE REVIEWED DATA MODELS

Throughout this work, 14 standards and protocols were analysed. Compared to CIM, other standards provide a rather narrow, case-specific view on data models. Nevertheless, described data models share some general commonalities: most data models are maintained in UML and have XML as the preferred serialization format, sometimes different models reflect the same aspects of the power system, mostly equipment and measurements. Table 10 summarises the application of described data models and protocols in the Smart Grid Architecture Model context. (See Chapter 6.1 for SGAM framework description).

TABLE 10: MAPPING DATA MODELS TO SGAM

Data exchange models	Information layer	Communication layer
Common Information Model	+	+ (MADES)
IEC 61850	+	+
DLMS/COSEM	+ (COSEM)	+ (DLMS)
Ediel	+	+
ebIX®	+	
Green Button	+	+
EEBUS	+ (SPINE)	+ (SHIP)
Fiware	+	
Estfeed		+
G3-PLC		+
MODBUS		+
OSGP		+
OPC UA	+	+
PRIME		+

4.4 DATA MODELS USED BY EU-SYSFLEX DEMONSTRATORS

The aim of this subchapter consists of identifying data models used by the EU-SysFlex demonstrators and their data needs.

An analysis has been realized on the basis of information provided by the demonstrator leaders and the following documents:

- “Demonstrators’ system use cases description” (EU-SysFlex D6.1, 2019);
- “General description of processes and data transfer within three EU-SysFlex demonstrators” (EU-SysFlex D6.4, 2019);
- “System uses cases and requirements: centralized and decentralized flexibility resources (WP7)” (EU-SysFlex D7.1, 2019);
- “Overall architectures for the VPP and Flexibility Hub (WP7)” (EU-SysFlex D7.2, 2019);
- “WP8 Demonstration Specification for Field Testing: Aggregation Approaches for Multi-services Provision from a Portfolio of Distributed Resources” (EU-SysFlex D8.1, 2018);
- “Affordable Tool for Smaller DSR Units for providing flexibility services” (EU-SysFlex D9.1, 2021);
- “Application for TSO-DSO flexibility data exchange - Flexibility platform” (EU-SysFlex D9.2, 2021);
- “Cross-border and cross-sectoral data exchange” (EU-SysFlex D9.3, 2021).

The objective of this analysis is to provide a high level and synthetic view of the data models used in the demonstrators, based on detailed information given by the demonstrators. For each demonstrator, this view has been built on the list of exchanged data (called Business Objects below), the System Use Cases where the exchanged data are mentioned, and the data models these exchanged data should comply with.

Special attention was paid on data models standards (e.g. CIM, IEC 61850) and their origins (e.g. IEC, CENELEC, national), as these standards avoid starting from the blank page and are extremely efficient and useful to share understanding between business and IT analysts and to achieve interoperability between systems.

TABLE 11: GERMAN DEMONSTRATOR DATA MODELS’ ANALYSIS

Business Objects	SUCs	Data models
Measurements	DE-OPF/DE-COM	CIM CGMES
Computed Forecast	DE-OPF/DE-COM	Custom
Flexibilities for active/reactive/voltage	DE-COM	CIM CGMES
Operating schedule for active/reactive power	DE-COM	ENTSO-E RESERVE RESOURCE PROCESS (ERRP)
Operating signal	DE-COM	IEC 60870-5-101

TABLE 12: ITALIAN DEMONSTRATOR DATA MODELS' ANALYSIS

Business Objects	SUCs	Data models
Data request	IT – NT SE	IEC 60870-5-104 Custom
Real time measurements	IT – NT SE	IEC 61850 IEC 60870-5-104
Device status	IT – NT SE	IEC 61850 IEC 60870-5-104
Network data	IT – NT SE/IT – AP OP/IT – RPC/IT – RP OP	Custom
Curve capability	IT – RPC	Custom

TABLE 13: FINNISH DEMONSTRATOR DATA MODELS' ANALYSIS

Business Objects	SUCs	Data models
AssetData	FIN – FC	To be defined
AssetForecast	FIN – FC / FIN – FLAG	To be defined
MarketForecast	FIN – FLAG	To be defined
AssetAllocation	FIN – FLAG	To be defined
AcceptedBid	FIN – FLAG	OPC UA
QMarketLaunch	FIN – RP MK	To be defined
AssetOffer	FIN – RP MK	To be defined
QMarketResults	FIN – RP MK	To be defined
BidActivation	FIN – RP MK	To be defined
NetworkData	FIN – RP MN	IEC 61850 IEC 60870-5-104
ReactorCapacitorSetPoints	FIN – RP MN	IEC 61850 IEC 60870-5-104
ReactivePowerNeeds	FIN – RP MN	To be defined
MeasurementDataRequest	FIN – RP MN	IEC 61850

TABLE 14: PORTUGUESE (VPP) DEMONSTRATOR DATA MODELS' ANALYSIS

Business Objects	SUCs	Data models
WP (Wind Park) availability schedule	VPP-AP optimal bidding	TASE.2 (ICCP) or OPC UA
VNIII (hydro) availability schedule	VPP-AP optimal bidding	TASE.2 (ICCP) or OPC UA
Weather info	VPP-AP optimal bidding	TXT files
Day-ahead/Intraday bid	VPP-AP optimal bidding	TXT files
Day-ahead/Intraday accepted bid	VPP-AP optimal bidding	TXT files
Generation breakdown	VPP-AP optimal bidding	TXT files
Daily program	VPP-AP optimal bidding	TXT files
WP info	VPP-AP optimal dispatch	TASE.2 (ICCP) or OPC UA
VNIII info	VPP-AP optimal dispatch	TASE.2 (ICCP) or OPC UA
Power dispatch plan	VPP-AP optimal dispatch	TXT files
Set points	VPP-AP optimal dispatch	TASE.2 (ICCP) or OPC UA

TABLE 15: PORTUGUESE (FLEXHUB) DEMONSTRATOR DATA MODELS' ANALYSIS

Business Objects	SUCs	Data models
Q Profile	RP-DM / RP-MC	Custom
P Profile	AP-DM	Custom
Q Bids	RP-DM	Custom
P Bids	AP-DM / AP-TLQ	Custom
SCADA and forecast data	RP-DM / AP-DM	XML file
Grid information	RP-DM	DPX23 from DPLAN tool
PQ maps	RP-DM / RP-MC	Custom
TLQ result	AP-DM	Custom
Q assigned	RP-DM / RP-MC	Custom
Assigned P per bid	AP-DM	Custom
Assigned P per resource	AP-DM	Custom
PF results	AP-TLQ	Custom
MOPF results	RP-MC / AP-TLQ	Custom
TLQ results	AP-TLQ	Custom
Settlement data	RP-STL	XML file
Dynamic model	DM-DM / DM-MC	Custom

EU-SysFlex

TABLE 16: FRENCH DEMONSTRATOR DATA MODELS' ANALYSIS

Business Objects	SUCs	Data models
Prices information	Distributed Energy Resources Aggregator Operation	Custom
Measurements	Distributed Energy Resources Aggregator Operation	IEC 60870-5-104
Generation forecast information	Distributed Energy Resources Aggregator Operation	Custom
Services scheduling	Distributed Energy Resources Aggregator Operation	Custom
Services Setpoints	Distributed Energy Resources Aggregator Operation	IEC 61850
FCU-W Services activation/deactivation	Distributed Energy Resources Aggregator Operation	IEC 60870-5-104
BCU-S Services activation/deactivation	Distributed Energy Resources Aggregator Operation	IEC 60870-5-104
ConceptGrid Load Curtailment	Distributed Energy Resources Aggregator Operation	Modbus
EDF Concept Grid request	Distributed Energy Resources Aggregator Operation	Modbus

TABLE 17: DATA MANAGEMENT DEMONSTRATORS DATA MODELS' ANALYSIS

Business Objects	SUCs	Data models
Flexibility Need	Predict flexibility availability Manage flexibility bids	ENTSO-E Reserve Resource Process (ERRP)
Flexibility Potential	Predict flexibility availability Manage flexibility bids Manage flexibility activations	ENTSO-E Reserve Resource Process (ERRP)
Flexibility Call for Tenders	Manage flexibility bids	ENTSO-E Reserve Resource Process (ERRP)
Flexibility Bid	Calculate flexibility baseline Manage flexibility activations	ENTSO-E Reserve Resource Process (ERRP)
Activated Flexibility	Manage flexibility activations	ENTSO-E Reserve Resource Process (ERRP)
Baseline	Calculate flexibility baseline	ENTSO-E Reserve Resource Process (ERRP)
Market Data	Collect energy data	TBD
Network Restriction	Manage flexibility bids	TBD
Meter Data	Collect energy data	ENTSO-E Reserve Resource Process (ERRP)
Sub-Meter Data	Manage sub-meter data	TBD

Authenticate Information	Authenticate data users Collect energy data Transfer energy data	Estfeed Service Payload Formats
Representation Rights	Authenticate data users	Estfeed Service Payload Formats
Authorization information	Manage access permissions	Estfeed Service Payload Formats
Data log	Manage data logs	Estfeed Service Payload Formats

The data models standards appearing in the detailed and abovementioned analysis are summarised in Table 18.

TABLE 18: EU-SYSFLEX DATA MODELS' GLOBAL OVERVIEW

Data models	WP6 Germany	WP6 Italy	WP6 Finland	WP7 Portugal VPP	WP7 Portugal FlexHub	WP8 France	WP9 Data manag.
CIM CGMES	X						
CIM based ENTSO-E Reserve Resource Process (ERRP)	X						X
CIM based ENTSO-E Market Data Exchange Standard (MADES)							X
IEC 60870-5 (101 or 104)	X	X	X			X	
IEC 61850		X	X			X	
IEC 60870 - TASE.2 (ICCP)				X			
OPC UA			X	X			
Modbus						X	
Estfeed							X

5. DATA EXCHANGE ROLE MODEL

The aim of this chapter is to define a data exchange role model describing, in a static way, how Business Roles interact with one another and which data they exchange. Based on deliverable 5.2 data exchange SUCs and associated definitions (EU-SysFlex D5.2, 2020)[37], an analysis has been realised on:

- The exchanged data;
- The systems used to exchange them;
- The mapping between these systems and the Business Roles who operate them;
- The mapping between these Business Roles and the roles defined in the Harmonized Electricity Market Role Model (HEMRM) developed by ENTSO-E, EFET and ebIX® (2020)[38] for Internal Electricity Market in Europe (IEM).

This analysis led to the definition of a data exchange role model built on the scenarios of data exchange SUCs and the Business Roles who operate the involved systems or interact with them. It is called data exchange role model because the focus was on data exchange and many new roles identified are about 'data exchange roles' which are agnostic to specific market processes. However, in this process also 'market roles' could not be ignored and some new were proposed.

The objective of this data exchange role model is to:

- Relate Business Roles with the already existing roles from the HEMRM;
- Identify new Business Roles motivated by business/market or IT/data needs.

5.1 DATA EXCHANGED, SYSTEMS USED, AND MAPPING TO BUSINESS ROLES

Figure 15 reflects every Business Object mentioned in data exchange SUCs. In this diagram, Business Objects are clustered into categories of Business Objects (e.g. Flexibilities, Network Monitoring).

[37] https://eu-sysflex.com/wp-content/uploads/2020/10/EU-SysFlex-Task-5.2-D5.2-FINAL.pdf
[38] https://www.entsoe.eu/digital/cim/role-models/

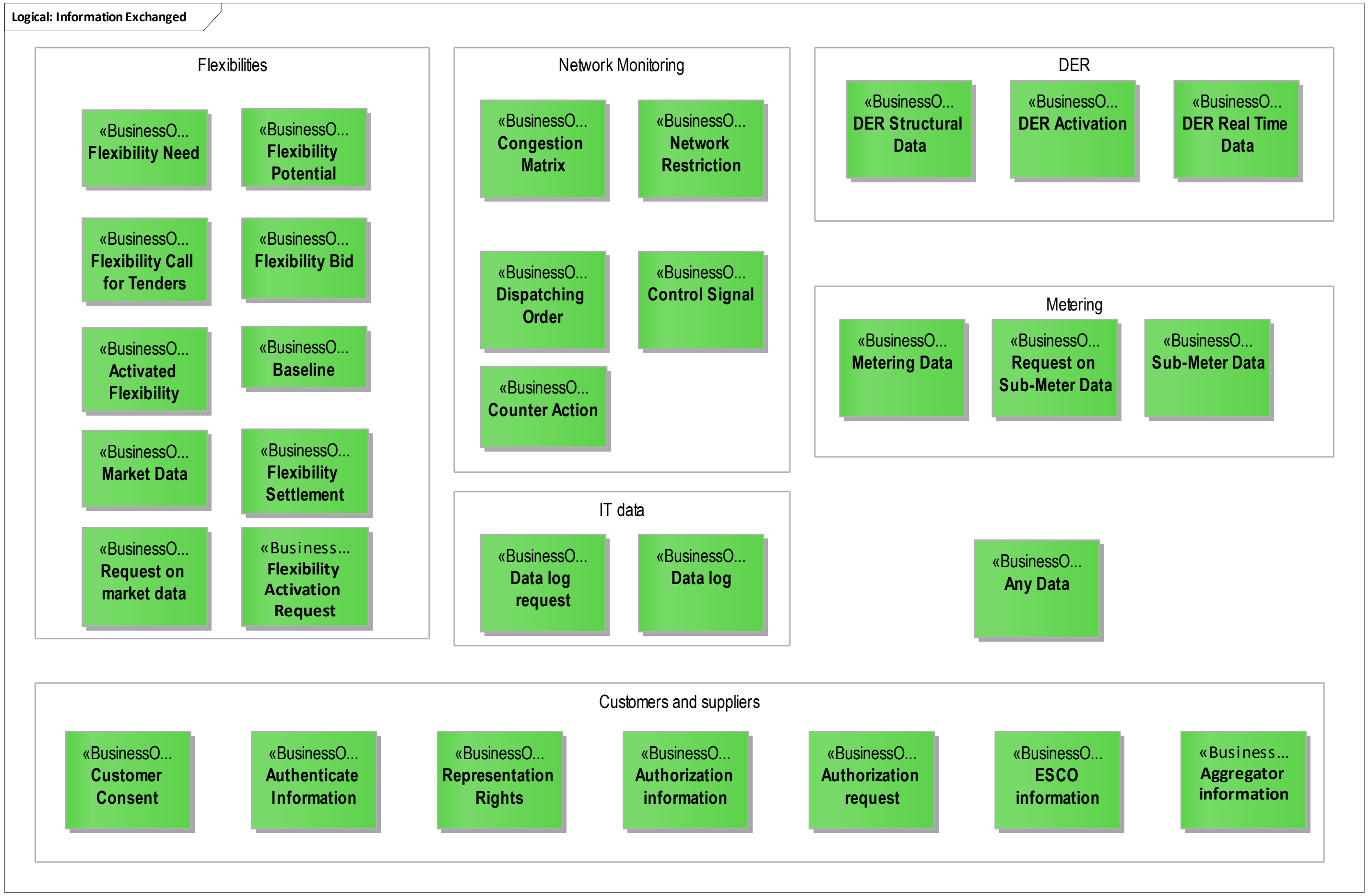

FIGURE 15: BUSINESS OBJECTS DIAGRAM

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773505.

Systems to be used for exchanging data as stated in data exchange SUCs are represented in Figure 16. In this diagram, systems are grouped into several categories of systems (e.g. platforms, metering systems, monitoring systems). Arrows between systems mean “is a kind of” (e.g. a Data Hub is a kind of Data Source). Descriptions of these systems are provided in EU-SysFlex D5.2 (2020).

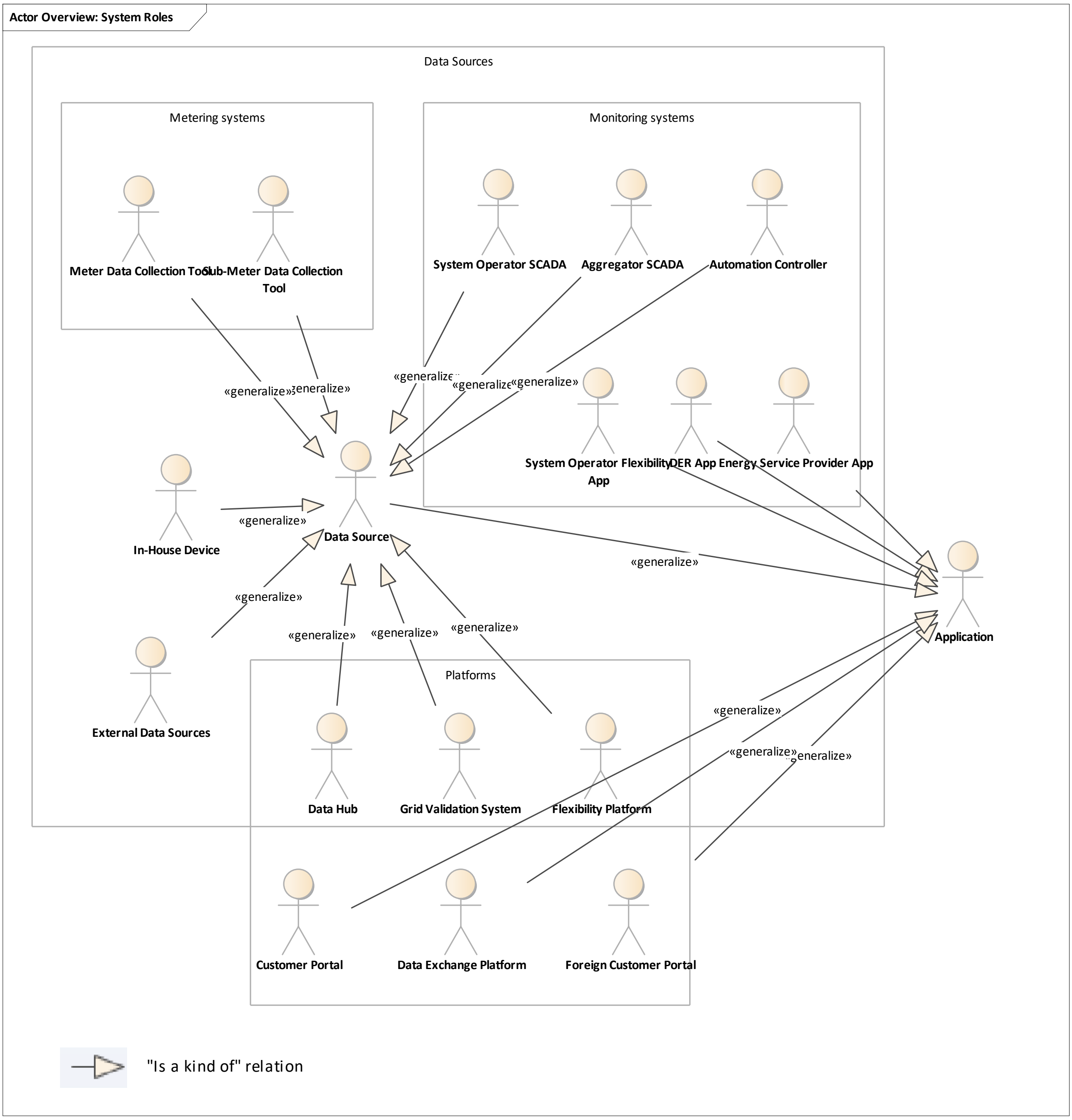

FIGURE 16: SYSTEM ROLES DIAGRAM

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 SO SCADA is operated by a SO). 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.).

