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WP3: SYNERGIES Reference Energy Data Space Implementation

D3.1: SYNERGIES Energy Data Space Release 1.00

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Executive Summary

The deliverable at hand accompanies and documents the software release of the initial version of the SYNERGIES Reference Energy Data Space on Month 18 of the SYNERGIES project.

The first part of the deliverable acts as a reference for the work progress achieved in the context of SYNERGIES Tasks T3.2, T3.3, T3.4, T3.5 and T3.6, which deliver the Data Interoperability and Governance Block, the Data Security and Sovereignty Block, the Trusted Data Sharing Block, the Data Value Accrual Block, and the Backbone SYNERGIES Data Space Infrastructure accordingly, until M18. For each building block, a structured documentation is provided, giving an overview of the underlying functionalities, a short description of the implementation status per identified feature, the technologies used in the development of this block, the assumptions and restrictions, and the features which are planned for the final release; such features have been either partially implemented in the draft release and are going to be enhanced in the final release, or shall be built altogether in the final release. The implementation status and the planning for the final release follow the development roadmap which was presented in the SYNERGIES Internal Deliverable ID3.1 [1]. Of the 63 features identified in total for the 5 building blocks, 14 features were fully implemented in the initial version and 7 features were left out of this version, to be implemented directly in the final release. The remaining 42 features have been partially implemented in the draft release; the completeness degree of each feature is documented in detail in this deliverable.

In its second part, the deliverable outlines the SYNERGIES platform experience (that is fully documented online in the Help menu), making a reference to the structure and main menus of the SYNERGIES Reference Energy Data Space that are visible for all users: Data Check-In, Data Monitoring, My Assets, Marketplace, Contracts, Data Retrieval, and Data Space Management. Furthermore, the integration approach followed during the software delivery cycles is described in detail, and the adopted support channels are presented.

Consequently, the deliverables lays down the next steps in the development and integration work of Work Package 3.

Finally, D3.1 presents the SYNERGIES Sectorial Data Models in Annex II, which are the result of the work in Task T3.1. There are four SYNERGIES Sectorial Data Models, which model the Energy, Building and EV domains and cover the General concepts, that are common across all domains. In total, the four data models comprise a total of 155 concepts and 2606 simple fields.

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List of Acronyms/Abbreviations

Acronym/ Abbreviation	Description
API	Application Programming Interface
BSP	Balancing Service Provider
CSS	Cascading Style Sheets
DB	Database
DER	Distributed Energy Resources
DSO	Distribution System Operator
EDS	Energy Data Space
EV	Electric Vehicle
IO	Input Output
IoT	Internet of Things
JS	JavaScript
JSON	JavaScript Object Notation
LEC	Local Energy Community
M	Month
ML	Machine Learning
MQTT	Message Queuing Telemetry Transport
RES	Renewable Energy Sources
SQL	Structured Query Language
TSO	Transmission System Operator
UC	Use Case
URL	Uniform Resource Locator
WP	Work Package
XML	eXtensible Markup Language

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1 Introduction

1.1 SYNERGIES Project Overview

The growing number of Distributed Energy Resources (DERs) connected to the network continuously expands the energy system "edge", in terms of controllability and operational complexity. The progressive decentralization, which is also accompanied by the introduction of new digitalized assets (EVs, Internet of Things (IoT), batteries), poses significant challenges for the resilience of the system, while introducing increased uncertainty in traditional control routines, given the stochastic and intermittent character of renewable generation and the new control variables (not currently addressed in existing tools for the system management) introduced by new assets.

SYNERGIES introduces a Reference Energy Data Space Implementation that will attempt to unleash the data-driven innovation and sharing potential across the energy data value chain by leveraging on data and intelligence coming from diverse energy actors (prioritizing on consumers and introducing them as data owners/ providers) and coupled sectors (buildings, mobility) and effectively making them reachable and widely accessible. In turn, it will facilitate the transition from siloed data management approaches to collaborative ones which promote the creation of a data and intelligence ecosystem around energy (and other types of) data and enable the realization of data (intelligence)-driven innovative energy services. The SYNERGIES solution will:

- value the flexibility capacity of consumers in optimizing energy networks' operation, maximizing Renewable Energy Sources (RES) integration and self-consumption at different levels of the system (community, building);
- evidently support network operators in optimally monitoring, operating, maintaining and planning their assets and coordinating between each other (Transmission System Operator (TSO) and Distribution System Operator (DSO) collaboration) for enhancing system resilience;
- create an inclusive pathway towards the energy transition, through consumer empowerment, awareness and informed involvement in flexibility market transactions;
- step on real data streams and intelligence to deliver personalized and automated features to increase prosumer acceptance and facilitate the establishment of sustainable Local Energy Communities (LECs) by enhancing their role with Aggregator and Business Service Provider functions; and
- establish solid grounds for the creation of a new economy around energy data produced and shared across a complex value chain, in a secure, trustful, fair and acceptable manner.

In this context, SYNERGIES aims at re-conceiving data sharing against traditionally bilateral contracting applied in the energy sector and acting as multiplier of the collective data value that can be accrued, shared and traded towards achieving the resilient operation of energy systems through the coordinated optimization of their constituent components (generation, demand, storage) and the orchestrated integration with relevant sectors that can inject significant amounts of flexibility (mobility and EV charging, buildings and heating/cooling systems' control). SYNERGIES will be extensively validated in 3 large-scale demonstration sites in Greece, Spain and Denmark involving complete value chains, diverse data sources, heterogeneous energy systems/assets and spanning different socio-economic characteristics.