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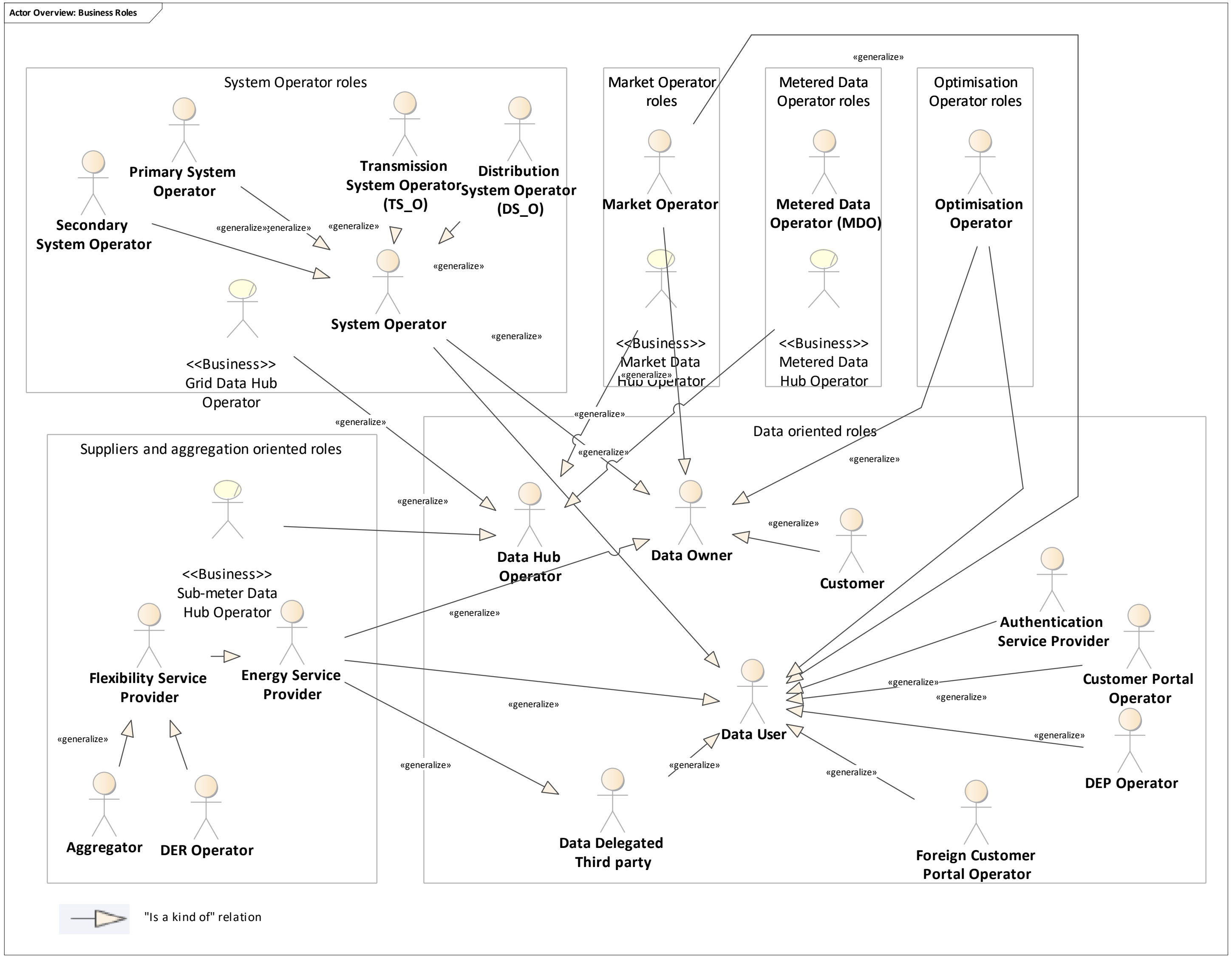

FIGURE 17: BUSINESS ROLES DIAGRAM

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773505.

Business Roles exchanging data and involved in data exchange SUCs are represented in Figure 17. In this diagram, Business Roles are grouped into several categories of Business Roles (e.g. SO roles, Data oriented roles). Arrows between Business Roles mean "is a kind of" (e.g. a TSO is a kind of SO). Descriptions of these Business Roles are available below.

The mapping between systems used to exchange data and Business Roles who operate them is represented in Figure 18.

FIGURE 18: SYSTEM ROLES ALONG WITH BUSINESS ROLES

EU-SysFlex data exchange SUCs focus on both business roles and systems. They do not formally associate systems and business roles, apart from what it is written in the descriptions of actors in SUCs (EU-SysFlex D5.2, 2020). Figure 18 is intended to represent these associations (notably MOs operating Flexibility Platforms and new business actors such as Customer Portal Operators operating new systems). It also maps systems with business roles inside business-oriented boundaries, as functionalities of systems must be aligned with business responsibilities of business roles.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773505.

As a business role model should only represent Business Roles and data exchanged between each other, this diagram should not be considered as part of the business role model per se. It is just presented as an intermediate analysis that gives coherence between systems, business roles, data exchanges SUCs and the business role model.

5.2 BUSINESS ROLE MODEL

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.

A data exchange role model was built based on the scenarios of data exchange SUCs and the Business Roles who operate the involved systems or interact with them. This business role model is represented in Figure 19.

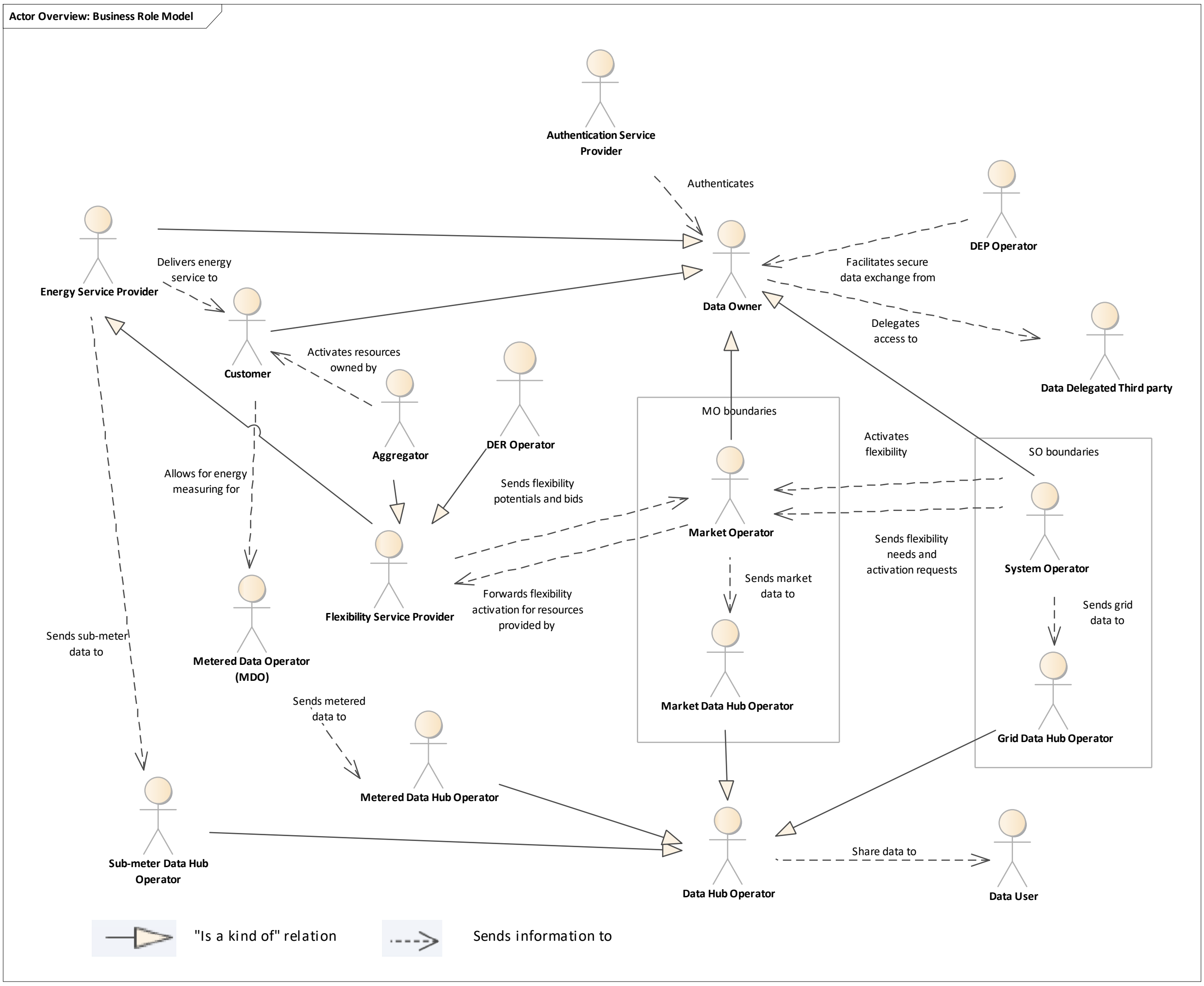

FIGURE 19: BUSINESS ROLE MODEL

The arrows with dashed lines represent relationships between Business Roles (e.g. the Metered Data Operator collects metered data from customers). The arrows with solid lines represent generalisations, meaning "is a kind of" (e.g. the Aggregator is a kind of Flexibility Service Provider). This figure does not show all "is a kind of" relations, meaning there are also further "is a kind of" relations between Business Roles displayed in Figure 17.

Figure 19 and the data exchange SUCs do not represent the role of Optimisation Operator (OO) as defined in EU-SysFlex D3.2 (2020)[39] which elaborates the discussion about optimization approaches, optimization operators and the allocation of this role to an actor. The OO role could operate Grid Validation System as defined in some data exchange SUCs. According to the results of D3.2 the OO role can theoretically be carried out by different actors, namely the MO, the SO or a third party.

In order to deal with the fact that there are more than one option to allocate the OO role and to deal with different underlying business assumptions, the data exchange SUCs, which theoretically would need to include the OO role, can entail two alternatives for OO role allocation:

- Alternative 1 for centralised optimisation as defined in D3.2. The MO selects flexibility bids based on partial grid data. Basically, the MO acts as OO.
- Alternative 2 for decentralised optimisation as defined in D3.2 with comprehensive grid data exchange. The SO selects the flexibility bids and therefore the OO role is implicitly allocated to the SO.

It means OO can be put either inside MO or SO boundary. For these three involved Business Roles, the two alternatives lead to the business role models as depicted in Figure 20.

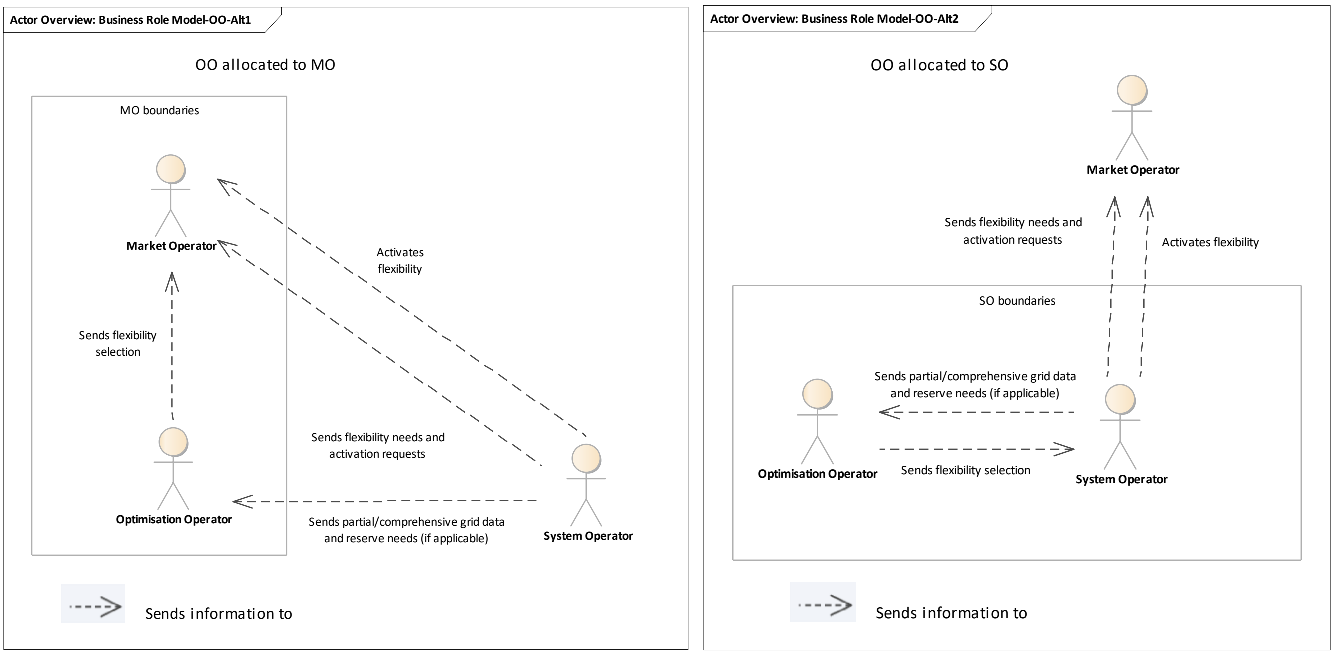

FIGURE 20: BUSINESS ROLE MODEL FOR OPTIMISATION OPERATOR

[39] https://eu-sysflex.com/wp-content/uploads/2020/06/EU-SysFlex_Task-3.2-Deliverable-Final.pdf

5.3 MAPPING THE ROLES TO HEMRM AND PROPOSAL FOR NEW ROLES

Most of these identified Business Roles can be mapped, fully or mostly, to the HEMRM (ENTSO-E, EFET and ebIX®, 2020). The other ones reflect the new business and IT needs. Table 19 lists those new roles which EU-SysFlex team has proposed to add to HEMRM.

The HEMRM describes a model identifying all the roles that can be played for given domains within the electricity market. It also identifies the different objects that are necessary in the electricity market for information exchange. HEMRM has made use of the UML class diagramming technique. It uses two UML symbols, the "actor" symbol and "class" symbol.

TABLE 19: BUSINESS ROLES TO BE ADDED TO HEMRM

EU-SysFlex	
Business Roles	Descriptions
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.
Customer Portal Operator	Operates a Customer Portal.
Data Delegated Third party	Any natural person who has received representation rights from a data owner.
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
Data User	Any person who uses data. Can be a Data Owner or a Data Delegated Third party.
DEP Operator	Data exchange platform operator owns and operates a communication system which basic functionality is data transfer.
Flexibility Service Provider	Can be a Distribution Network Flexibility Provider or a Transmission Network Flexibility Provider (cf. definitions in T3.3 deliverable). Similar to Flexibility Aggregator. Can be both aggregator and individual consumer/generator. Type of Energy Service Provider.
Foreign Customer Portal Operator	Customer Portal Operator in another country. Can also mean an operator of a separate customer portal in the same country.
Optimization Operator	Optimize and select the bids; clear the market for auctions (organised by the MO) or select individual bids in the order book (organized by the MO) taking into account the grid data (constraints and sensitivities/topology if needed) provided by DS_O and TS_O; communicate results (rewarded offers and prices) to the MO. The OO role can be carried out by a system operator, a market operator or a third party.

6. SGAM BASED DATA EXCHANGE MODEL

This chapter reports on the modelling of Smart Grid systems following the Smart Grid Architecture Model (SGAM) approach using the data exchange SUCs elaborated in EU-SysFlex D5.2 (2020) as main input. The SGAM methodology is described in the Smart Grid Reference Architecture document (CEN-CENELEC-ETSI, 2012)[40] along with a complete description of the SGAM framework. As for the practical modelling tasks, SGAM Toolbox[41] is used, an Enterprise Architect add-on which is a support tool for SGAM modelling works, offering guidelines (Neureiter, 2014)[42] to apply the aforementioned SGAM methodology.

6.1 SGAM FRAMEWORK

"The SGAM framework aims at offering a support for the design of smart grids use cases with an architectural approach allowing for a representation of interoperability viewpoints in a technology neutral manner, both for the current implementation of the electrical grid and future implementations of the smart grid. /…/ It allows the presentation of the current state of implementations in the electrical grid, but furthermore to depict the evolution to future smart grid scenarios by supporting the principles universality, localisation, consistency, flexibility and interoperability." (CEN-CENELEC-ETSI, 2012) SGAM consists in a 3-dimensional model (Figure 21) composed by:

- 5 *interoperability layers*, each of them offering a specific viewpoint on the architecture: *business*, *function*, *information*, *communication* and *component* layers.
- For each layer, the *smart grid plane*, a 2-dimensional representation consisting of:
  - *Domains* representing the "electrical energy conversion chain" from "bulk generation" to "customer premises",
  - *Zones* representing the hierarchical management of the electrical process.

Brief explanation of these concepts follows as extracted from CEN-CENELEC-ETSI (2012) while complete details about the SGAM framework and the related methodology can be found in the section 7 of the same document.

Each interoperability layer focuses on a particular architectural viewpoint.

- Business layer: offers a business view on the information exchange by mapping the business actors as well as the business capabilities and the processes.
- Function layer: describes functions and services as well as their relationships.
- Information layer: highlights the semantics of information exchanged between functions, services and components as well as underlying standardised canonical data models.
- Communication layer: identifies the protocols and data formats supporting information exchanges between components.
- Component layer: focuses on the physical distribution of the components.

[40] https://ec.europa.eu/energy/sites/ener/files/documents/xpert_group1_reference_architecture.pdf
[41] https://sgam-toolbox.org
[42] https://sgam-toolbox.org/downloads/Introduction-to-SGAM-Toolbox.pdf

The domains highlight the whole electrical conversion chain in the smart grid plane.

- Generation: represents generation of electrical energy in bulk quantities.
- Transmission: represents the infrastructure and organization which transports electricity over long distances.
- Distribution: represents the infrastructure and organization which distributes electricity to customers.
- DER: represents distributed electrical resources directly connected to the public distribution grid.
- Customer Premises: represents end users but also producers of electricity.

The zones represent the hierarchical levels of power system management.

- Process: includes the physical, chemical or spatial transformations of energy and the physical equipment directly involved.
- Field: includes equipment to protect, control and monitor the process of the power system.
- Station: represents the areal aggregation level for field level.
- Operation: hosts power system control operation in the respective domain.
- Enterprise: includes commercial and organizational processes, services and infrastructures for enterprises.
- Market: reflects the market operations possible along the energy conversion chain.

6.2 MODELLING CONTENT

Figure 21 sums up the information retrieved from data exchange SUCs (EU-SysFlex D5.2, 2020) to feed the SGAM model. The content of the SUCs, which is based on IEC 62559-2 (2015)[43] standard template, addresses only the top 3 layers (business, function and information layers). It was then necessary to rely on other sources to complete the information layer (data models), the communication layer and the component layer. The following subsections highlight the content of each layer using the SGAM toolbox terms. For detailed explanations, see SGAM Toolbox guidelines (Neureiter, 2014).

[43] https://webstore.iec.ch/publication/22349

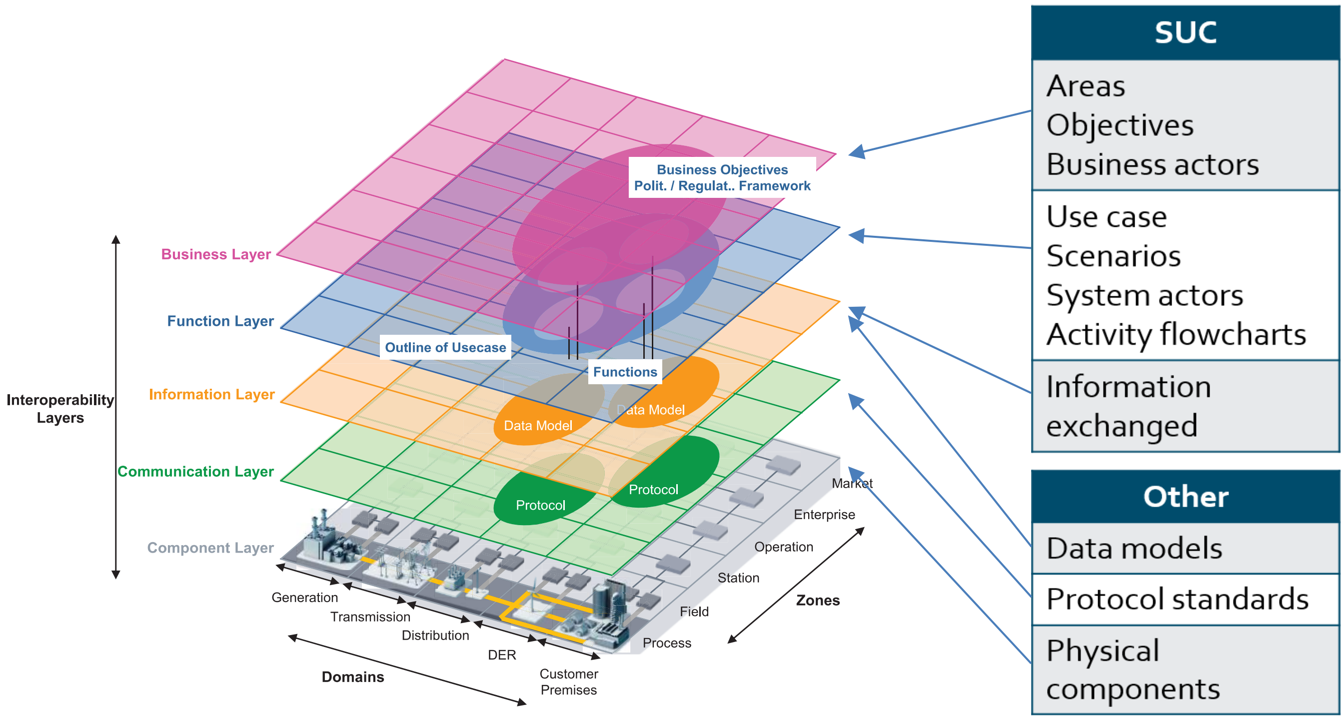

FIGURE 21: INPUT FOR THE SGAM LAYERS (MODIFIED FROM CEN-CENELEC-ETSI, 2012)

6.2.1 BUSINESS LAYER

The business layer identifies the Business Actors, their Business Goals and the corresponding Business Cases which are the ways Business Actors reach their goals. The Business Cases refer to High Level Use Cases. Table 20 shows the equivalent content in the SUCs.

TABLE 20: BUSINESS LAYER – SGAM TOOLBOX-SUC DESCRIPTION EQUIVALENCE

SGAM toolbox	SUCs
Business actor	Business actor[44]
Business Goal	Objectives
Business Case	Area(s)/Domain(s)/Zone(s)
High Level Use Case (HLUC)	Name of SUC

In order to structure the model, all modelled elements of a business case are grouped in an Enterprise Architect package (i.e. a logical place).

6.2.2 FUNCTION LAYER

In function layer, the main objective is to decompose HLUCs into several Primary Use Cases (PUC). In the model, under the function layer, there is one package per High Level Use Case.

[44] In EU-SysFlex, they are referred to as 'business roles'.

A HLUC refers to several PUCs. It gives information on how these PUCs are organised dynamically (e.g. scenarios, activity diagrams) and their interrelation (e.g. information exchanged between PUCs).

A PUC identifies the Logical Actors and offers also a dynamic view of the use case through activity and sequence diagrams. Each PUC offers a link to the EU-SysFlex data exchange SUCs' activity diagrams. Table 21 shows the equivalence between SGAM toolbox terms and the SUCs.

TABLE 21: FUNCTION LAYER – SGAM TOOLBOX-SUC DESCRIPTION EQUIVALENCE

SGAM toolbox	SUCs
High Level Use Case (HLUC)	Name of the SUC
Primary Use Case (PUC)	Scenario
Logical actor	System actor

6.2.3 COMPONENT LAYER

The component layer presents two kinds of information:

- A mapping of the logical actors to physical (real) components;
- Electrical and ICT links between the components.

It is reasonable to model the component layer before the information and communication layers as the identified physical components are represented in these layers also.

The data exchange SUCs don't refer to any physical components. Therefore it was decided to consider the IT systems involved in the SUCs (system actors in the SUCs or information systems used by the SUC business actors) as SGAM physical components. For placing these correctly on the SGAM plane, the equivalent IEC IT systems were identified as their positioning in the SGAM plane has been fixed in the Smart Grid standards map[45] (IEC TR 62357-1, 2016)[46]. Corresponding IEC domains are also reflected in the component layer. The mapping is shown on Table 22. Generic components like Data source, Application, etc. are not represented as they cannot be placed precisely on the SGAM plane.

To identify the links between the components, it is checked if the equivalent system actors in the SUCs are exchanging information. This can be derived from the activity diagrams, for example. ICT links between components were identified only, and not electrical links. However, this is fully acceptable and even desirable as the purpose of this modelling exercise is to propose data exchange model.

[45] http://smartgridstandardsmap.com/
[46] https://webstore.iec.ch/publication/26251

TABLE 22: EU-SYSFLEX - IEC IT SYSTEMS MAPPING

EU-SysFlex IT System	IEC Domain	IEC IT System
System Operator Flexibility Application (Information System for flexibility management)	Wholesale Energy Market	Energy Market Management (EMM), EMS, Settlement
Energy Service Provider Application	Retail Energy Market incl. VPP	Energy Trading Application/ Demand Response Management System (DRMS)
Flexibility Platform	Retail Energy Market incl. VPP	Energy Trading Application
Data Exchange Platform	Electric System Operation Wholesale Energy Market / Retail Energy Market incl. VPP	Intra Center Integration Bus / Model Exchange Platform
Grid Validation System	Wholesale Energy Market	Energy Management System (EMS)
Market Data Hub	Wholesale Energy Market	Energy Market Management (EMM) / Settlement
Grid Data Hub	Electric System Operation	EMS / Model Exchange Platform
Meter Data Hub	Retail Energy Market incl. VPP	Meter Data Management System (MDMS)
Sub-meter Data Hub	Industrial Automation / Home&Building Automation	Customer Energy Management
Data Source		n/a
DER Application	Distributed Energy	DER Control
System Operator SCADA	Electric System Operation	SCADA
Aggregator SCADA	Distributed Energy	Station Controller
Meter Data Collection Tool	Retail Energy Market incl. VPP	AMI Head End
Sub-Meter Data Collection Tool	Home & Building Automation / Industrial Automation	Building Management System / Customer Energy Management
Customer Portal	Enterprise / Retail Energy Market incl. VPP	Customer Portal
In-House Device	Home & Building Automation	Local Storage / Load / DER / SmartPlug / Appliances
Automation Controller	Industrial Automation	Process Automation System

6.2.4 INFORMATION LAYER

In information layer, two kinds of information can be found:

- Business context view: what information objects are exchanged between the components?
- Standard and information object mapping: what are the applicable underlying canonical data model standards? A standard is associated with one or more components and defines one or more information objects.
- Location on information layer: which domains and zones are covered by these canonical data models?

The data exchange SUCs identify the business objects exchanged between the actors. These business objects are summarised in Figure 15. Hence, it is straightforward to indicate the information objects (=business objects) exchanged between the components, according to the mapping in Table 22. For readability, the business context view is presented per HLUC.

The data exchange SUCs don't refer explicitly to any standards. The data model standards that are mentioned in this layer are the ones used by the EU-SysFlex demonstrators and as summarised in Chapter 4.4. Also this view is presented per HLUC. Some demo business objects could not be linked to any data model. In the model, these are associated with data model standards marked with a question mark. These remain to be defined in the future.

6.2.5 COMMUNICATION LAYER

The communication layer provides information on the communication links between the components and the (standardised) communication protocols on which they rely. Since no communication protocol information is clearly provided in the data exchange SUCs, only the communication links between components is modelled and communication protocol are not referenced. This remains to be addressed in future.

6.3 SAMPLES OF SGAM MODELLING RESULTS

This subchapter provides a sample of the model for each of the SGAM layers.

6.3.1 MODELLING OF BUSINESS LAYER

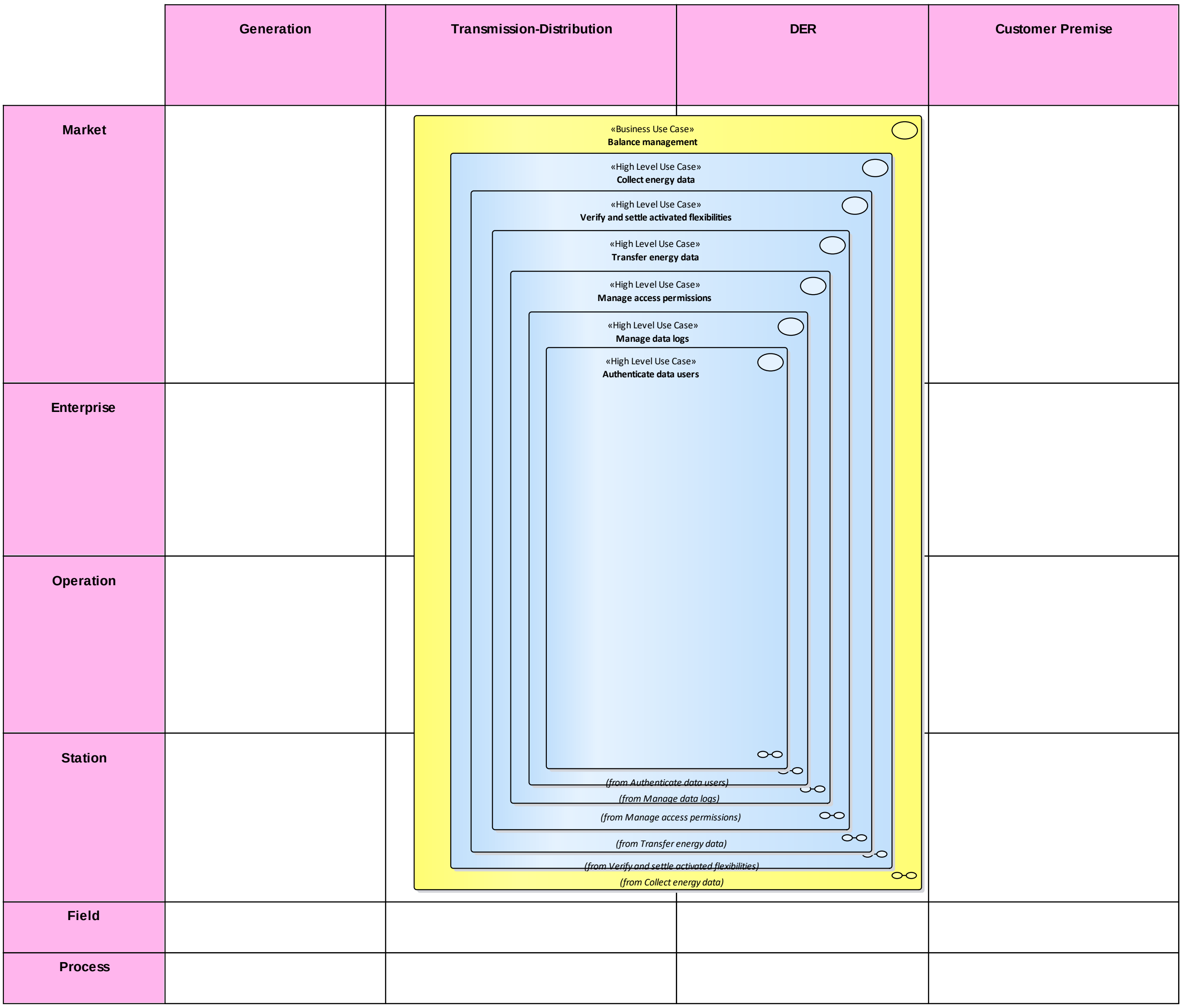

FIGURE 22: SGAM BUSINESS LAYER OF ‘BALANCE MANAGEMENT’ BUSINESS USE CASE

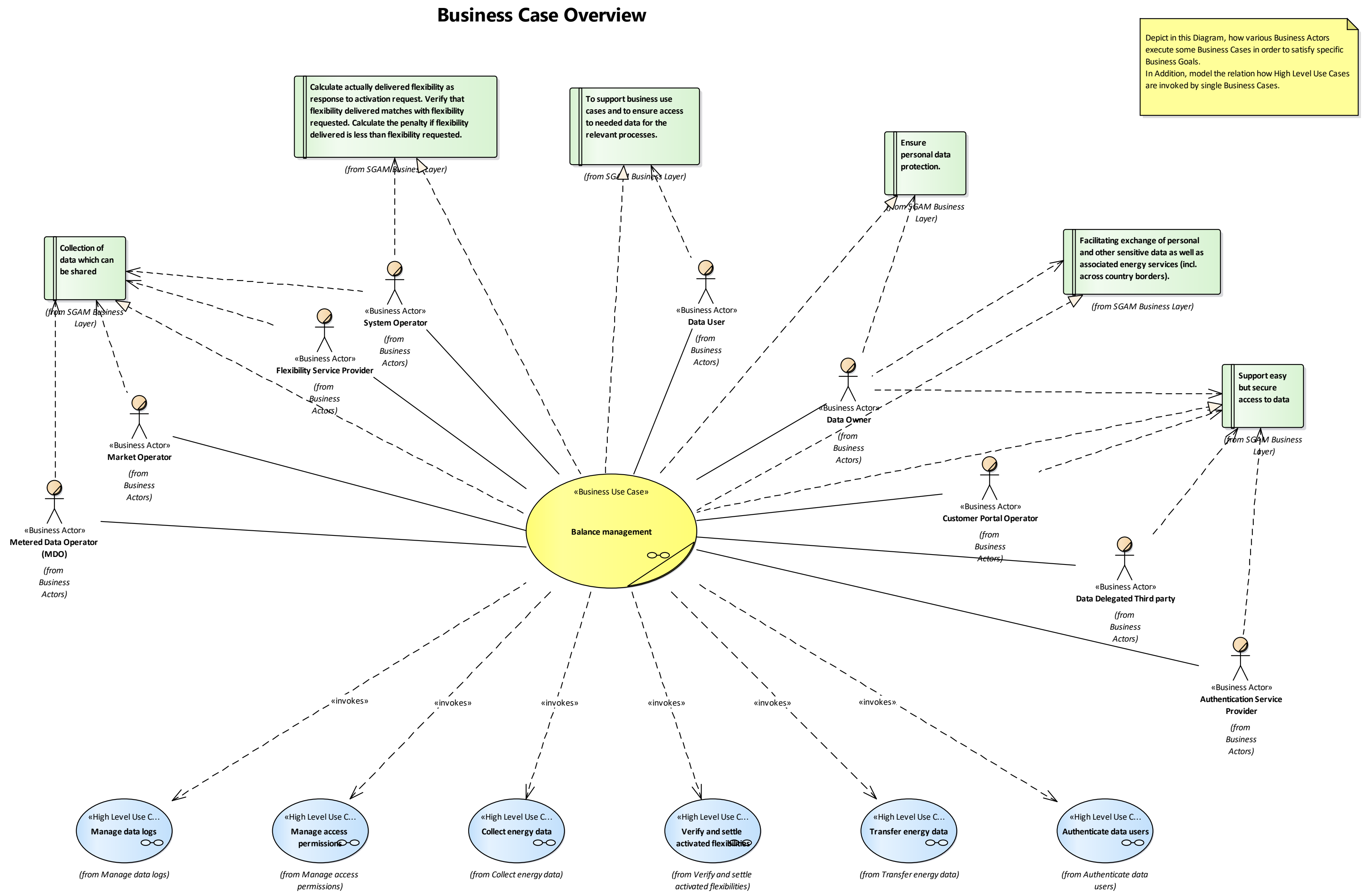

FIGURE 23: 'BALANCE MANAGEMENT' BUSINESS CASE ANALYSIS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773505.