1.2 Deliverable Purpose and Structure

The purpose of this deliverable is to serve as a progress reference for SYNERGIES Tasks T3.1 "SYNERGIES Network of Sectorial Data Models", T3.2 "Data Interoperability and Governance Block", T3.3 "Data Security and Sovereignty Block", T3.4 "Trusted Data Sharing Block", T3.5 "Data Value Accrual Block", and T3.6 "Backbone SYNERGIES Data Space Infrastructure and Continuous Integration", until M18. It includes, for each building block, a structured documentation with an

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overview of functionalities, a brief description of the implementation status for identified features, utilized technologies, assumptions and restrictions, and planned features for the final release. Furthermore, it highlights the SYNERGIES platform experience, that is fully documented online in the Help menu by referencing the structure and main menus of the SYNERGIES Reference Energy Data Space visible to all users: Data Check-In, Data Monitoring, My Assets, Marketplace, Contracts, Data Retrieval, and Data Space Management. Additionally, the deliverable details the integration approach during software delivery cycles and presents the adopted support channels. Finally, it presents the SYNERGIES Sectorial Data Models in Annex II.

The structure of this document is organized as follows:

- Section 2 presents the progress in the development of each building block and the planned enhancements and features for the next release.
- Section 3 presents the first release of the SYNERGIES Reference Energy Data Space and provides integration- and deployment-related information.
- Section 4 concludes the deliverable and provides an outlook on the next steps.

1.3 Positioning in SYNERGIES

The SYNERGIES deliverable D3.1 takes as input the SYNERGIES reference architecture described in section 8 of the SYNERGIES Deliverable D2.1 [2], the technical specifications described in section 9 of the SYNERGIES Deliverable D2.1 [2], and the development roadmap of the different services and components that comprise the SYNERGIES Energy Data Space, as documented in the SYNERGIES Internal Deliverable ID3.1 [1].

In essence, the SYNERGIES Energy Data Space is the "meeting point" where different energy stakeholders, as represented by the SYNERGIES demo and technical partners, shall manage and share their data in a reliable, interoperable and trusted manner. The SYNERGIES EDS provides the underlying infrastructure for the data management and sharing activities based on which the SYNERGIES data sharing-driven digital solutions and energy services marketplace will be developed and delivered in WP4. In parallel, all demonstration partners will leverage the SYNERGIES EDS to implement their demo cases in WP5 "Demonstration and Impact Assessment". Following a user-driven approach, the experience that shall be gained by the real-life use of the SYNERGIES EDS by the demo partners (who mostly act as data providers) and the technical partners (who typically act as data consumers) will be documented and fed back to the ongoing development activities of the SYNERGIES EDS, to improve the provided features and the overall user experience and deliver a final version of the EDS that brings tangible added value.

In essence, D3.1 accompanies the initial release of the SYNERGIES Reference Energy Data Space in order to document the progress achieved until M18 in the development, integration and deployment activities of the SYNERGIES Reference Energy Data Space. It is also planned to be used to guide the enhancements to the deployed features, the finalisation of the partially deployed features and the development of the missing features in Release 2, always taking into account the feedback and the priorities expressed by the project's technical partners and demo sites who will actively use the first EDS release from M18 onwards.

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2 SYNERGIES Building Blocks Development

This section documents the development progress of all SYNERGIES Building Blocks in the draft release of the Energy Data Space.

2.1 Data Interoperability & Governance Block

2.1.1 Overview

As described in the SYNERGIES Deliverable D2.1 [2], the Data Interoperability & Governance Block includes: (a) the Data Handling Manager, (b) the Data Certification Service, (c) the Data Check-in Pipeline Execution Service, (d) the Data Observability Service, and (e) the Data Minimisation Service.

The **Data Handling Manager** is a key component of the Data Mesh Coordination Platform in the Cloud that plays an instrumental role in the data ingestion processes of the SYNERGIES Energy Data Spaces in any modality. It offers user-friendly interfaces for configuring, managing and cloning data check-in pipelines. In particular, data providers have the flexibility to choose their preferred data harvesting method among the manual and automated methods supported. Once the data harvesting step is configured, data providers define the necessary staging and pre-processing steps for their data, including: (a) the mandatory Data Mapping Step, (b) the optional Data Curation Step, (c) the optional Data Privacy Preservation Step, (d) the optional Data Encryption Step, (e) the mandatory Data Storage Step.

The **Data Check-in Pipeline Execution Service** is responsible for the execution of the data ingestion process within SYNERGIES, in the appropriate Energy Data Space environment according to the configuration of the data provider. It implements a wide range of options for collecting data (including file-based datasets, APIs, and real-time streaming mechanisms), pre-processing and storing energy data. The component is designed to run in various environments, including centralized cloud, federated cloud, and server or federated edge environments.

The **Data Observability Service** provides real-time monitoring, alerting, and troubleshooting capabilities for data check-in pipelines. The service operates across various storage modalities, including the Centralized Cloud, Federated Cloud or On-Premises Environments (Server, Federated Edge), ensuring comprehensive observability throughout the data handling process. The Data Observability Service identifies incidents related to the data check-in pipelines and ensures the health and high quality of their resulting datasets. The Data Observability stores the appropriate monitoring messages for each active data check-in pipeline as generated by the Data Check-in Pipeline Execution Service and can, in turn, provide on-demand, valuable insights into the overall data quality and reliability of data check-in, offering "heartbeat" information regarding all data check-in pipelines that belong to a user or his/her organisation along with their execution details, as well as all datasets that belong to a user or his/her organisation along with their completeness and timeliness.

The **Data Certification Service** operates in the Data Mesh Coordination Platform, with the purpose of verifying and certifying the authenticity of data assets, in order to increase trust in data providers and sources. Such a service is scheduled to run once at the time a dataset is created, and utilizes automatically assigned metrics, including the predefined mappings derived from the SYNERGIES Data Models and the profile of each organisation. Such metrics together with the automatically calculated quality metrics serve as criteria to determine the trustworthiness of the data asset. The results of the certification process are published in the specific dataset's profile in the Data Marketplace.