6.3.2 MODELLING OF FUNCTION LAYER

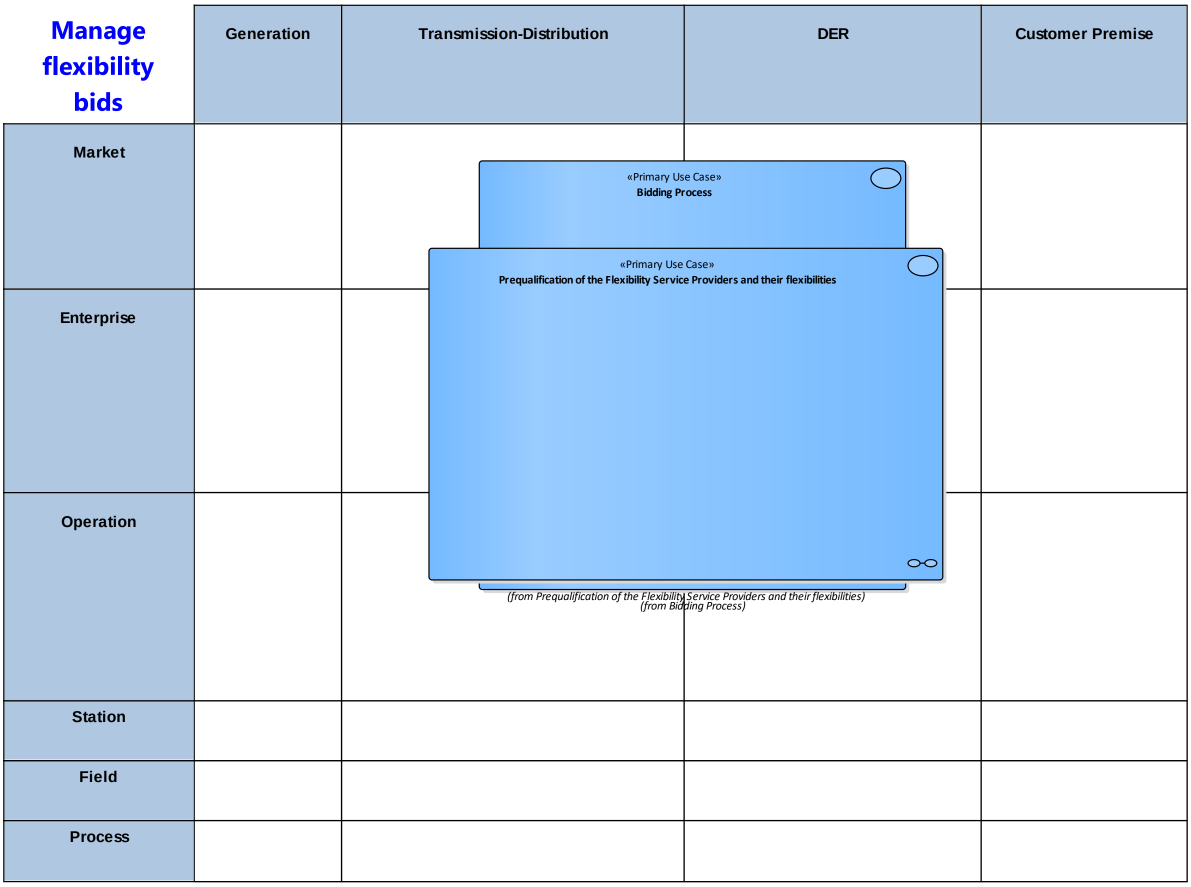

FIGURE 24: SGAM FUNCTION LAYER OF 'MANAGE FLEXIBILITY BIDS' HIGH LEVEL USE CASE

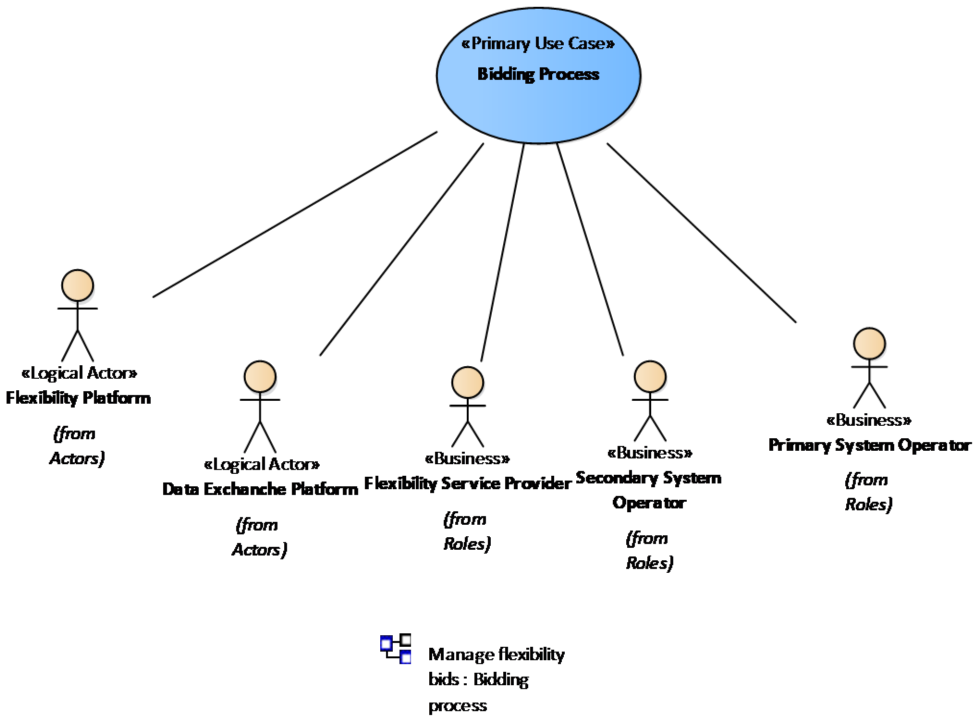

FIGURE 25: 'BIDDING PROCESS' PRIMARY USE CASE

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773505.

6.3.3 MODELLING OF COMPONENT LAYER

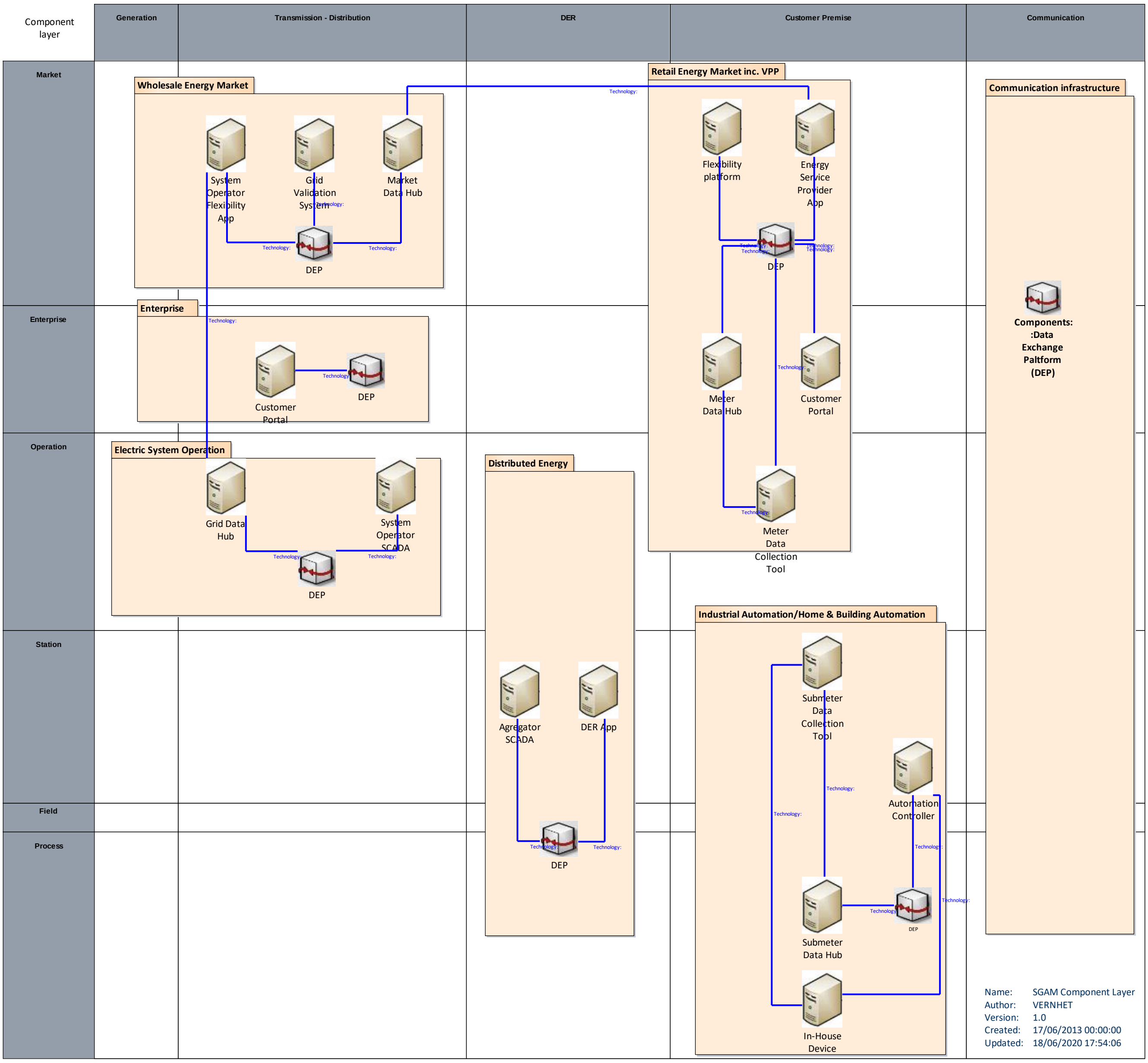

FIGURE 26: SGAM COMPONENT LAYER OF ALL SUCS

6.3.4 MODELLING OF INFORMATION LAYER

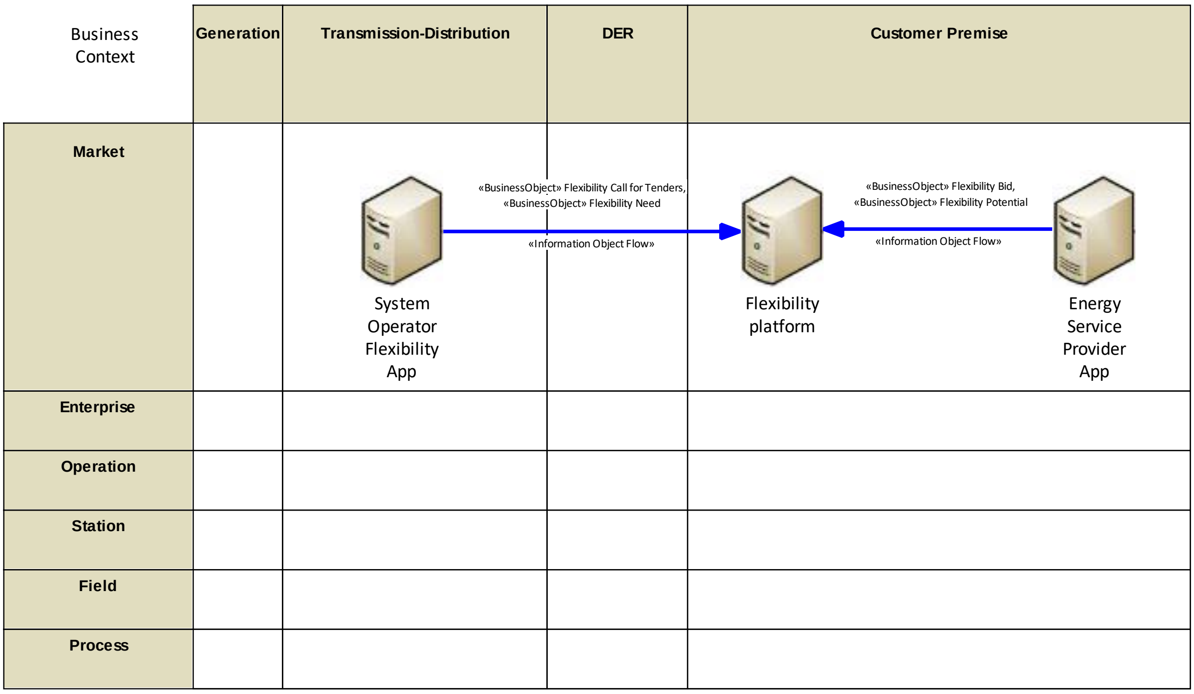

FIGURE 27: SGAM INFORMATION LAYER OF 'MANAGE FLEXIBILITY BIDS' HIGH LEVEL USE CASE

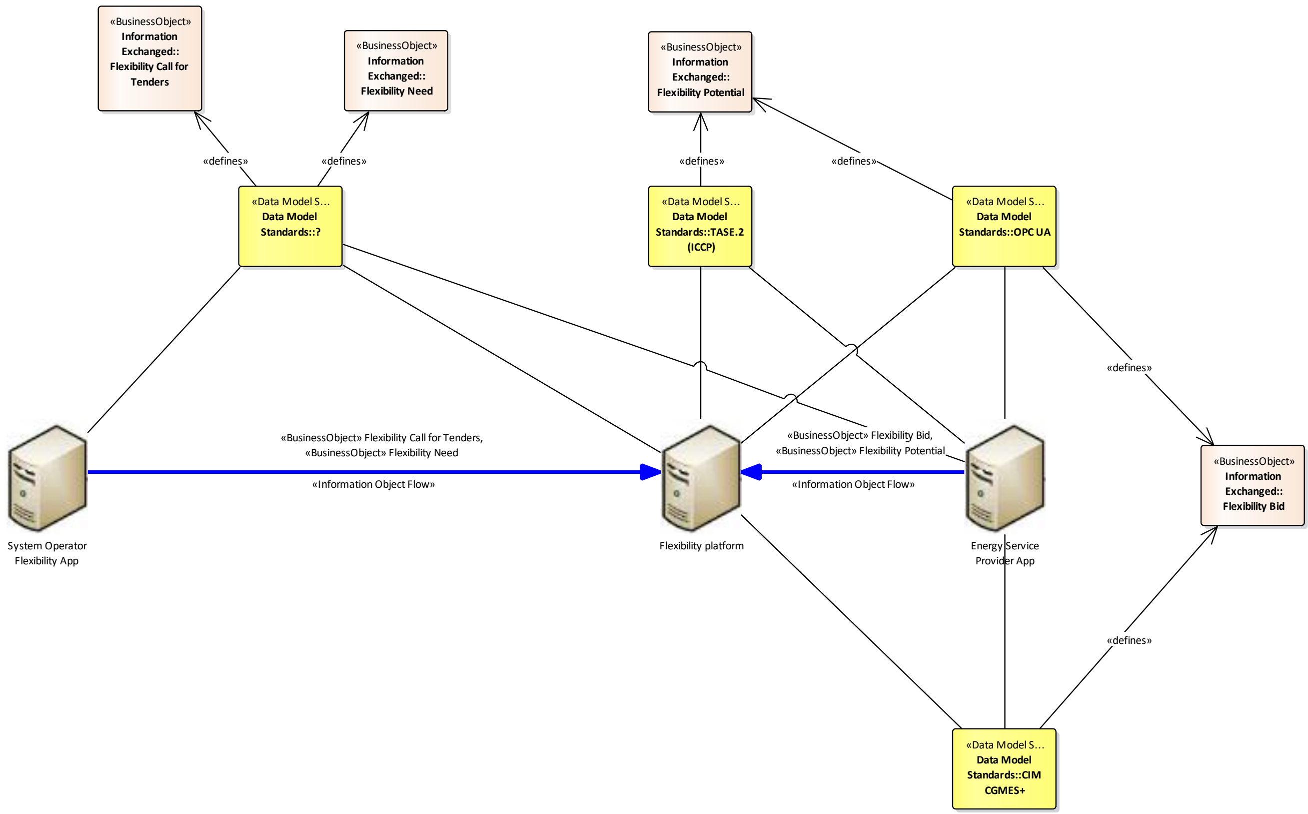

FIGURE 28: MAPPING OF STANDARDS AND INFORMATION OBJECTS OF 'MANAGE FLEXIBILITY BIDS' HIGH LEVEL USE CASE

6.3.5 MODELLING OF COMMUNICATION LAYER

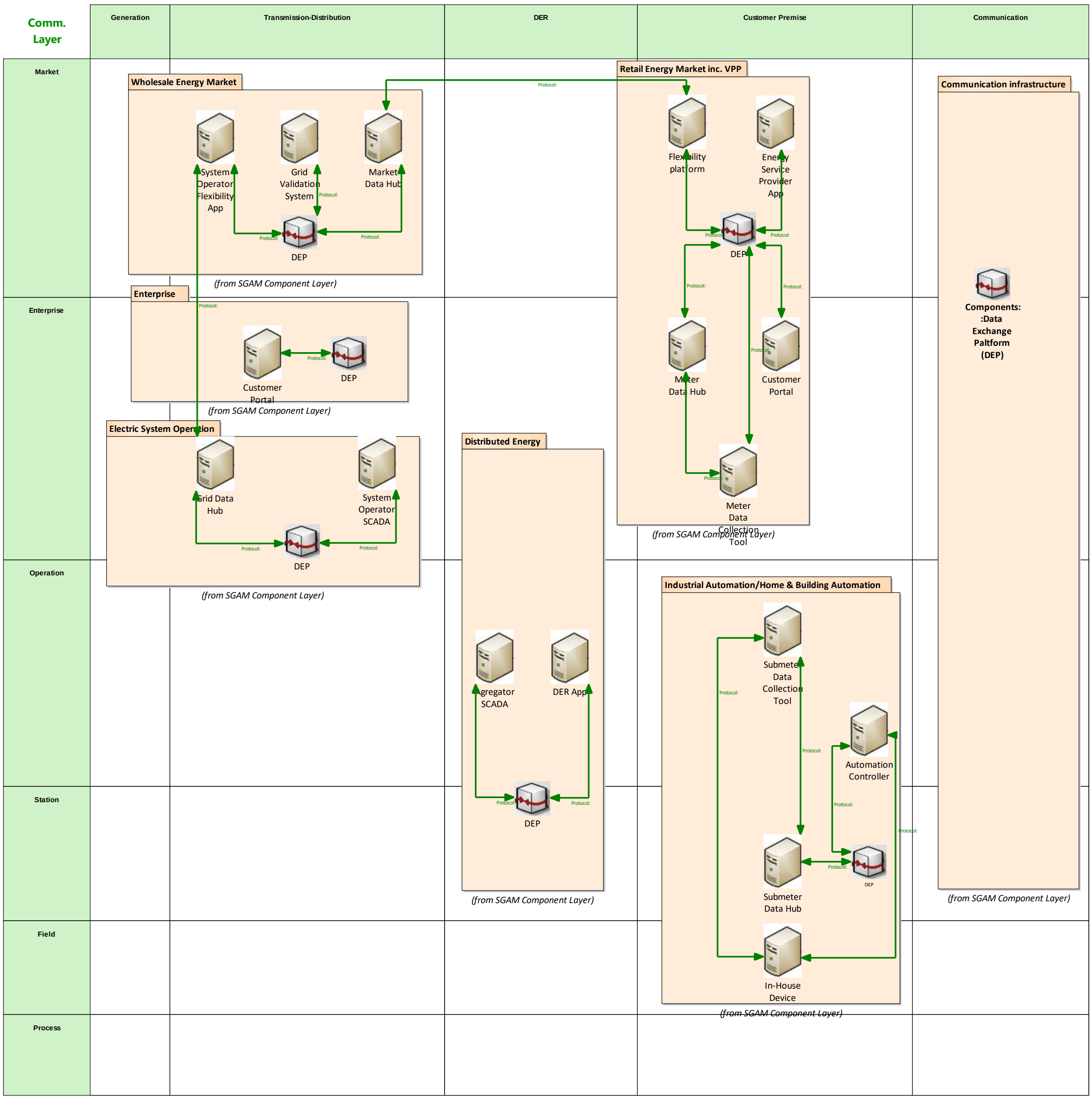

FIGURE 29: SGAM COMMUNICATION LAYER OF ALL SUCS

6.4 DATA EXCHANGE CONCEPTUAL MODEL

The data exchange conceptual model to be recommended to Europe combining the concepts described in this deliverable and in other associated EU-SysFlex data exchange deliverables is presented in Figure 30.

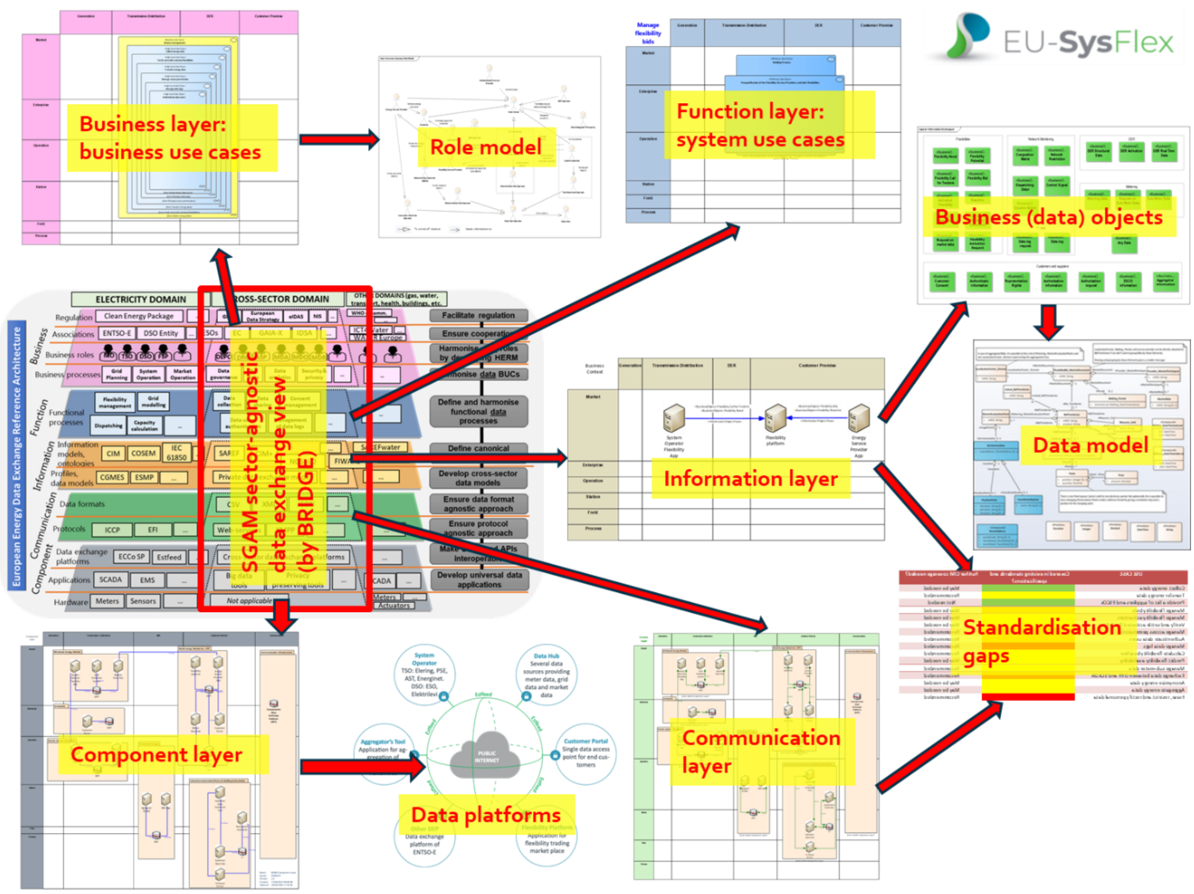

FIGURE 30: EU-SYSFLEX DATA EXCHANGE CONCEPTUAL MODEL FOR EUROPE

This conceptual model starts with the data exchange reference architecture proposed by BRIDGE Initiative. In 2020-2021 EU-SysFlex project was the leading party in elaborating and proposing the "European energy data exchange reference architecture" (BRIDGE, 2021)[47]. This was in cooperation with many other Horizon2020 projects under the European Commission's BRIDGE Initiative[48]. This reference architecture also benefits from SGAM approach and is largely based on EU-SysFlex data exchange SUCs and data exchange demonstrators. It specifically points on the data exchange viewpoint ('cross-sector domain') by representing data related aspects on each SGAM interoperability layer. The purpose of doing so is to lighten the way forward for cross-sector interoperability as the data issues are similar (if not the same) in any sector.

The high-level SGAM based reference architecture for European energy data exchange as proposed by BRIDGE is depicted in Figure 31.

[47] https://ec.europa.eu/energy/sites/default/files/documents/bridge_wg_data_management_eu_reference_architcture_report_2020-2021.pdf
[48] https://www.h2020-bridge.eu/

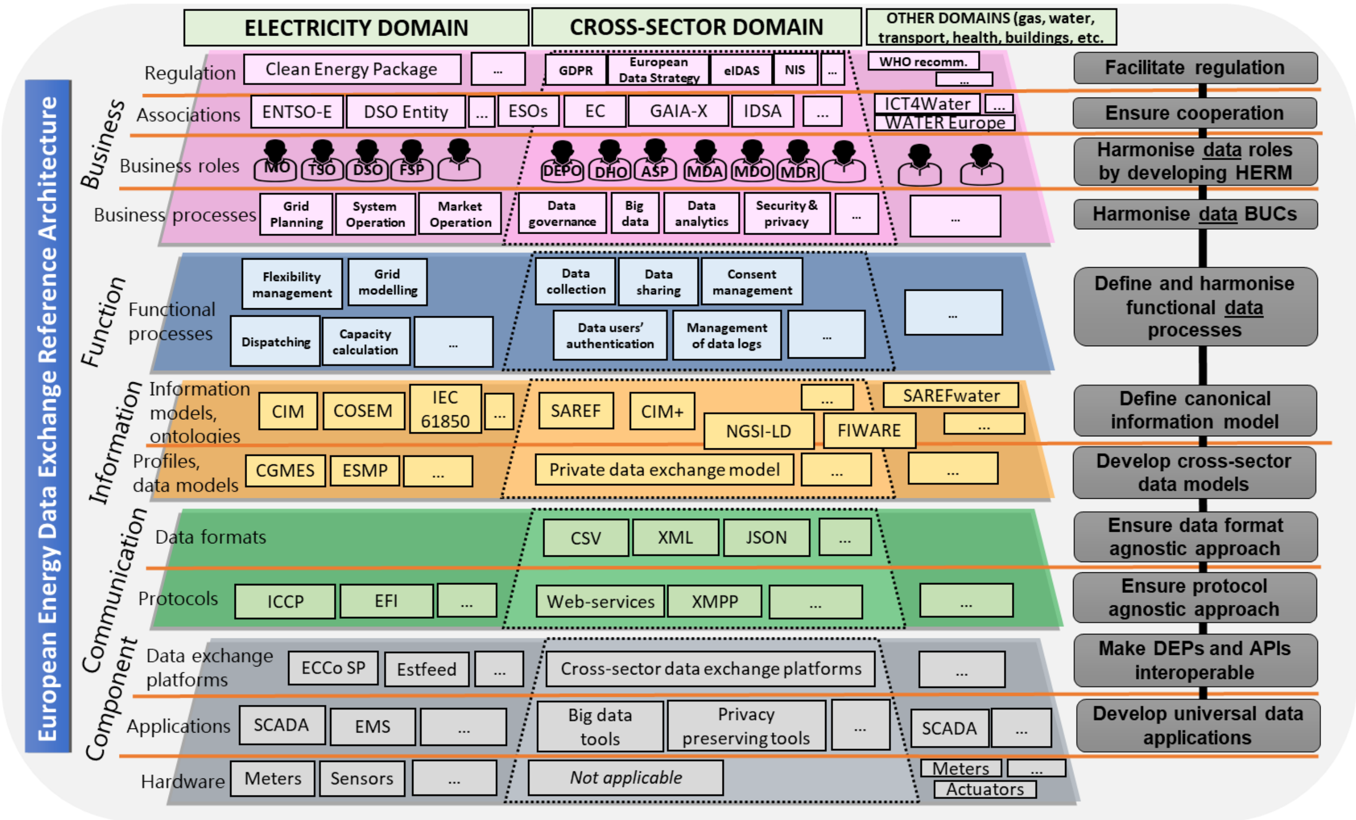

FIGURE 31: EUROPEAN ENERGY DATA EXCHANGE REFERENCE ARCHITECTURE (BRIDGE, 2021)

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ANNEX I. REVIEW OF LEGAL REQUIREMENTS

I-1. DIRECTIVE ON COMMON RULES FOR THE INTERNAL MARKET IN ELECTRICITY

	Can a DEP support fulfilling the requirement?	EU-SysFlex WP5 and WP9 use cases
Article 3 – Competitive, consumer-centred, flexible and non-discriminatory electricity markets - Paragraph 4: Member States shall ensure a level playing field where electricity undertakings are subject to transparent, proportionate and non-discriminatory rules, fees and treatment, in particular with respect to balancing responsibility, access to wholesale markets, access to data, switching processes and billing regimes and, where applicable, licensing.	DEP can ensure easy access to data and via DEP to different energy services	All SUCs and BUCs
Article 13 – Aggregation contract - Paragraph 3: Member States shall ensure that final customers are entitled to receive all relevant demand response data or data on supplied and sold electricity free of charge at least once every billing period if requested by the customer.	DEP can facilitate access to meter data from both certified meters and sub-meters necessary for demand response	Data collection, data transfer, sub-meter SUCs. Affordable Tool BUC
Article 14 – Comparison tools - Paragraph 1: Member States shall ensure that at least household customers, and microenterprises with an expected yearly consumption of below 100 000 kWh, have access, free of charge, to at least one tool comparing the offers of suppliers, including offers for dynamic electricity price contracts. Tools shall be independent from market participants and ensure that electricity undertakings are given equal treatment in search results. Member States shall ensure that at least one tool covers the entire market.	Comparison tools can be connected with DEP thereby providing them necessary data and enabling consumers to find and choose between tools	SUC on list of ESCOs
Article 17 – Demand response through aggregation - Paragraph 3(c): Non-discriminatory and transparent rules and procedures for the exchange of data between market participants engaged in aggregation and other electricity undertakings that ensure easy access to data on equal and non-discriminatory terms while fully protecting commercially sensitive information and customers' personal data.	DEP can ensure secure exchange of personal and commercially sensitive data between any market parties	All SUCs. Affordable Tool BUC, Flexibility Platform BUC, ENTSO-E BUC

Article 19 – Smart metering systems - Paragraph 1: In order to promote energy efficiency and to empower final customers, Member States or, where a Member State has so provided, the regulatory authority shall strongly recommend that electricity undertakings and other market participants optimise the use of electricity, inter alia, by providing energy management services, developing innovative pricing formulas, and introducing smart metering systems that are interoperable, in particular with consumer energy management systems and with smart grids, in accordance with the applicable Union data protection rules. - Paragraph 3: Member States shall ensure the interoperability of those smart metering systems, as well as their ability to provide output for consumer energy management systems. In that respect, Member States shall have due regard to the use of the relevant available standards, including those enabling interoperability, to best practices and to the importance of the development of smart grids and the development of the internal market for electricity.	DEP can link 'consumer energy management systems' to data from certified meters. DEP enables secure data exchange in accordance with data protection requirements	Data source and application integration SUCs, data collection, data transfer and sub-metering SUCs, data protection related (authentication, access permissions, data logs, data breaches). Affordable Tool BUC
Article 20 – Functionalities of smart metering systems - Paragraph (a): Validated historical consumption data shall be made easily and securely available and visualised to final customers on request and at no additional cost. Non-validated near real-time consumption data shall also be made easily and securely available to final customers at no additional cost, through a standardised interface or through remote access, in order to support automated energy efficiency programmes, demand response and other services. - Paragraph (b): The security of the smart metering systems and data communication shall comply with relevant Union security rules, having due regard of the best available techniques for ensuring the highest level of cybersecurity protection while bearing in mind the costs and the principle of proportionality. - Paragraph (c): The privacy of final customers and the protection of their data shall comply with relevant Union data protection and privacy rules. - Paragraph (e):If final customers request it, data on the electricity they fed into the grid and their electricity consumption data shall be made available to them, in accordance with the implementing acts adopted pursuant to Article 24, through a standardised communication interface or through remote access, or to a third party acting on their behalf, in an easily understandable format allowing them to compare offers on a like-for-like basis. - It shall be possible for final customers to retrieve their metering data or transmit them to another party at no additional cost	DEP can enable secure transfer of personal data, both 'validated' and 'non-validated' data. DEP customer interface enables access to data and managing access permissions	Data transfer SUC, authentication SUC, access permissions SUC. All BUCs

and in accordance with their right to data portability under Union data protection rules.		
Article 22 – Conventional meters - Paragraph 2: Member States shall ensure that final customers are able to easily read their conventional meters, either directly or indirectly through an online interface or through another appropriate interface.	DEP can provide access to data from conventional meters similarly to smart meter data	Data collection SUC, data transfer SUC, authentication SUC. All BUCs
Article 23 – Data management - Paragraph 1: Authorities shall specify the rules on the access to data of the final customer by eligible parties in accordance with applicable Union legal framework. Data shall be understood to include metering and consumption data as well as data required for customer switching, demand response and other services. - Paragraph 2: Member States shall organise the management of data in order to ensure efficient and secure data access and exchange, as well as data protection and data security. Independently of the data management model applied in each Member State, the parties responsible for data management shall provide access to the data of the final customer to any eligible party. Eligible parties shall have the requested data at their disposal in a non-discriminatory manner and simultaneously. Access to data shall be easy and the relevant procedures for obtaining access to data shall be made publicly available. - Paragraph 3: The processing of personal data shall be carried out in accordance with Regulation (EU) 2016/679. - Paragraph 4: Competent authorities, shall authorise and certify or, where applicable, supervise the parties responsible for the data management, in order to ensure that they comply with the requirements of the Directive. Member States may decide to require that parties responsible for the data management appoint compliance officers who are to be responsible for monitoring the implementation of measures taken by those parties to ensure non-discriminatory access to data and compliance with the requirements of the Directive. - Paragraph 5: No additional costs shall be charged to final customers for access to their data or for a request to make their data available. Member States shall be responsible for setting the relevant charges for access to data by eligible parties.	DEP can provide in compliance to GDPR different types of data easily and simultaneously to different types of stakeholders, incl. final customers themselves.	All SUCs and BUCs
Article 24 – Interoperability requirements and procedures for access to data	DEP can be designed in the way that different	All SUCs and BUCs

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- Paragraph 1: In order to promote competition in the retail market and to avoid excessive administrative costs for the eligible parties, Member States shall facilitate the full interoperability of energy services within the Union. - Paragraph 2: The Commission shall adopt, by means of implementing acts, interoperability requirements and non-discriminatory and transparent procedures for access to metering data. - Paragraph 3: Member States shall ensure that electricity undertakings apply the interoperability requirements and procedures for access to metering data. Those requirements and procedures shall be based on existing national practices.	data sources and data users can be connected to this. Different DEPs should be able to communicate with each other. It makes possible cross-border data exchange respecting different countries legal restrictions	
Article 34 – Tasks of distribution system operators in data management - Member States shall ensure that all eligible parties have non-discriminatory access to data under clear and equal terms, in accordance with the relevant data protection rules. In Member States where smart metering systems have been deployed and where distribution system operators are involved in data management, the compliance programmes shall include specific measures in order to exclude discriminatory access to data from eligible parties. Where distribution system operators are not subject to unbundling, Member States shall take all necessary measures to ensure that vertically integrated undertakings do not have privileged access to data for the conduct of their supply activities.	DEP if properly managed can ensure non-discriminatory access to data	SUCs on data transfer, access permissions, data logs, application integration. All BUCs
Article 40 – Tasks of transmission system operators - Paragraph 1(l): Digitalisation of transmission systems. - Paragraph 1(m): Data management, including the development of data management systems, cybersecurity and data protection, subject to the applicable rules, and without prejudice to the competence of other authorities.	DEP can facilitate TSO tasks on data management and digitalization	All SUCs and BUCs
Article 41 – Confidentiality and transparency requirements for transmission system operators and transmission system owners - Paragraph 3: Information necessary for effective competition and the efficient functioning of the market shall be made public. That obligation shall be without prejudice to preserving the confidentiality of commercially sensitive information.	DEP can be used for transferring data for publication	SUC on data transfer. Flexibility Platform BUC