The **Data Minimization Service** is a component only available in Edge Environments, which coordinates data collection and processing in the edge. Data minimisation in SYNERGIES serves a dual purpose: (a) to generate data at lower granularity levels, specifically retaining essential information for the intended purpose in the edge, in alignment with the typical definition of data minimisation

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according to GDPR, that is about collecting the minimum amount of (personal) data that are needed to deliver an individual element of a service; (b) to discard or transfer the detailed data to the appropriate Federated Cloud/Server Data Space as defined in the corresponding data check-in pipeline configuration.

2.1.2 Implemented Features

The draft release of the Data Interoperability & Governance Block implements a set of features of its associated components, following the overall development roadmap of the different services and components that comprise the SYNERGIES Energy Data Space, as documented in the SYNERGIES Internal Deliverable ID3.1 [1]. The following table presents the implementation status of the Data Interoperability & Governance Block in its first release on M18 of the SYNERGIES project.

Feature		Status	Notes
DHM_1	Creation of data check-in pipelines from scratch	Implemented	The creation of a pipeline from scratch includes: (a) selection of the data harvesting method, (b) selection of the applicable staging (mapping, curation, privacy preservation and encryption) steps, and (c) selection of the energy data space modality where the data check-in pipeline will be executed.
DHM_2	Configuration of the data harvesting method in a data check-in pipeline	Partially Implemented	Different data harvesting methods are currently supported, including: (a) batch data ingestion (through the browser or through a cloud storage space for large files), (b) on-demand data ingestion (through the data provider's APIs or custom EDS-exposed APIs), (c) streaming data ingestion (through the kafka or MQTT mechanisms that the data provider has in place or that the SYNERGIES cloud coordination platform offers).
DHM_3	Configuration of the staging and pre-processing steps in a data check-in pipeline	Partially Implemented	Support to the configuration of the mapping, curation, privacy preservation and encryption steps of a data check-in pipeline based on state-of-the-art, non-ML-based techniques.
DHM_4	Cloning an existing data check-in pipeline	Implemented	Cloning of an existing data check-in pipeline is possible by on-demand copying the configuration of all steps included in the cloned pipeline, and allowing the users to sequentially update them while getting appropriate notifications for any changes that may be irreversible.
DHM_6	Management of already configured data check-in pipeline	Implemented	The management (e.g., editing of the title/description, update of the harvesting schedule if applicable) of an already configured data check-in pipeline is supported.
DHM_7	Sample run of a data check-in pipeline	Implemented	The execution of a sample run is supported at each step of the configuration of a data check-in pipeline, using the sample (provided by the user or collected during the configuration of the harvester step). The results of the sample run help the data providers to verify that the configuration they have provided in each step brings coherent results, according to their expectations.

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Feature		Status	Notes
DCPES_1	Execution of a Data Check-in Pipeline Configuration	Partially Implemented	A data check-in pipeline can be executed in the centralized cloud or private server/edge data space environments, with the resulting data being stored in the centralized cloud or on-premise. A data check-in pipeline is executed on-demand or according to the schedule set by the data provider; the correct execution of the data check-in pipeline, or possible errors and exceptions, are logged for the information of the data provider and for troubleshooting purposes.
DCPES_2	Batch Data Check-in	Implemented	The batch data (e.g. historical data) can be uploaded as files, through the browser or an online storage location (i.e. in the S3 cloud provided by the SYNERGIES cloud coordination platform). The supported formats include: csv, json, xml, parquet and any other format (handled as other file).
DCPES_3	On-Demand Data Check-in	Partially Implemented	Near real-time data check-in is supported from the data providers' APIs, the APIs exposed by the stakeholder's Energy Data Space in the cloud and from Open Data APIs (also known as Public APIs). It is possible to send only text data (in json and xml formats), but also text and binary data (that may be in any format).
DCPES_4	Streaming Data Check-in	Partially Implemented	Streaming data can be checked-in as long as they are published in different PubSub mechanisms (e.g. Kafka, MQTT) that are either already in place on the stakeholder's side or that can be leveraged from the SYNERGIES centralized cloud platform.
DCPES_5	Data Update	Partially Implemented	Updates of the actual data that have been stored are possible by appending new data. Appending new data is the default mode for all new data that arrive in the on-demand data check-in through APIs and the streaming data check-in. The user can manually trigger the data update in batch data check-in by uploading new files.
DOS_1	Real-time Monitoring of Data Check-in Pipelines	Partially Implemented	Real-time status monitoring of all data check-in pipelines (at the user and the organization level) is available for the data providers. Such monitoring highlights the incidents per data check-in pipeline as well as their reliability and any failures encountered. In addition, the execution history per data check-in pipeline displays the number of total/successful/failed executions, average execution time and information and warning messages.
DOS_2	Real-time Tracking of Data Health	Partially Implemented	Real-time status monitoring of datasets (at the user and the organization level) is available for the data providers. The completeness, quality improvement and timeliness metrics per dataset can be tracked over time in order to monitor the overall data quality.
DOS_3	Alerts for Data Check-in Pipelines	Implemented	Custom alerts can be configured per user for the data check-in pipelines and their corresponding assets in order to define the conditions under which they need to be instantly notified (in the SYNERGIES cloud coordination platform and via email). Such alerts are defined based on the different quality metrics (e.g. failed

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Feature		Status	Notes
			executions of a data check-in pipeline, completeness of the admitted data).
DOS_4	On-demand Execution Updates for Applications	Implemented	Monitoring the execution of a data check-in pipeline for specific data that have been sent through the custom APIs exposed by SYNERGIES, is possible through a corresponding endpoint with "monitor" scope.
DCS_1	Data Provider Verification	Partially Implemented	The verification of the data provider is performed during the registration process of a new organization.
DMS_1	Efficient Edge Data Handling	Partially Implemented	The data collected through the edge data space modality can be handled in the predefined - by the data provider – granularity, without any change to optimize the usage performance.
DMS_2	Secure Data Transfer	Partially Implemented	SYNERGIES supports secure data transfer from the stakeholder's edge energy data space modality to their corresponding centralized ones.