I-2. REGULATION ON THE INTERNAL MARKET FOR ELECTRICITY

	Can a DEP support fulfilling the requirement?	EU-SysFlex use cases
Article 6 – Balancing market - Paragraph 13: Transmission system operators or their delegated operators shall publish, as close to real time as possible but with a delay after delivery of no more than 30 minutes, the current system balance of their scheduling areas, the estimated imbalance prices and the estimated balancing energy prices.	DEP can be used for transferring data for publication	SUC on data transfer. Flexibility Platform BUC
Article 30 – Tasks of the ENTSO for Electricity - Paragraph 1(h): The ENTSO for Electricity shall promote the digitalisation of transmission networks including deployment of smart grids, efficient real time data acquisition and intelligent metering systems. - Paragraph 1(k): The ENTSO for Electricity shall contribute to the establishment of interoperability requirements and non-discriminatory and transparent procedures for accessing data. - Paragraph 1(n): The ENTSO for Electricity shall promote cyber security and data protection in cooperation with relevant authorities and regulated entities.	DEP can facilitate TSO tasks on data management and digitalization	All SUCs and BUCs
Article 50 – Provision of information - Paragraph 4: TSOs shall publish relevant data on aggregated forecast and actual demand, on availability and actual use of generation and load assets, on availability and use of the networks and interconnections, on balancing power and reserve capacity and on the availability of flexibility. For the availability and actual use of small generation and load assets, aggregated estimate data may be used. - Paragraph 5: The market participants concerned shall provide the TSOs with the relevant data. - Paragraph 6: Generation undertakings which own or operate generation assets, where at least one generation asset has an installed capacity of at least 250 MW, or which have a portfolio comprising at least 400 MW of generation assets, shall keep at the disposal of the regulatory authority, the national competition authority and the Commission, for five years all hourly data per plant that is necessary to verify all operational dispatching decisions and the bidding behaviour at power exchanges, interconnection auctions, reserve markets and over-the-counter-markets.	TSOs can use DEP to receive data collected in data hubs (incl. historical data from data hubs) from different stakeholders, share theses data for publication (incl. to Transparency Platform), and exchange these data with other TSOs	SUCs on data collection, data transfer, data source integration, sub-meter data. Flexibility Platform BUC, ENTSO-E BUC

- Paragraph 7: TSOs shall exchange regularly a set of sufficiently accurate network and load flow data in order to enable load flow calculations for each TSO in its relevant area. The same set of data shall be made available to the regulatory authorities, and to the Commission and Member States upon request.		
Article 55 – Tasks of the EU DSO entity - Paragraph 1(d): The tasks of the EU DSO entity shall be contributing to the digitalisation of distribution systems including deployment of smart grids and intelligent metering systems. - Paragraph 1(e): The tasks of the EU DSO entity shall be supporting the development of data management, cyber security and data protection in cooperation with relevant authorities and regulated entities.	DEP can be used to facilitate DSO tasks on data management and digitalization	All SUCs and BUCs
Article 57 – Cooperation between distribution system operators and transmission system operators - Paragraph 1: DSOs and TSOs shall cooperate with each other in planning and operating their networks. In particular, distribution system operators and transmission system operators shall exchange all necessary information and data regarding, the performance of generation assets and demand side response, the daily operation of their networks and the long-term planning of network investments, with the view to ensure the cost-efficient, secure and reliable development and operation of their networks.	DEP can facilitate TSO-DSO cooperation	All SUCs. Flexibility Platform BUC
Article 59 – Establishment of network codes - Paragraph 2(b): data exchange, settlement and transparency rules, including in particular rules on transfer capacities for relevant time horizons, estimates and actual values on the allocation and use of transfer capacities, forecast and actual demand of facilities and aggregation thereof including unavailability of facilities, forecast and actual generation of generation units and aggregation thereof including unavailability of units, availability and use of networks, congestion management measures and balancing market data. Rules should include ways in which the information is published, the timing of publication, the entities responsible for handling.	Potential network code in the area of data exchange could consider the relevance of DEP as a possible solution, incl. for cross-border data exchange	All SUCs and BUCs

I-3. DIRECTIVE ON ENERGY EFFICIENCY

	Can a DEP support fulfilling the requirement?	EU-SysFlex use cases

Article 9 – Metering for gas and electricity
 	
- Paragraph 2: Where, and to the extent that, Member States implement intelligent metering systems and roll out smart meters:
  o they shall ensure that the metering systems provide to final customers information on actual time of use and that the objectives of energy efficiency and benefits for final customers are fully taken into account when establishing the minimum functionalities of the meters and the obligations imposed on market participants;
  o they shall ensure the security of the smart meters and data communication, and the privacy of final customers, in compliance with relevant Union data protection and privacy legislation;
  o they shall ensure that if final customers request it, metering data on their electricity input and off-take is made available to them or to a third party acting on behalf of the final customer in an easily understandable format that they can use to compare deals on a like-for-like basis.
	DEP can enable consent management (access permissions), secure data exchange and access	All SUCs and BUCs

Article 11 – Cost of access to metering and billing information for electricity and gas - Member States shall ensure that final customers receive all their bills and billing information for energy consumption free of charge and that final customers have access to their consumption data in an appropriate way and free of charge.	DEP can provide access to consumption and billing information	Data transfer SUC. All BUCs

I-4. GUIDELINE ON ELECTRICITY BALANCING

	Can a DEP support fulfilling the requirement?	EU-SysFlex use cases
Article 11 – Confidentiality obligations - Paragraph 3: Confidential information received by the persons or regulatory authorities in the course of their duties may not be divulged to any other person or authority, without prejudice	DEP can enable secure data exchange. Data may be exchanged with	Several SUCs and BUCs related to exchange of personal data

to cases covered by national law, the other provisions of this Regulation or other relevant Union legislation	consent of the person	
Article 12 – Publication of information - Paragraph 2: All entities shall ensure that information is published at a time and in a format that does not create an actual or potential competitive advantage or disadvantage to any individual or companies - Paragraph 3(a)-(i): TSOs shall publish the information as soon as it becomes available, incl. information on system balance, information related to individual balancing bids – volumes and prices (anonymized where necessary), aggregated information on offered and activated bids, information related to allocation of cross-zonal capacity	Through DEP stakeholders have simultaneous and non-discriminatory access to data. DEP can have its customer portal to enable access to data or forward data to other portals for publication, incl. Transparency Platform	SUCs related to flexibility processes, data transfer, aggregation, anonymization. “Flexibility Platform” BUC, “ENTSO-E” BUC
Article 15 – Cooperation with DSOs - Paragraph 1: DSOs, TSOs, balancing service providers and balance responsible parties shall cooperate in order to ensure efficient and effective balancing - Paragraph 2: Each DSO provides all necessary information to perform the imbalance settlement to the connecting TSO	DEP can facilitate coordinated TSO-DSO data exchange. DEP can facilitate easy access to flexibility market	Flexibility baseline SUC, flexibility verification SUC. “Affordable Tool” BUC, “Flexibility Platform BUC”
Article 16 – Role of balancing service providers - Paragraph 1: Successful completion of the prequalification, ensured by the connecting TSO as a prerequisite for the successful completion of the qualification process to become a balancing service provider - Paragraphs 2-5: Each balancing service provider shall submit to the connecting TSO information related to its balancing bids	DEP can facilitate data exchange between FSP, MO and SO	Flexibility bidding SUC. “Affordable Tool” BUC, “Flexibility Platform BUC”
Article 18 – Terms and conditions related to balancing - Paragraph 4(b),(c): Allow the participation of the demand/ aggregated demand, aggregated distributed energy sources, storage to balancing (be balancing service provider) - Paragraph 5(d),(f),(g): Requirement on data for DSO-connected reserves should be defined in terms and condition of BSP (Terms and conditions of balancing service provider should contain the requirements on data and information to be delivered to the connecting TSO and where relevant the reserve connecting DSO during prequalification and operation; the requirements on data and information to be delivered to the connecting TSO and where relevant the reserve connecting	Through DEP all technologies providing flexibility can provide and receive data necessary to participate in the flexibility market	Flexibility bidding SUC, flexibility activation SUC, flexibility baseline SUC, flexibility verification SUC. “Flexibility Platform” BUC

DSO to evaluate the provision of balancing services and to calculate imbalance; the definition of a location for each product) - Paragraph 6(d): Requirement on data and information to be delivered to the connecting TSO to calculate the imbalance is defined in terms and condition of BRP		
Article 19 – European platform for the exchange of balancing energy from replacement reserves - Paragraph 2: Shall consist of at least the activation optimisation function and the TSO-TSO settlement function - Paragraph 5(a),(b): Submit and exchange all balancing energy bids from all standard products for replacement reserves	DEP can be used to integrate different market platforms	n/a
Article 20 – European platform for the exchange of balancing energy from frequency restoration reserves with manual activation - Paragraph 2: Shall consist of at least the activation optimisation function and the TSO-TSO settlement function - Paragraph 6(a),(b): Submit and exchange all balancing energy bids from all standard products for frequency restoration reserves with manual activation	DEP can be used to integrate different market platforms	DEP shall be used to exchange data with Baltic mFRR platform CoBA (analogue to 'MARI') in "Flexibility Platform"BUC
Article 21 – European platform for the exchange of balancing energy from frequency restoration reserves with automatic activation - Paragraph 2: Shall consist of at least the activation optimisation function and the TSO-TSO settlement function - Paragraph 6(a),(b): Submit and exchange all balancing energy bids from all standard products for frequency restoration reserves with automatic activation	DEP can be used to integrate different market platforms	n/a
Article 22 – European platform for imbalance netting process - Paragraph 2: Shall consist of at least the imbalance netting process function and the TSO-TSO settlement function - Paragraph 5: For TSOs performing the automatic frequency restoration process; at least for the Continental Europe synchronous area	DEP can be used to integrate different market platforms	n/a
Article 27 – Conversion of bids in a central dispatching model - Paragraph 2: TSOs to use bids to provide balancing services to other TSOs	Bids can be forwarded (e.g. to a flexibility platform) via DEP	Flexibility bidding SUC. "Flexibility Platform" BUC

I-5. GUIDELINE ON SYSTEM OPERATION

	Can a DEP support fulfilling the requirement?	EU-SysFlex use cases
Article 12 – Confidentiality obligations - Paragraph 3: Confidential information received by the persons or regulatory authorities in the course of their duties may not be divulged to any other person or authority, without prejudice to cases covered by national law, the other provisions of this Regulation or other relevant Union legislation.	DEP can enable secure data exchange. Data may be exchanged with consent of the person	Several SUCs and BUCs related to exchange of personal data
Article 40 – Organisation, roles, responsibilities and quality of data exchange - Paragraph 1: The exchange and provision of data and information shall reflect, to the extent possible, the real and forecasted situation of the transmission system - Paragraph 3: TSOs shall gather the following information about its observability area and shall exchange this data with all other TSOs to the extent that it is necessary for carrying out the operational security analysis in accordance with Article 72: (a) generation; (b) consumption; c) schedules; (d) balance positions; (e) planned outages and substation topologies; and (f) forecasts - Paragraph 6: TSOs shall jointly agree on key organisational requirements, roles and responsibilities (KORRR) in relation to exchange of structural data, scheduling and forecast data, real-time data between TSOs, DSOs and SGUs, incl. frequency of information exchange, format for the reporting of the data and information - Paragraph 9: Each TSO shall agree with the relevant DSOs on processes for providing and managing data exchanges between them, including the provision of data related to distribution systems and SGUs	DEP can be used for data exchanges between TSOs, DSOs and SGUs	Data transfer SUC, sub-meter data SUC, DER-SCADA data exchange SUC. "ENTSO-E" BUC, "Flexibility Platform" BUC
Article 41 – Structural and forecast data exchange (between TSOs) - Paragraph 1: Structural data to be exchanged between neighbouring TSOs includes topology of substations, technical data on transmission lines, technical data on transformers connecting the DSOs and SGUs, maximum and minimum active and reactive power of SGUs which are power generating modules, etc	Addressed in ENTSO-E's ECCo SP DEP but same data could be forwarded from ECCo SP to other DEP to facilitate access to data by third parties	Interoperability of two DEPs to be demonstrated in "ENTSO-E" BUC

- Paragraphs 3-4: Data exchange necessary to coordinate operational security analysis and to establish the common grid model, to coordinate the dynamic stability assessments		
Article 42 – Real-time data exchange (between TSOs) - Paragraph 1: TSOs of the same synchronous area exchange the following data on the system state of its transmission system using the IT tool for real-time data exchange at pan-European level as provided by ENTSO-E: frequency, frequency restoration control error, measured active power interchanges between LFC areas, aggregated generation infeed, system state, etc. - Paragraph 2: TSOs in the same observability area exchange the following data about its transmission system using SCADA systems and energy management systems: actual substation topology, active and reactive power, etc.	Addressed in ENTSO-E ECCo SP DEP and in SCADA-to-SCADA data exchange but same data could be forwarded from ECCo SP and SCADA to other DEP to facilitate access to data	Interoperability of two DEPs to be demonstrated in “ENTSO-E” BUC
Article 43 – Structural data exchange (between TSOs and DSOs) - Paragraphs 1-2: Applies to transmission-connected DSOs in the TSO observability area and to non-transmission-connected distribution system which has a significant influence in terms of voltage, power flows or other electrical parameters - Paragraph 3: Structural information provided by DSO to the TSO includes: substations by voltage, lines that connect the substations, transformers from the substations, SGUs, reactors and capacitors connected to the substations	DEP can be used for data exchanges between TSOs and DSOs, would facilitate access to the same data by third parties	n/a
Article 44 – Real-time data exchange (between TSOs and DSOs) - DSO shall provide its TSO, in real-time, the information related to the observability area of the TSO, including: actual substation topology, active and reactive power, best available data for aggregated generation per primary energy source in the DSO area, the best available data for aggregated demand in the DSO area, etc.	DEP can be used for data exchanges between TSOs and DSOs, would facilitate access to the same data by third parties. Applicability of DEP for TSO-DSO real-time data exchanges needs to be studied further	n/a
Article 45 – Structural data exchange (between TSOs and SGUs, line owners) - Paragraphs 1-5: Applies to SGUs which are power generating facility owners of a type B, C and D power generating module	DEP can be used for data exchanges between TSOs and SGUs, would facilitate access to the same data	Flexibility bidding (incl. prequalification) SUC. “Flexibility Platform” BUC,

connected to the transmission system, AC interconnector owners, HVDC system owners and interconnector owners - Paragraphs 1-2: Data to be provided by generators includes: general data of the power generating module (including installed capacity and primary energy source), FCR, FRR and RR data, protection data, reactive power control capability, etc.	by third parties and would facilitate data provision by SGUs	"Affordable Tool" BUC
Article 46 – Scheduled data exchange (between TSOs and SGUs, line owners) - Paragraph 1: Type B, C and D power generating module owner connected to the transmission system shall provide the TSO with at least the following data: active power output and active power reserves amount and availability, on a day-ahead and intra-day basis; scheduled unavailability or active power restriction; forecasted restriction in the reactive power control capability - Paragraph 2: HVDC system operator shall provide the TSOs with at least the following data: active power schedule and availability on a day-ahead and intra-day basis; scheduled unavailability or active power restriction; forecast restriction in the reactive power or voltage control capability - Paragraph 3: AC interconnector and line operators shall provide scheduled unavailability or active power restriction data to the TSOs	DEP can be used for data exchanges between TSOs and SGUs, would facilitate access to same data by third parties and would facilitate data provision by SGUs	Flexibility bidding SUC. "Flexibility Platform" BUC, "Affordable Tool" BUC
Article 47 – Real-time data exchange (between TSOs and SGUs, line owners) - Paragraph 1: Type B, C or D power generating module owner shall provide the TSO, in real-time, at least the following data: position of the circuit breakers, active and reactive power, in case of power generating facility with consumption other than auxiliary consumption net active and reactive power - Paragraph 2: HVDC system or AC interconnector owner shall provide, in real-time, at least the following data to the TSOs: position of the circuit breakers, operational status, active and reactive power	DEP can be used for data exchanges between TSOs and SGUs, would facilitate access to the same data by third parties and would facilitate data provision by SGUs. Applicability of DEP for TSO-DSO real-time data exchanges needs to be studied further	DER-SCADA data exchange SUC. "Flexibility Platform" BUC, "Affordable Tool" BUC
Article 48 – Structural data exchange (between TSOs, DSOs and distribution-connected power generating modules) - Paragraph 1: Power generating facility owner of a power generating module which is a SGU and by aggregation of the	DEP can be used for data exchanges between TSOs, DSOs and SGUs,	Flexibility bidding (incl. prequalification) SUC.