Table 1: Implemented features in the draft release of SYNERGIES Data Interoperability & Governance Block

2.1.3 Technologies & Implementation Tools

As presented in the SYNERGIES Deliverable D2.1, the Data Interoperability & Governance Block leverages a set of underlying technologies developed in the H2020-SYNERGY project: (a) the Data Handling Manager and (b) the Data Check-in Pipeline Execution Service extend the functionalities provided in the H2020-SYNERGY Platform. On the contrary, the Data Observability Service, the Data Certification Service and the Data Minimization Service have been developed from scratch.

As depicted in the following table, the overall Data Interoperability & Governance Block builds on a number of open-source technologies and is developed based on TypeScript, Python and Go as the underlying programming languages. Since the deliverable at hand is a public deliverable, the exact versions are not provided for certain technologies due to security reasons.

Library	Version	License
NodeJS	18	MIT
FastAPI	0.110	MIT
Vue.js	2.7	MIT
TailwindCSS	2	MIT
Pandas	1.4.4	New BSD
NumPy	1.26	BSD
Kafka	-	Apache License 2.0
Zookeeper	-	Apache License 2.0
EMQX	-	Apache License 2.0
Apache Spark	3.3.4	Apache License 2.0
PostgreSQL	-	PostgreSQL License (similar to BSD/MIT)
Redis	-	3-clause BSD License
MinIO	-	Apache License 2.0

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Library	Version	License
MongoDB	-	Apache License 2.0

Table 2: Technology Stack used in the development of SYNERGIES Data Interoperability & Governance Block

2.1.4 Assumptions & Restrictions

In the first release of the Data Interoperability & Governance Block, the following assumptions have been made, which in turn may pose restrictions in the capabilities offered by the SYNERGIES Energy Data Space:

- All data ingestion modalities are offered in the SYNEGIES Data Mesh Coordination Platform in the Cloud. When it comes to the Private Server and Edge data space environments, only selected data ingestion methods are supported at the moment. For example, only files upload is currently supported in the Private Server data space modality since core features that are provided by the Private Server data space modality, such as the end-to-end encryption and the on-premise storage, are mostly critical for batch data.
- The data observability functionalities at the data check-in pipeline and at the dataset levels are fully available for batch data check-in and on-demand data check-in (through APIs) while they are only partially available for large files data check-in (that has triggered the execution of the data check-in pipeline in spark) and for streaming data check-in.
- As the issuing of alerts on-time requires resource-intensive operations to run under the hood in each stakeholder's energy data space, there is currently a limit of 10 alerts that can be configured per user.

2.1.5 Planned Features for the Next Release

In continuation of the development activities during the second half of the SYNERGIES project, the first release of the Data Interoperability & Governance Block will be enhanced by the following features, which will be implemented, or enriched, in the final release planned for M36, as shown in the following table.

Feature	Notes
DHM_2 "Configuration of the data harvesting method in a data check-in pipeline"	The supported data harvesting methods shall be complemented by direct connectors and any other method requested after the draft release has been extensively used by the SYNERGIES demo partners.
DHM_3 "Configuration of the staging and pre-processing steps in a data check-in pipeline"	The manual configuration of the staging steps in the data check-in pipeline will be enriched with the help of more sophisticated techniques (e.g. ML-based) in the final release, especially for the mapping and curation steps.
DHM_5 "Creation of data check-in pipelines based on templates"	Due to their complexity, the creation of data check-in pipelines based on reusable templates will be directly deployed in the final release. The patterns of data check-in pipelines that are followed by the different data providers while using the initial release of the SYNERGIES EDS will be leveraged in the design of such templates.
DCPES_1 "Execution of a Data Check-in Pipeline Configuration"	In addition to performance improvements for the data check-in pipeline execution, updates and further work shall be performed to ensure the full support in the federated cloud data space environments.

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Feature	Notes
DCPES_3 "On-Demand Data Check-in"	Support for open-standards based connectors, as well as the APIs exposed by the stakeholder's Energy Data Space "on-premise" shall be added in the final release.
DCPES_4 "Streaming Data Check-in"	Updates and optimizations to handle the data velocity and scalability aspects are expected to be implemented as necessary, in the final release.
DCPES_5 "Data Update"	The option of replacing the existing data (e.g., while marking old data as obsolete) shall be added in the final release.
DOS_1 "Real-time Monitoring of Data Check-in Pipelines"	Updates and optimizations to complement the data check-in observability aspects and handle the large files and streaming data check-in pipelines shall be added in the final release.
DOS_2 "Real-time Tracking of Data Health"	Updates and optimizations to complement the diverse data observability aspects at dataset level shall be added in the final release.
DCS_1 "Data Provider Verification"	The verification of the data provider by the SYNERGIES admin shall be complemented by the categories of data assets that the specific organization is typically certified to upload in accordance with the network of sectorial data models.
DCS_2 "Data Asset Certification"	Due to the - currently limited - practical approaches on data certification, the specific feature will be further investigated and directly deployed in the final release.
DMS_1 "Efficient Edge Data Handling"	Extended edge data handling support to change the temporal granularity of the timeseries data by downsampling or upsampling prior to storing them at the edge or in the private cloud shall be added in the final release.
DMS_2 "Secure Data Transfer"	Implement peer-to-peer transfer among the different federated data spaces (e.g. from an edge environment to a private cloud data space modality of a stakeholder) shall be added in the final release.

Table 3: Planned features in the Final Release of the SYNERGIES Data Interoperability & Governance Block

2.2 Data Security & Sovereignty Block

2.2.1 Overview

As described in deliverable D2.1 [2], the Data Security & Sovereignty Block includes: (a) the Privacy Preservation Service, (b) the Encryption Engine, (c) the KeyTray, (d) the Access Policy Engine, and (e) the Security, Authentication & Authorisation Engine.