SGUs connected to the distribution system shall provide at least the following data to the TSO and to the DSO to which it has a connection point: general data of the power generating module, including installed capacity and primary energy source or fuel type; FCR, FRR and RR data; protection data; reactive power control capability; capability of remote access to the circuit breaker; data necessary for performing dynamic simulation; voltage level and location of each power generating module	would facilitate access to same data by third parties and would facilitate data provision by SGUs	"Flexibility Platform" BUC, "Affordable Tool" BUC
Article 49 – Scheduled data exchange (between TSOs, DSOs and distribution-connected power generating modules) - Power generating facility owner of a power generating module which is a SGU connected to the distribution system shall provide the TSO and the DSO to which it has the connection point, with at least the following data: its scheduled unavailability, scheduled active power restriction and its forecasted scheduled active power output at the connection point; any forecasted restriction in the reactive power control capability	DEP can be used for data exchanges between TSOs, DSOs and SGUs, would facilitate access to same data by third parties and would facilitate data provision by SGUs	Flexibility bidding SUC. "Flexibility Platform" BUC, "Affordable Tool" BUC
Article 50 – Real-time data exchange (between TSOs, DSOs and distribution-connected power generating modules) - Paragraph 1: Power generating facility owner of a power generating module which is a SGU connected to the distribution system shall provide the TSO and the DSO to which it has the connection point, in real-time, at least the following data: status of the switching devices and circuit breakers at the connection point; active and reactive power flows, current, and voltage at the connection point. - Paragraph 2: Each TSO shall define in coordination with the responsible DSOs which SGUs may be exempted from providing the real-time data. In such cases, the responsible TSOs and DSOs shall agree on the aggregated real-time data of the SGUs concerned to be delivered to the TSO.	DEP can be used for data exchanges between TSOs, DSOs and SGUs, would facilitate access to same data by third parties and would facilitate data provision by SGUs	DER-SCADA data exchange SUC. "Flexibility Platform" BUC, "Affordable Tool" BUC
Article 51 – Data exchange between TSOs and DSOs concerning significant power generating modules - Paragraph 1: Each DSO shall provide to its TSO the information specified in Articles 48, 49 and 50 with the frequency and level of detail requested by the TSO. - Paragraph 2: Each TSO shall make available to the DSO, to whose distribution system SGUs are connected, the information specified in Articles 48, 49 and 50 as requested by the DSO.	DEP can be used for data exchanges between TSOs, DSOs and SGUs, would facilitate access to same data by third parties and would	Flexibility bidding (incl. prequalification) SUC, DER-SCADA data exchange SUC, data transfer SUC. "Flexibility Platform" BUC,

- Paragraph 3: A TSO may request further data from a power generating facility owner of a power generating module which is a SGU connected to the distribution system, if it is necessary for the operational security analysis and for the validation of models.	facilitate data provision by SGUs	“Affordable Tool” BUC
Article 52 – Data exchange between TSOs and transmission-connected demand facilities - Paragraph 1: Transmission-connected demand facility owner shall provide the following structural data to the TSO: electrical data of the transformers connected to the transmission system; characteristics of the load of the demand facility; characteristics of the reactive power control. - Paragraph 2: Transmission-connected demand facility owner shall provide the following data to the TSO: scheduled active and forecasted reactive power consumption on a day-ahead and intraday basis, including any changes of those schedules or forecast; any forecasted restriction in the reactive power control capability; in case of participation in demand response, a schedule of its structural minimum and maximum power range to be curtailed. - Paragraph 3: Transmission-connected demand facility owner shall provide the following data to the TSO in real-time: active and reactive power at the connection point; the minimum and maximum power range to be curtailed. - Paragraph 4: Each transmission-connected demand facility owner shall describe to its TSO its behaviour at the voltage ranges referred to in Article 27.	DEP can be used for data exchanges between TSOs and demand facility, would facilitate access to same data by third parties and would facilitate data provision by demand facilities	Flexibility bidding (incl. prequalification) SUC, DER-SCADA data exchange SUC, data transfer SUC. “Flexibility Platform” BUC, “Affordable Tool” BUC, “ENTSO-E” BUC
Article 53 – Data exchange between TSOs and distribution-connected demand facilities or third parties participating in demand response - Paragraph 1: SGU which is a distribution-connected demand facility and which participates in demand response other than through a third party shall provide the following scheduled and real-time data to the TSO and to the DSO: structural minimum and maximum active power available for demand response and the maximum and minimum duration of any potential usage of this power for demand response; a forecast of unrestricted active power available for demand response and any planned demand response; real-time active and reactive power at the connection point; a confirmation that the estimations of the actual values of demand response are applied. - Paragraph 2: SGU which is a third party participating in demand response shall provide the TSO and the DSO at the day-ahead and close to real-time and on behalf of all of its distribution-connected demand facilities, with the following data: structural minimum and maximum active power available for demand	DEP can be used for data exchanges between DSOs and demand facilities, would facilitate access to same data by third parties and would facilitate data provision by demand facilities	Flexibility bidding (incl. prequalification) SUC, DER-SCADA data exchange SUC, data transfer SUC. “Flexibility Platform” BUC, “Affordable Tool” BUC, “ENTSO-E” BUC

response and the maximum and minimum duration of any potential activation of demand response in a specific geographical area defined by the TSO and DSO; a forecast of unrestricted active power available for the demand response and any planned level of demand response in a specific geographical area defined by the TSO and DSO; real-time active and reactive power; a confirmation that the estimations of the actual values of demand response are applied.		
Article 108 – Ancillary services - Paragraph 1: Each TSO shall monitor the availability of ancillary services. - Paragraph 3: Each TSO shall publish the levels of reserve capacity necessary to maintain operational security. - Paragraph 4: Each TSO shall communicate the available level of active power reserves to other TSOs upon request.	Through DEP TSO and/or flexibility market operator can communicate the flexibility needs	Flexibility bidding (incl. prequalification) SUC. “Flexibility Platform” BUC
Article 111 – Notification of schedules within scheduling areas - Paragraph 1: Obligation for scheduling agents to submit to the TSO operating the scheduling area, if requested by the TSO, and, where applicable, to third party, the following schedules: generation schedules; consumption schedules; internal commercial trade schedules; external commercial trade schedules.	DEP can be used for exchanging schedules	n/a
Article 113 – Provision of information to other TSOs (schedules) - Paragraph 1: At the request of another TSO, the requested TSO shall calculate and provide: aggregated netted external schedules; netted area AC position, where the scheduling area is interconnected to other scheduling areas via AC transmission links. - Paragraph 2: When required for the creation of common grid models each TSO operating a scheduling area shall provide any requesting TSO with: generation schedules; consumption schedules.	DEP can be used for exchanging schedules	n/a
Article 114 – General provisions for ENTSO for Electricity operational planning data environment - Paragraph 1: By 24 months after entry into force of this Regulation, ENTSO for Electricity shall implement and operate an ENTSO for Electricity operational planning data environment for the storage, exchange and management of all relevant information.	DEP can be used to make data from ENTSO-E’s operational planning data environment available to interested parties	SUCs on data collection, data transfer, data aggregation. ENTSO-E” BUC

- Paragraph 2: By 6 months after entry into force of this Regulation, all TSOs shall define a harmonised data format for data exchange, which shall be an integral part of the ENTSO for Electricity operational planning data environment. - Paragraph 3: All TSOs and regional security coordinators shall have access to all information contained on the ENTSO for Electricity operational planning data environment.		
Article 147 – Cross-border FRR activation process - Paragraph 2: Each TSO shall have the right to implement the cross-border FRR activation process for LFC areas within the same LFC block, between different LFC blocks or between different synchronous areas by concluding a cross-border FRR activation agreement.	DEP can enable forwarding the activation requests, incl. cross-border	Flexibility activation SUC. “Affordable Tool” BUC, “Flexibility Platform” BUC
Article 148 – Cross-border RR activation process - Paragraph 2: Each TSO shall have the right to implement the cross-border RR activation process for LFC areas within the same LFC block, between different LFC blocks or between different synchronous areas by concluding a cross-border RR activation agreement.	DEP can enable forwarding the activation requests, incl. cross-border	Flexibility activation SUC. “Affordable Tool” BUC, “Flexibility Platform” BUC
Article 149 – General requirements for cross-border control processes - Paragraph 1: All TSOs participating in an exchange or sharing of FRR or RR shall implement a cross-border FRR or RR activation process, as appropriate. - Paragraph 3: All TSOs participating in the same imbalance netting process, in the same cross-border FRR activation process or in the same cross-border RR activation process shall specify in the respective agreements, the roles and responsibilities of all TSOs including the provision of all input data necessary for: (i) the calculation of the power interchange with respect to the operational security limits; and (ii) the performance of real-time operational security analysis by participating and affected TSOs.	DEP can enable forwarding the activation requests, incl. cross-border	Flexibility activation SUC. “Affordable Tool” BUC, “Flexibility Platform” BUC
Article 154 – FCR technical minimum requirements - Paragraph 1: Each reserve connecting TSO shall ensure that the FCR fulfils the properties listed for its synchronous area in the Table of Annex V of the regulation. - Paragraph 8: Each FCR provider shall make available to the reserve connecting TSO, for each of its FCR providing units and FCR providing groups, at least the following information: (a)	DEP can be used to exchange data necessary for verification of flexibility activations	Flexibility activation SUC, flexibility baseline SUC, DER-SCADA data exchange SUC, sub-metering SUC. “Affordable

time-stamped status indicating if FCR is on or off; (b) time-stamped active power data needed to verify FCR activation, including time-stamped instantaneous active power; (c) droop of the governor for type C and type D power generating modules acting as FCR providing units, or its equivalent parameter for FCR providing groups consisting of type A and/or type B power generating modules, and/or demand units with demand response active power control. - Paragraphs 9-11: Each FCR provider shall have the right to aggregate the respective data for more than one FCR providing unit if the maximum power of the aggregated units is below 1,5 MW and a clear verification of activation of FCR is possible. At the request of the reserve connecting TSO, the FCR provider shall make this information available in real-time, with a time resolution of at least 10 seconds. At the request of the reserve connecting TSO and where necessary for the verification of the activation of FCR, a FCR provider shall make available the data concerning technical installations that are part of the same FCR providing unit.		Tool" BUC, "Flexibility Platform BUC
Article 155 – FCR prequalification process - Paragraph 2: A potential FCR provider shall demonstrate to the reserve connecting TSO that it complies with the technical and the additional requirements set out in Article 154 by completing successfully the prequalification process. - Paragraph 3: A potential FCR provider shall submit a formal application to the reserve connecting TSO together with the required information of potential FCR providing units or FCR providing groups. - Paragraph 6: The qualification of FCR providing units or FCR providing groups shall be re-assessed: (a) at least once every 5 years; (b) in case the technical or availability requirements or the equipment have changed; and (c) in case of modernisation of the equipment related to FCR activation.	DEP can be used to exchange data necessary for prequalification of flexibility providers	Flexibility bidding (incl. prequalification) SUC, DER-SCADA data exchange SUC, sub-metering SUC. "Affordable Tool" BUC, "Flexibility Platform BUC
Article – 156 FCR provision - Paragraph 5: Each FCR provider shall inform its reserve connecting TSO, as soon as possible, about any changes in the actual availability of its FCR providing unit and/or its FCR providing group, in whole or in part, relevant for the results of prequalification.	DEP can be used to exchange data for flexibility availability	Flexibility bidding (incl. prequalification) SUC, DER-SCADA data exchange SUC. "Affordable Tool" BUC, "Flexibility Platform BUC
Article 158 – FRR minimum technical requirements	DEP can be used to exchange data necessary for verification of	Flexibility activation SUC, flexibility baseline SUC,

- Paragraph 1(b): A FRR providing unit or FRR providing group shall activate FRR in accordance with the setpoint received from the reserve instructing TSO. - Paragraph 1(e): A FRR provider shall ensure that the FRR activation of the FRR providing units within a reserve providing group can be monitored. For that purpose, the FRR provider shall be capable of supplying to the reserve connecting TSO and the reserve instructing TSO real-time measurements of the connection point or another point of interaction agreed with the reserve connecting TSO concerning: (i) time-stamped scheduled active power output; (ii) time-stamped instantaneous active power for each FRR providing unit, for each FRR providing group, and for each power generating module or demand unit of a FRR providing group with a maximum active power output larger than or equal to 1,5 MW. - Paragraph 4(b): Each FRR provider shall inform its reserve instructing TSO about a reduction of the actual availability of its FRR providing unit or its FRR providing group or a part of its FRR providing group as soon as possible.	flexibility activations	DER-SCADA data exchange SUC, sub-metering SUC. “Affordable Tool” BUC, “Flexibility Platform BUC
Article 159 – FRR prequalification process - Paragraph 2: A potential FRR provider shall demonstrate to the reserve connecting TSO or the TSO designated by the reserve connecting TSO in the FRR exchange agreement that it complies with the FRR minimum technical requirements, the FRR availability requirements, the ramping rate requirements and the connection requirements in Article 158 by completing successfully the prequalification process of potential FRR providing units or FRR providing groups. - Paragraph 3: A potential FRR provider shall submit a formal application to the relevant reserve connecting TSO or the designated TSO together with the required information of potential FRR providing units or FRR providing groups. - Paragraph 6: The qualification of FRR providing units or FRR providing groups shall be re-assessed: (a) at least once every 5 years; and (b) where the technical or availability requirements or the equipment have changed.	DEP can be used to exchange data necessary for prequalification of flexibility providers	Flexibility bidding (incl. prequalification) SUC, DER-SCADA data exchange SUC, sub-metering SUC. “Affordable Tool” BUC, “Flexibility Platform BUC
Article 161 – RR minimum technical requirements - Paragraph 1(f): A RR provider shall ensure that the RR activation of the RR providing units within a reserve providing group can be monitored. For that purpose, the RR provider shall be capable of supplying to the reserve connecting TSO and the reserve instructing TSO real-time measurements of the connection point or another point of interaction agreed with the reserve connecting TSO concerning: (i) the time-stamped scheduled active power output, for each RR providing unit and	DEP can be used to exchange data necessary for verification of flexibility activations	Flexibility activation SUC, flexibility baseline SUC, DER-SCADA data exchange SUC, sub-metering SUC. “Affordable Tool” BUC,

group and for each power generating module or demand unit of a RR providing group with a maximum active power output larger than or equal to 1,5 MW; (ii) the time-stamped instantaneous active power, for each RR providing unit and group, and for each power generating module or demand unit of a RR providing group with a maximum active power output larger than or equal to 1,5 MW.		"Flexibility Platform BUC
Article 162 – RR prequalification process - Paragraph 2: A potential RR provider shall demonstrate to the reserve connecting TSO or the TSO designated by the reserve connecting TSO in the RR exchange agreement that it complies with the RR technical minimum requirements, the RR availability requirements and the connection requirements referred to in Article 161 by completing successfully the prequalification process of potential RR providing units or RR providing groups - Paragraph 3: A potential RR provider shall submit a formal application to the relevant reserve connecting TSO or the designated TSO together with the required information of potential RR providing units or RR providing groups. - Paragraph 5: The qualification of RR providing units or RR providing groups shall be reassessed: (a) at least once every 5 years; and (b) where the technical or availability requirements or the equipment have changed.	DEP can be used to exchange data necessary for prequalification of flexibility providers	Flexibility bidding (incl. prequalification) SUC, DER-SCADA data exchange SUC, sub-metering SUC. "Affordable Tool" BUC, "Flexibility Platform BUC
Article 182 – Reserve providing groups or units connected to the DSO grid - Paragraph 1: TSOs and DSOs shall cooperate in order to facilitate and enable the delivery of active power reserves by reserve providing groups or reserve providing units located in the distribution systems. - Paragraph 2: For the purposes of the prequalification processes for FCR, FRR and RR, each TSO shall develop and specify, in an agreement with its reserve connecting DSOs and intermediate DSOs, the terms of the exchange of information required for these prequalification processes for reserve providing units or groups located in the distribution systems and for the delivery of active power reserves. - Paragraph 2(a)-(d): The prequalification processes for FCR in Article 155, FRR in Article 159 and RR in Article 162 shall specify the information to be provided by the potential reserve providing units or groups, which shall include: voltage levels and connection points of the reserve providing units or groups; the type of active power reserves; the maximum reserve capacity provided by the reserve providing units or groups at each connection point; the maximum rate of change of active power for the reserve providing units or groups.	DEP can be used to exchange data necessary for prequalification of flexibility providers, for activation of flexibilities, for identifying congestions in the grid and setting limits	Flexibility bidding (incl. prequalification) SUC, flexibility activation SUC, DER-SCADA data exchange SUC, sub-metering SUC. "Affordable Tool" BUC, "Flexibility Platform BUC

- Paragraph 4: During the prequalification of a reserve providing unit or group connected to its distribution system, each reserve connecting DSO and each intermediate DSO, in cooperation with the TSO, shall have the right to set limits to or exclude the delivery of active power reserves located in its distribution system, based on technical reasons such as the geographical location of the reserve providing units and reserve providing groups. - Paragraph 5: Each reserve connecting DSO and each intermediate DSO shall have the right, in cooperation with the TSO, to set, before the activation of reserves, temporary limits to the delivery of active power reserves located in its distribution system. The respective TSOs shall agree with their reserve connecting DSOs and intermediate DSOs on the applicable procedures.		

I-6. NETWORK CODE ON DEMAND CONNECTION

	Can a DEP support fulfilling the requirement?	EU-SysFlex use cases
Article 11 – Confidentiality obligations - Paragraph 3: Confidential information received by the persons or regulatory authorities in the course of their duties may not be divulged to any other person or authority, without prejudice to cases covered by national law, the other provisions of this Regulation or other relevant Union legislation.	DEP can enable secure data exchange. Data may be exchanged with consent of the person	Several SUCs and BUCs related to exchange of personal data
Article 18 – Information exchange - Paragraphs 1-2: Transmission-connected demand facilities and transmission-connected distribution systems shall be equipped in order to exchange information with the relevant TSO with the specified time stamping. - Paragraph 3: The relevant TSO shall specify the information exchange standards. The relevant TSO shall make publicly available the precise list of data required.	Through DEP the demand facilities and DSOs can exchange required data with TSOs	SUCs related to flexibility processes, DER-SCADA data exchange, data transfer, sub-metering. "Affordable Tool" BUC, "Flexibility Platform" BUC, "ENTSO-E" BUC
Article 28 – Specific provisions for demand units with demand response active power control, reactive power control and transmission constraint management	DEP can be used to exchange data necessary for activation of flexibilities and for verification of	Flexibility activation SUC, flexibility verification SUC, DER-SCADA data exchange

- Paragraph 2(e): Demand units with demand response active power control, demand response reactive power control, or demand response transmission constraint management, either individually or, where it is not part of a transmission-connected demand facility, collectively as part of demand aggregation through a third party shall be equipped to receive instructions, directly or indirectly through a third party, from the relevant system operator or the relevant TSO to modify their demand and to transfer the necessary information. The relevant system operator shall make publicly available the technical specifications approved to enable this transfer of information.	the activated flexibilities	SUC, sub-metering SUC. "Affordable Tool" BUC, "Flexibility Platform BUC

I-7. NETWORK CODE ON REQUIREMENTS FOR GRID CONNECTION OF GENERATORS

	Can a DEP support fulfilling the requirement?	EU-SysFlex use cases
Article 12 – Confidentiality obligations - Paragraph 3: Confidential information received by the persons or regulatory authorities in the course of their duties may not be divulged to any other person or authority, without prejudice to cases covered by national law, the other provisions of this Regulation or other relevant Union legislation.	DEP can enable secure data exchange. Data may be exchanged with consent of the person	Several SUCs and BUCs related to exchange of personal data
Article 14 – General requirements for type B power-generating modules - Paragraph 5(d)(i): Power-generating facilities shall be capable of exchanging information with the relevant system operator or the relevant TSO in real time or periodically with time stamping, as specified by the relevant system operator or the relevant TSO. - Paragraph 5(d)(ii): The relevant system operator, in coordination with the relevant TSO, shall specify the content of information exchanges including a precise list of data to be provided by the power-generating facility.	Through DEP the generators can exchange required data with system operators	SUCs related to flexibility processes, DER-SCADA data exchange, data transfer, sub-metering. "Flexibility Platform" BUC
Article 15 – General requirements for type C power-generating modules - Paragraph 6(b)(iv): The facilities for quality of supply and dynamic system behaviour monitoring shall include arrangements for the power-generating facility owner, and the relevant system operator and the relevant TSO to access the information. The communications protocols for recorded data shall be agreed between the power-generating facility owner, the relevant system operator and the relevant TSO.	Through DEP the generators can exchange required data with system operators	SUCs related to flexibility processes, DER-SCADA data exchange, data transfer, sub-metering. "Flexibility Platform" BUC