The **Privacy Preservation Service** helps the data providers to prevent unintended disclosure of sensitive information, data breaches, or data exposure. At design time, the Privacy Preservation Service is an optional step of the data check-in pipeline configuration, conceptually placed after the Data Curation step and before the Data Encryption step. The data provider defines the privacy preservation actions that should be performed on the checked-in data, for example which fields should be anonymized, which techniques to be used and how much information loss is tolerated, in an effort to balance between privacy preservation and data usability. In order to help the data provider, the Privacy Preservation Service may run on-demand and inform the user about potentially sensitive information within the datasets (in individual fields or in combinations of fields) prior to taking any action. At run time, the Privacy Preservation Service enforces the privacy preservation mechanisms defined at design time.

The **Encryption Engine** helps the data providers to fortify the transmission of data from the data provider to the authorized data consumer(s) or between different modalities of the stakeholder's

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Energy Data Spaces. As a result of the Encryption Engine's operation, the defined encryption rules are enforced at run-time for the data when they are transferred between various federated data spaces or from a federated data space to a centralized data space owned by the same stakeholder, or other stakeholders with authorized access. At data check-in design time, the data provider defines whether encryption should be applied on a given dataset transfer. At data check-in run time, the Encryption Engine applies encryption whenever appropriate. At data retrieval/usage time, the Encryption Engine is triggered on-demand based on the active contract's terms in order to ensure data encryption on transit. Furthermore, the Encryption Engine implements data decryption at the receiving end.

The **KeyTray** is responsible to secure, store, and tightly control access to: (a) private keys, tokens and API keys, that concern a specific Energy Data Space instance, and the configured data check-in pipelines, and (b) the wallet concerning the blockchain account of the organization's manager and the interaction with the blockchain in the DLT Smart Contract Management Engine. The KeyTray also oversees the secure exchange of decryption keys between the federated environments of different stakeholders who have an active data sharing contract.

The **Access Policy Engine** is responsible for regulating and controlling access to datasets in the SYNERGIES Data Marketplace and across the SYNERGIES Energy Data Spaces, through fine-grained access control policies. When a dataset is ingested in the designated SYNERGIES Energy Data Space, the Access Policy Engine allows the corresponding data provider to define flexible and fine-grained access rules (e.g., which stakeholders can be allowed or must be denied from viewing details of specific data assets and any applicable exceptions). At run time, the Access Policy Engine is triggered whenever appropriate as dictated by the data asset licenses and the access requests recorded in the Data Marketplace, to enforce at run-time the applicable access policies across all operations.

The **Security, Authentication & Authorisation Engine** is responsible for all security operations, related to identity and access management, across the Energy Data Space and the Energy Services Marketplace. In essence, the Security, Authentication & Authorisation Engine handles the holistic user/organization account management lifecycle, providing the single core identity provider of the SYNERGIES solutions by undertaking the operations related to the registration, verification and authentication of all the users across all SYNERGIES services/components and allowing the single sign-on functionalities in the Energy Data Spaces, the Energy Services Marketplace, the Analytics AI On-Demand Platform, the Digital Twins, and the Energy Apps. In addition, the Security, Authentication & Authorisation Engine manages the authorized and secure communication between the various components.

2.2.2 Implemented Features

The draft release of the Data Security & Sovereignty Block implements a set of features of its associated components, following the development roadmap of the different services and components that comprise the SYNERGIES Energy Data Space, as documented in the SYNERGIES Internal Deliverable ID3.1 [1]. The following table presents the implementation status of the Data Security & Sovereignty Block in its first release on M18 of the SYNERGIES project.

Feature		Status	Notes
PPS_1	Configuration of privacy preservation techniques	Partially Implemented	The configuration of the k-anonymity technique for privacy preservation on the collected batch datasets is supported.
PPS_2	Verification of privacy preservation techniques	Implemented	Verification of the applicable privacy preservation technique during data check-in pipeline design time over a sample dataset (that has been provided by the user in the harvester step configuration). Although the execution of the same configuration for the full

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Feature		Status	Notes
			dataset may yield different results, it is important for the user to check if/how the original data shall be irrevocably altered.
PPS_3	Execution of privacy preservation techniques	Partially Implemented	The execution of the implemented privacy preservation technique is possible for specific data ingestion methods (i.e. batch data check-in) and data space modalities (e.g. centralized cloud data space) in a data check-in pipeline.
EE_1	Encryption and decryption of in-transit datasets at data check-in	Partially Implemented	The encryption of datasets at data check-in is supported only through the Private Server data space modality in order to ensure that the data are transferred to the organization's Centralized Cloud data space modality in an end-to-end secure manner. For the data, symmetric encryption is applied over the whole dataset while for the exchange of the keys, asymmetric encryption is applied.
KT_1	Storage and controlled access to private keys	Partially Implemented	A dedicated KeyTray in the centralized cloud data spaces, handles the encrypted, isolated storage and controlled access to all sensitive information per organization and user, including access tokens and credentials (username, password) for sending data through a streaming data check-in pipeline, as well as the blockchain wallet assigned to the organization's legal representative.
KT_2	Revocation of private keys	Partially Implemented	The revocation of private keys is possible for the KeyTray in the centralized cloud data spaces. The cases that are currently supported are: (a) expiration of an active contract that results into revoking access to an acquired dataset (e.g. in retrieval queries), (b) deletion of a dataset within the data provider's organization (in case it has not been shared with other stakeholders through the SYNERGIES Marketplace).
APE_1	Intuitive configuration of access policies on data assets and derivative data assets	Partially Implemented	The definition of the appropriate access level spans 3 layers: organization-based, selective sharing and public. In the case of selective sharing, it is complemented by the definition of a single or multiple access policies, through combinations of different attributes, on datasets. The applicable attributes indicatively refer to the organization's country and the organization's type.
APE_2	Management of licenses of data assets and derivative data assets	Partially Implemented	The attribution of a certain license, and the specification of any applicable Intellectual Property Rights is available on each uploaded dataset, as per the preferences set by the data provider. Such IPR refer not only to the copyright owner, but also to the expected usage and the allowances for offline retention of a dataset.
APE_3	Run-time View-Access Control	Partially implemented	The applicable access policies are enforced at run-time both when navigating the SYNERGIES Marketplace and when utilizing an acquired dataset (e.g. during the configuration of retrieval queries).

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Feature		Status	Notes
SAAE_1	Single Sign-on across the SYNERGIES Services/ Components/ Environments	Partially Implemented	Single sign-on in the SYNERGIES Energy Data Space ecosystem is supported on an organization basis, across the different roles that are anticipated (i.e. organization's manager, organization's members, organization's legal representative). Preparatory steps for the extension of the single sign-on functionality to all solutions/services of the SYNERGIES Energy Services Marketplace have been also taken.
SAAE_2	Authorization Control across the SYNERGIES Services/ Components/ Environments	Partially Implemented	Full authorization control on the services/components deployed with the draft release in the centralized cloud and in the private server/edge environments.

Table 4: Implemented features in the draft release of SYNERGIES Data Security & Sovereignty Block

2.2.3 Technologies & Implementation Tools

As presented in the SYNERGIES Deliverable D2.1, the Data Security & Sovereignty Block leverages a set of underlying technologies developed in the H2020-SYNERGY project: (a) the Privacy Preservation Service, (b) the Encryption Engine, (c) the KeyTray and (d) the Security, Authentication & Authorization Engine extend the functionalities provided in the H2020-SYNERGY Platform. On the contrary, the Access Policy Engine is developed from scratch.

As depicted in the following table, the overall Data Security & Sovereignty Block builds on a number of open-source technologies and is developed based on TypeScript and Python as the underlying programming languages. Since the deliverable at hand is a public deliverable, the exact versions are not provided for certain technologies due to security reasons.

Library	Version	License
NodeJS	18	MIT
Flask	-	MIT
Vue.js	2.7	MIT
TailwindCSS	2	MIT
Keycloak	-	LGPL-3.0
Pandas	1.4.4	New BSD
NumPy	1.26	BSD
Kafka	-	Apache License 2.0
Zookeeper	-	Apache License 2.0
Apache Spark	3.3.4	Apache License 2.0
PostgreSQL	-	PostgreSQL License (similar to BSD/MIT)
Redis	-	3-clause BSD License
MinIO	-	Apache License 2.0
MongoDB	-	Apache License 2.0
Vault	-	Mozilla Public License 2.0
SpiceDB	-	Apache License 2.0

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Table 5: Technology Stack used in the development of SYNERGIES Data Security & Sovereignty Block

2.2.4 Assumptions & Restrictions

In the first release of the Data Security & Sovereignty Block, the following assumptions have been made, which in turn may pose restrictions in the capabilities offered by the SYNERGIES Energy Data Space:

- When configuring the access policies of a data asset, each attribute (e.g. organization type, organization country) can be used once. By default, the evaluation of the different attributes occurs with an "AND" operator while the values per attribute are evaluated with an "OR" operator.
- In the data check-in configuration, the encryption step is enabled only if the pipeline is to be executed in a federated data space environment (in particular, in a private server).
- The application of privacy preservation techniques is allowed only for only selected data ingestion methods, i.e. for batch data upload, due to the nature of the processing performed that requires all data to be available.
- The application of privacy preservation techniques in Spark is currently encountered with significant performance overhead that needs to be improved in the final release.
- The manager of an organization can promote other users to managers, demote another manager, and deactivate users that have left an organization or do not work anymore in SYNERGIES, in addition to inviting new members. For security reasons, though, the manager of an organization cannot appoint the legal manager that is handled centrally and exclusively by the SYNERGIES (cloud coordination platform) admin.

2.2.5 Planned Features for the Next Release

In continuation of the development activities during the second half of the SYNERGIES project, the first release of the Data Security & Sovereignty Block will be enhanced by the following features, which will be implemented, or enriched, in the final release planned for M36, as shown in the following table.

Feature	Notes
PPS_1 "Configuration of privacy preservation techniques"	Configuration of additional techniques (e.g. l-diversity, t-closeness) for privacy preservation on the collected batch datasets at the data check-in time, in the final release.
PPS_3 "Execution of privacy preservation techniques"	Execution of any additional privacy preservation techniques for batch data in the different data space modalities in the final release.
EE_1 "Encryption and decryption of in-transit datasets at data check-in"	Improvements in encryption to be provided once the demo data start becoming available, mainly orientated towards improving the performance of the encryption/decryption process.
EE_2 "Encryption and decryption of in-transit, acquired datasets"	The encryption and decryption of acquired datasets is directly planned for the final release, once federated data sharing shall be implemented.
KT_1 "Storage and controlled access to private keys"	Updates to support the private keys and blockchain wallet management in fully federated data spaces in the final release.
KT_2 "Revocation of private keys"	Updates to support revocation of private keys when an (own/acquired) dataset is used in federated data spaces in the final release.

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Feature	Notes
APE_1 "Intuitive configuration of access policies on data assets and derivative data assets"	Extend the support for the 3-layer access levels and the configuration of a single or multiple access policies to derivative data assets (i.e. results) in the final release.
APE_2 "Management of licenses of data assets and derivative data assets"	Extend the support for the license and IPR management to derivative data assets (i.e. results) in the final release.
APE_3 "Run-time View-Access Control"	Extend the enforcement of access policies in the SYNERGIES Marketplace to derivative assets in the final release.
SAAE_1 "Single Sign-on across the SYNERGIES Services/ Components/ Environments"	Full support for single sign-in across all SYNERGIES services.
SAAE_2 "Authorization Control across the SYNERGIES Services/ Components/ Environments"	Extend authorization control to the additional functionalities and services/components deployed with the final release.