I-8. NETWORK CODE ON ELECTRICITY EMERGENCY AND RESTORATION

	Can a DEP support fulfilling the requirement?	EU-SysFlex use cases
Article 9 – Confidentiality obligations - Paragraph 3: Confidential information received by the persons or regulatory authorities in the course of their duties may not be divulged to any other person or authority, without prejudice to cases covered by national law, the other provisions of this Regulation or other relevant Union legislation.	DEP can enable secure data exchange. Data may be exchanged with consent of the person	Several SUCs and BUCs related to exchange of personal data
Article 40 – Information exchange - Paragraph 1: Each TSO, when in the emergency, blackout or restoration states, shall be entitled to gather information from DSOs and SGUs. - Paragraph 2: During the emergency, blackout or restoration states, each TSO shall provide in due time and for the purposes of system defence plan procedures and restoration plan procedures information to neighbouring TSOs, to the frequency leader of its synchronised region, to defence service providers, to DSOs and SGUs and to restoration service providers. - Paragraph 3: TSOs in emergency, blackout or restoration state shall exchange among themselves information. - Paragraph 4: A TSO in emergency, blackout or restoration state shall provide, in due time, information about the system state of its transmission system and, where available, additional information explaining the situation on the transmission system: (a) to the NEMO(s), who shall make this information available to their market participants; (b) to its relevant regulatory authority; and (c) to any other relevant party, as appropriate.	DEP could be used for some data exchanges in emergency, blackout or restoration states. (According to art. 41 voice communication system is required. DEP could be used in addition.)	n/a

I-9. GUIDELINE ON CAPACITY ALLOCATION AND CONGESTION MANAGEMENT

	Can a DEP support fulfilling the requirement?	EU-SysFlex use cases
Article 7 – NEMO tasks - Paragraph 1: NEMOs shall act as market operators in national or regional markets to perform in cooperation with TSOs single day-ahead and intraday coupling. Their tasks shall include receiving orders from market participants, having overall	DEP can be used for exchange of relevant market data between relevant stakeholders	Data collection SUC, data transfer SUC. Not to be demonstrated in EU-SysFlex

responsibility for matching and allocating orders in accordance with the single day-ahead and intraday coupling results, publishing prices and settling and clearing the contracts resulting from the trades according to relevant participant agreements and regulations.		
Article 13 – Confidentiality obligations - Paragraph 3: Confidential information received by the persons or regulatory authorities in the course of their duties may not be divulged to any other person or authority, without prejudice to cases covered by national law, the other provisions of this Regulation or other relevant Union legislation.	DEP can enable secure data exchange. Data may be exchanged with consent of the person	Several SUCs related to exchange of personal data. Not to be demonstrated in EU-SysFlex
Article 16 – Generation and load data provision methodology - Paragraph 1: All TSOs shall jointly develop a proposal for a single methodology for the delivery of the generation and load data required to establish the common grid model. - Paragraph 2: The proposal for the generation and load data provision methodology shall specify which generation units and loads are required to provide information to their respective TSOs for the purposes of capacity calculation. - Paragraph 3: The proposal for a generation and load data provision methodology shall specify the information to be provided by generation units and loads to TSOs. The information shall at least include the following: (a) information related to their technical characteristics; (b) information related to the availability of generation units and loads; (c) information related to the schedules of generation units; (d) relevant available information relating to how generation units will be dispatched. - Paragraph 5: Each TSO shall use and share with other TSOs the information above (for capacity calculation purposes only).	Addressed by ENTSO-E in CGMES project. However, data related to common grid model can be exchanged via DEP which would facilitate access to the same data by third parties and would facilitate data provision by generators and consumers	Data collection SUC, data transfer SUC. Not to be demonstrated in EU-SysFlex
Article 62 – Publication of market information - Paragraph 1: As soon as the orders are matched, each NEMO shall publish for relevant market participants at least the status of execution of orders and prices per trade produced by the continuous trading matching algorithm. - Paragraph 2: Each NEMO shall ensure that information on aggregated executed volumes and prices is made publicly available in an easily accessible format for at least 5 years.	DEP can be used for publication of relevant market data	Data collection SUC, data transfer SUC. Not to be demonstrated in EU-SysFlex

EU-SysFlex

I-10. REGULATION ON SUBMISSION AND PUBLICATION OF DATA IN ELECTRICITY MARKETS

	Can a DEP support fulfilling the requirement?	EU-SysFlex use cases
Article 1 – Subject matter - This Regulation lays down the minimum common set of data relating to generation, transportation and consumption of electricity to be made available to market participants. It also provides for a central collection and publication of the data.	Through DEP data between different stakeholders can be exchanged, incl. for publication	Data collection SUC, data transfer SUC, aggregation SUC. “ENTSO-E” BUC, “Flexibility Platform” BUC
Article 3 – Establishment of a central information transparency platform - Paragraph 1: A central information transparency platform shall be established and operated within ENTSO-E. ENTSO-E shall publish on the transparency platform all data which TSOs are required to submit to the ENTSO-E in accordance with this Regulation. The central information transparency platform shall be available to the public free of charge through the internet. The data shall be up to date, easily accessible, downloadable and available for at least five years. Data updates shall be time-stamped, archived and made available to the public.	DEP can be used to facilitate data submission from data owners via TSOs or data providers to ENTSO-E transparency platform. ENTSO-E’s ECCo SP DEP in conjunction with another DEP can be used to facilitate access to data on transparency platform	Data collection SUC, data transfer SUC, aggregation SUC. “ENTSO-E” BUC
Article 4 – Submission and publication of data - Paragraph 1: Primary owners of data shall submit data to TSOs or to data providers, ensuring that data are complete, of the required quality and provided in a manner that allows TSOs or data providers to process and deliver the data to the ENTSO-E in sufficient time to allow the ENTSO-E. - Paragraph 2: Primary owners of data may fulfil their obligation by submitting data directly to the central information transparency platform provided they use a third party acting as data provider on their behalf. This way of submitting data shall be subject to the prior agreement of the TSO in whose control area the primary owner is located.	DEP can be used to facilitate data submission from data owners via TSOs or data providers to ENTSO-E transparency platform. ENTSO-E’s ECCo SP DEP in conjunction with another DEP can be used to facilitate access to data on transparency platform	Data collection SUC, data transfer SUC, aggregation SUC. “ENTSO-E” BUC

I-11. REGULATION ON A FRAMEWORK FOR THE FREE FLOW OF NON-PERSONAL DATA IN THE EUROPEAN UNION

	Can a DEP support fulfilling the requirement?	EU-SysFlex use cases
Article 4 – Free movement of data within the Union - Paragraph 1: Data localisation requirements shall be prohibited, unless they are justified on grounds of public security in compliance with the principle of proportionality.	DEP does not contain restrictions on the data localisation	All SUCs and BUCs
Article 5 – Data availability for competent authorities - Paragraph 1: This Regulation shall not affect the powers of competent authorities to request, or obtain, access to data for the performance of their official duties in accordance with Union or national law. Access to data by competent authorities may not be refused on the basis that the data are processed in another Member State.	DEP can be used to provide data for competent authorities	All SUCs and BUCs
Article 6 – Porting of data - Paragraph 1: The Commission shall encourage and facilitate the development of self-regulatory codes of conduct at Union level ('codes of conduct'), in order to contribute to a competitive data economy, based on the principles of transparency and interoperability and taking due account of open standards, covering, inter alia, the following aspects: (a) best practices for facilitating the switching of service providers and the porting of data in a structured, commonly used and machine-readable format including open standard formats where required or requested by the service provider receiving the data; (b) minimum information requirements to ensure that professional users are provided, before a contract for data processing is concluded, with sufficiently detailed, clear and transparent information regarding the processes, technical requirements, timeframes and charges that apply in case a professional user wants to switch to another service provider or port data back to its own IT systems;	DEP can be used for porting of data in a structured, commonly used, and machine-readable format	All SUCs and BUCs

EU-SysFlex

I-12. REGULATION ON LAYING DOWN HARMONISED RULES ON ARTIFICIAL INTELLIGENCE (ARTIFICIAL INTELLIGENCE ACT) – EC PROPOSAL

	Can a DEP support fulfilling the requirement?	EU-SysFlex use cases
Article 10 – Data and data governance - Paragraph 2: Training, validation and testing data sets shall be subject to appropriate data governance and management practices. Those practices shall concern in particular, (…) (b) data collection; (c) relevant data preparation processing operations, such as annotation, labelling, cleaning, enrichment and aggregation;	DEP can be used for data collection, transfer, and aggregation. The above functionalities are well documented, which reduces the risk of misinterpretation of data by the AI system.	SUCs Aggregate energy data Collect energy data Transfer energy data
Article 12 – Record-keeping - Paragraph 1 et seq: High-risk AI systems shall be designed and developed with capabilities enabling the automatic recording of events ('logs') while the high-risk AI systems is operating. Those logging capabilities shall conform to recognised standards or common specifications (…).	DEP has event ('logs') recording functionality	SUC Manage data logs
Article 17 – Quality management system - Paragraph 1: Providers of high-risk AI systems shall put a quality management system in place that ensures compliance with this Regulation. That system shall be documented in a systematic and orderly manner in the form of written policies, procedures and instructions, and shall include at least the following aspects: (…) (f) systems and procedures for data management, including data collection, data analysis, data labelling, data storage, data filtration, data mining, data aggregation, data retention and any other operation regarding the data that is performed before and for the purposes of the placing on the market or putting into service of high-risk AI systems; (…) (j) the handling of communication with national competent authorities, competent authorities, including sectoral ones, providing or supporting the access to data, notified bodies, other operators, customers or other interested parties;	DEP can be used for data collection, transfer, and aggregation. DEP can be used to provide data for competent authorities	All SUCs and BUCs

ANNEX II. ANSWERS FROM DPOs REGARDING SUCs AND BUCs

		BUSINESS USE CASES												
		ACCESS TO DATA	BALANCE MANAGEMENT	MARKET FOR FLEXIBILITIES	SERVICES RELATED TO END CUSTOMER	SERVICES OF RSCs	OPERATIONAL PLANNING AND FORECASTING	ENERGY TRADING	CAPACITY ALLOCATION	REPORTING	LONG-TERM NETWORK PLANNING	CONNECTING TO THE NETWORK	RES ADMIN.	Rationale
		1	2	3	4	5	6	7	8	9	10	11	12	
SYSTEM USE CASES	Data collection	NL,IT,EE	NL		NL,EE		IT	NL,IT		NL		NL	EE	
	Data transfer	NL,EE	NL,EE	EE	NL,EE		IT	NL,IT		NL,EE		NL	EE	
	Data storage	IT,EE			EE			IT					EE	
	Assignment of EIC codes	NL,EE	EE		NL,EE			NL		NL,EE		NL	EE	
	Retrospective corrections of data	NL,IT,EE	NL,EE	NL	NL,EE	NL	NL,IT			NL,EE		NL?	NL?,EE	
	Management of supply agreement		NL,EE		NL,EE									
	Management of network agreement		NL,EE		NL,EE							NL		
	List of suppliers and service providers	EE	EE	NL	NL,EE									
	Management of portfolio agreement		NL,EE		NL?			NL						
	Management of bids and offers in DA, ID and forward markets							NL						
	Management of flexibility bids			NL	NL									
	Management of flexibility activations			NL								NL?		
	Verification of activated flexibilities		NL	NL			NL,IT					NL?		
	Management of user's requests	NL,IT,EE	NL,EE	NL	NL,EE	NL	NL,IT	NL			NL	NL	NL,EE	
	Customer notifications	NL,IT	NL	NL	NL	NL	NL,IT	NL				NL	NL	
	Management of authorizations	NL,IT,EE	NL,EE	NL,EE	NL,EE	NL	NL,IT	NL		NL		NL	NL	
	Authentication of data users	NL,IT,EE	NL,EE	NL	NL,EE	NL	NL,IT	NL		NL		NL	NL,EE	
	Baseline calculation			NL										
	Change of data format inside DEP	NL	NL	NL	NL	NL	NL,IT	NL	IT	NL	NL	NL?	NL	
	Massive data processing		NL	NL	NL	NL	NL,IT	NL						
	Quality check of data	NL,IT	NL	NL	NL	NL	NL,IT	NL		NL		NL	NL	
	Device level (sub-meter) metering	NL,IT		NL	NL		NL,IT					NL?		
	Data exchange between DER and SCADA						IT?							
	Peer-to-peer trading			NL				NL						
	Anonymisation of data	NL			NL	NL		NL		NL				
	Aggregation of data	NL,IT,EE	NL,EE	NL	NL	NL	NL,IT	NL		NL,EE		NL	EE	
	Integrating new data source	EE			EE									
	Integrating new application	IT,EE		EE	EE									
	Maintaining list of platform services	IT,EE			EE	NL								
	Erasure, restriction and rectification of person	IT,EE			EE		IT						NL,EE	
	Detect data breaches													
	Manage security logs													
	Predict flexibility availability													

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ANNEX III. RECONCILIATION OF EU-SYSFLEX ROLES IN DATA EXCHANGE SUCS WITH HEMRM

EU-SysFlex		HEMRM v2020-01	
Business Roles	Descriptions	Business Roles	Descriptions
Aggregator	Aggregate and maximise the value of the portfolio(s) of resources (definition from EU-SysFlex D3.3, 2018).	Resource Aggregator	A party that aggregates resources for usage by a service provider for energy market services.
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	Consumer, generator or storage facility owner.	Party Connected to the Grid	A party that contracts for the right to consume or produce electricity at an Accounting Point.
Customer Portal Operator	Operates a Customer Portal.	Not available	
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 • 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	Data Provider	A party that has the mandate to provide information to other parties in the energy market.
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	

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EU-SysFlex		HEMRM v2020-01	
Business Roles	Descriptions	Business Roles	Descriptions
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	
DER Operator	Operates a single DER unit. Distributed Energy Resources can consist of generation sources, energy storage facilities and facilities participating in Demand Response. Are mainly connected to distribution power grids but can also be connected to transmission power grids (e.g. Portugal). Can be an Asset Operator, a Generator or a Generation Asset Operator (definition from EU-SysFlex D3.3, 2018).	Resource Provider	A role that manages a resource and provides production/consumption schedules for it, if required.
Energy Service Provider	A party offering energy-related services to any other party (definition adapted from ENTSOE-EFET-ebIX, 2020). An energy service provider (ESCO – energy service company) is a market-based role which is responsible for delivering energy services to the customers (or to other parties on behalf of the customers). In case these services necessitate the access to customer's data, the consent of this customer is required. Examples of the executors of this role include aggregator, flexibility service provider, energy efficiency provider, energy monitoring provider. This role does not appear in T3.3 Business Use Cases. Can also be an Aggregator or a Generator (definition from EU-SysFlex D3.3, 2018).	Energy Service Company (ESCO) covers a part of Energy Service Provider responsibilities.	A party offering energy-related services to the Party Connected to Grid, but not directly active in the energy value chain or the physical infrastructure itself. The ESCO may provide insight services as well as energy management services.

EU-SysFlex		HEMRM v2020-01	
Business Roles	Descriptions	Business Roles	Descriptions
Flexibility Service Provider	Can be a Distribution Network Flexibility Provider or a Transmission Network Flexibility Provider (definition from EU-SysFlex D3.3, 2018). Similar to Flexibility Aggregator. Can be both aggregator and individual consumer/generator. Type of Energy Service Provider.	Balance Service Provider covers a part of FSP responsibilities.	
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	
Market Operator	A market operator is a party that provides a service whereby the offers to sell electricity are matched with bids to buy electricity (definition from ENTSOE-EFET-ebIX, 2020). In EU-SysFlex project, a market operator not only trades electricity but also flexibility services. Organizes auctions (continuous auctions, discrete auctions, calls for tender) between buyers and sellers of electricity-related products in the markets, and more generally publish the corresponding prices, for assets connected to a power grid. Manages/operates the platform for trading (where bids and offers are collected). Clears the market and communicate results. (definition from EU-SysFlex D3.3, 2018)	Market Operator	A market operator is a party that provides a service whereby the offers to sell electricity are matched with bids to buy electricity. Additional Information: This usually is an energy/power exchange or platform.
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 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.

EU-SysFlex		HEMRM v2020-01	
Business Roles	Descriptions	Business Roles	Descriptions
Optimization Operator	Optimise and select the bids, where relevant in combination with switching measures; clear the market for auctions or select individual bids in the order book organised by the MO taking into account the grid data (constraints and sensitivities/topology if needed) provided by DS_O and TS_O ; communicate results (rewarded offers and prices) to the MO. The OO role can be carried out by a system operator, market operator or a third party. (definition from EU-SysFlex D3.3, 2018)	Not available	
Primary System Operator	Initiates the call for tenders or initiates the activation of a flexibility.	A kind of System Operator	(see System Operator)
Secondary System Operator	Operates the power grid on which a flexibility service unit is connected or this unit may otherwise impact its grid. Assesses the impact on its network of the flexibility to be procured by Primary System Operator because the activation of such flexibility may potentially cause congestion in its grid.	A kind of System Operator	(see System Operator)

<table>
<tr><th colspan="2">EU-SysFlex</th><th colspan="2">HEMRM v2020-01</th></tr>
<tr><th>Business Roles</th><th>Descriptions</th><th>Business Roles</th><th>Descriptions</th></tr>
<tr><td>System Operator</td><td>System Operator means a natural or legal person responsible for operating, ensuring the maintenance of and, if necessary, developing the system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet reasonable demands for the distribution or transmission of electricity (definition from ENTSOE-EFET-ebIX, 2020).
Can be:
A Transmission System Operator (definition from EU-SysFlex D3.3, 2018), for frequency control, congestion management and voltage control on transmission network,
A Distribution System Operator (definition from EU-SysFlex D3.3, 2018), for congestion management and voltage control on a distribution network.
NB: In some countries (e.g. Germany and Poland), the high voltage network is part of the distribution grid and in other countries (e. g. France and Italy) the high voltage network is part of the transmission grid.
A System Operator is called:
A Primary System Operator,
A Secondary System Operator.</td><td>System Operator</td><td>A party responsible for operating, ensuring the maintenance of and, if necessary, developing the system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet reasonable demands for the distribution or transmission of electricity.
Additional information: The definition is based on DIRECTIVE 2009/72/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC, Article 2 (Definitions)</td></tr>
</table>