Table 6: Planned features in the Final Release of the SYNERGIES Data Security & Sovereignty Block

2.3 Trusted Data Sharing Block

2.3.1 Overview

As described in deliverable D2.1 [2], the Trusted Data Sharing Block includes: (a) the Data Marketplace, (b) the DLT Smart Contract Management Engine, (c) the Contract Settlement Engine, and (d) the Data Sharing Service.

The **Data Marketplace** acts as the one-stop shop for cross-sector energy-related data assets (datasets, results) sharing. It implements a centralised "catalogue" and data exploration services which allow energy data value chain stakeholders to navigate through available data assets of interest (e.g., open data or, more commonly, proprietary data from other stakeholders), irrespectively of the Energy Data Space they are stored, in a time- and effort-wise efficient manner. The data assets themselves could be available in different SYNERGIES Energy Data Spaces across cloud and federated environments, though this is transparent to the interested stakeholder, since the data exploration services will enable navigation to the public profile of the data assets only (i.e. at metadata level). As a consequence of using the Data Marketplace, the interested stakeholder obtains deeper understanding of the data assets' contents and features (e.g., assessing their potential, their origin, their volume, etc.). Furthermore, the Data Marketplace provides the stakeholder with intelligent recommendations for relevant data assets (that may be potentially of interest). Finally, through the Data Marketplace, the stakeholder is offered with means to contact the data providers and discuss/negotiate on the prospective transaction (quotation, terms of use, quality assurances, etc.).

The **DLT Smart Contract Management Engine** is based on distributed ledger technologies and is used to create and manage structured, machine-processable data sharing contracts, which automate to the extent possible the data sharing agreements between stakeholders. The DLT Smart Contract Management Engine allows the interested stakeholders to draft, negotiate, approve/reject, extend, revise the terms, and ultimately enforce smart contracts which apply across cloud and federated data spaces. Furthermore, the DLT Smart Contract Management Engine supports the upload and reuse of data contract templates which ensure the legitimacy of such smart contracts, as those templates can be prepared or reviewed by the legal department of an organization.

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The **Contract Settlement Engine** is responsible for handling the payment of the monetary cost or the fulfilment of the counter price (e.g. other dataset) in order to activate a smart contract that has been already duly signed by the legal representatives of the involved parties. To this end, the Contract Settlement Engine on the one hand manages agreements based on data bartering, i.e., an agreement between two parties to exchange data assets at specific granularity levels and time frames based on a predefined agreement, instead of a monetary transaction. On the other hand, there are smart contracts which foresee a traditional monetary compensation; the Contract Settlement Engine supports crypto-payments and verifies the money exchange between the related data asset providers and the data consumer in payment of a data asset contract. In the case that a result is involved, the Contract Settlement Engine also manages the remuneration of all involved data providers, who may have provided the original data out of which the specific derivative data asset was produced.

The **Data Sharing Service** implements the necessary mechanisms for the efficient transfer of acquired data assets (datasets, results) between stakeholders, according to their preferences and terms dictated in an active data contract. The Data Sharing Service can accommodate on the one hand centralized data sharing, between stakeholders who have uploaded their data assets to the SYNERGIES cloud environment; on the other hand, federated data sharing between stakeholders who have decided to keep their data assets at their premises. The functionality of the Data Sharing Service itself is offered seamlessly to the users, be it at a centralized level in the cloud or as federated data sharing. The nature of the shared data assets which are supported by the Data Sharing Service include raw data, appropriate subsets of data, and computations on data (results), or any combination of the above.

2.3.2 Implemented Features

The draft release of the Trusted Data Sharing Block implements a set of features of its associated components, following the development roadmap of the different services and components that comprise the SYNERGIES Energy Data Space, as documented in the SYNERGIES Internal Deliverable ID3.1 [1]. The following table presents the implementation status of the Trusted Data Sharing Block in its first release on M18 of the SYNERGIES project.

Feature		Status	Notes
DM_1	Navigate to data assets (datasets) and derivative data assets (results) across cloud and federated data spaces	Partially Implemented	A centralized catalogue of all datasets residing in the cloud and federated energy data spaces is available. The user can view the basic information of each available dataset that his/her organization is eligible to view, and then select one particular dataset and view more detailed information for the specific asset. The user can search through the available datasets directly from the marketplace landing page or apply selected filters/facets and sort the results according to his/her preferences.
DM_2	Management of access, licensing terms and pricing of data assets and derivative data assets	Partially Implemented	Any user can view only the available datasets of the SYNERGIES Marketplace that his/her organization is eligible to view and acquire once all access policies are resolved. Particular attention has been laid on the performance during the runtime access policies' evaluation. The users are also informed about the licensing terms and the pricing details of each dataset they may view; such default terms may be negotiated further during the contract preparation phase.

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Feature		Status	Notes
DM_3	Get recommendations on data assets and derivative data assets	Partially Implemented	In general, (content-based) recommendations for additional, relevant datasets of interest for a data consumer, based on certain attributes (e.g., asset name, asset provider name) are provided per dataset.
DM_4	Managing a wish list with data assets of interest	Implemented	Each user can manage his/her own wish list, where they can add datasets and at any moment, view their favourite datasets (that are already in the wish list) and delete any dataset that is not relevant anymore. Once a dataset has been acquired by an organization, it is removed by the wish list of its members.
DM_5	Initiate negotiation process for data assets and derivative data assets	Partially Implemented	In general, any organization member can request to acquire a specific asset. Such a request will trigger the contract negotiation process that is performed only between the legal representatives of the involved organizations (either as data asset consumer or as data asset providers) in order to reach an agreement on the exact sharing terms.
DLTE_1	Lifecycle management of data sharing contracts	Partially Implemented	Effectively handling data sharing contracts involves all phases of their lifecycle including their creation, negotiation, management and enforcement in a fully traceable manner, leveraging the SYNERGIES blockchain implementation based on the proof-of-authority protocol. The organisations' legal representatives need to collectively define and agree on the exact sharing terms, the applicable license details, and the related reimbursement method. Data sharing contracts span over monetary / fiscal reimbursement and exchange of the requested data asset with another data asset of interest that belongs to the data consumer and to which the data provider wants access to view and use (bartering option).
DLTE_2	Revision of active data sharing contracts	Partially Implemented	Any active contract can be revised in terms of (a) updating the applicable terms and (b) extending its duration. The request for an extension may be initiated by the data asset consumer only and needs to be approved by the data asset provider. Any change is fully traceable.
DLTE_3	Support during the preparation of a data sharing contract	Implemented	Management of templates for data sharing contracts that encapsulate an organization's prerequisite legal terms is fully supported. The organisation's legal representative can add a new contract template, as well as reuse, edit or delete a previously saved contract template in the "Contract Templates" tab under the Organization page.
CSE_1	Settle data bartering agreements	Partially Implemented	The settlement of any contract for which the reimbursement involves data bartering is supported by allowing concurrent access to the initial and bartered data assets to the involved organizations in their centralized data spaces.

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Feature		Status	Notes
CSE_2	Settle monetary transactions of data sharing agreements	Partially Implemented	Any contract for which a monetary reimbursement has been agreed is automatically settled in the case of online payment through cryptocurrency in SYNERGIES or manually confirmed in the case of bank transfer.
CSE_3	Monitor any active contract to ensure compliance with the agreed terms	Partially Implemented	Constant monitoring of active smart contracts is supported to ensure compliance with the agreed terms by all involved parties. Compliance with the agreed terms involves both the data provider (in terms of providing up-to-date data with the agreed update rate) and the data consumer (in terms of using the dataset as dictated in the contract terms).
DSS_1	Transferring of acquired data that reside centrally to the data consumer's energy data space based on the contract terms	Partially Implemented	Secure transferring of acquired data assets is possible only between the centralized cloud data spaces of the data provider and the data consumer.

Table 7: Implemented features in the draft release of SYNERGIES Trusted Data Sharing Block

2.3.3 Technologies & Implementation Tools

As presented in the SYNERGIES Deliverable D2.1, the Trusted Data Sharing Block leverages a set of underlying technologies developed in the H2020-SYNERGY project: (a) the Data Marketplace, (b) the DLT Smart Contract Management Engine, (c) the Contract Settlement Engine and (d) the Centralized Data Sharing Service extend the functionalities provided in the H2020-SYNERGY Platform. On the contrary, the Federated Data Sharing Service shall be developed from scratch.

As depicted in the following table, the overall Trusted Data Sharing Block builds on a number of open-source technologies and is developed based on TypeScript and Solidity as the underlying programming languages. Since the deliverable at hand is a public deliverable, the exact versions are not provided for certain technologies due to security reasons.

Library	Version	License
NodeJS	18	MIT
Vue.js	2.7	MIT
TailwindCSS	2	MIT
Ethereum	-	LGPL-3.0
OpenZeppelin Contracts	-	MIT
Kafka	-	Apache License 2.0
PostgreSQL	-	PostgreSQL License (similar to BSD/MIT)
Redis	-	3-clause BSD License
MinIO	-	Apache License 2.0
MongoDB	-	Apache License 2.0
Vault	-	Mozilla Public License 2.0

Table 8: Technology Stack used in the development of SYNERGIES Trusted Data Sharing Block

2.3.4 Assumptions & Restrictions

In the first release of the Trusted Data Sharing Block, the following assumptions have been made, which in turn may pose restrictions in the capabilities offered by the SYNERGIES Energy Data Space:

- Sharing of datasets that are stored on-premise in the federated private server or edge environments cannot be shared with other stakeholders through the SYNERGIES Data Marketplace at the moment. Once federated data sharing is supported (in the final release), this restriction will be lifted.
- Due to its efficient use of resources and its fast transactions and considering that blockchain nodes are expected to be installed in the federated environments, the blockchain consensus mechanism that was adopted is Proof-of-Authority (PoA).
- Acquisition of multiple data assets through the cart functionality has a limit of 5 data assets. The reimbursement of such contracts is possible only through a crypto-currency payment.

2.3.5 Planned Features for the Next Release

In continuation of the development activities during the second half of the SYNERGIES project, the first release of the Trusted Data Sharing Block will be enhanced by the following features, which will be implemented, or enriched, in the final release planned for M36, as shown in the following table.

Feature	Notes
DM_1 "Navigate to data assets (datasets) and derivative data assets (results) across cloud and federated data spaces"	The Data Marketplace shall be extended to support navigation to derivative data assets (i.e. results), but also to data assets that are available only in federated data spaces, in the final release.
DM_2 "Management of access, licensing terms and pricing of data assets and derivative data assets"	The support for licensing and access control to data assets shall be extended to derivative data assets (i.e. results) as well in the final release. Any additional licensing or reimbursement terms that may be proposed by the demo partners shall be also considered.
DM_3 "Get recommendations on data assets and derivative data assets"	Based on the end user feedback, the recommendations algorithm shall be updated (either towards a more sophisticated content-based approach or a hybrid "collaborative filtering and content-based" approach) and embrace derivative data assets (i.e. results) in the final release.
DM_5 "Initiate negotiation process for data assets and derivative data assets"	It will be possible to enter a negotiation process for sharing a derivative data asset (e.g. result) in 2 phases: (a) to make it available to the marketplace once the consent of its original data provider is granted and the re-sharing terms are agreed, (b) to actually "sell"/share a derivative data asset to a data consumer.
DLTE_1 "Lifecycle management of data sharing contracts"	The underlying lifecycle management functionalities will be extended to derivative assets (to ensure the consent of the original data providers and to allow their sharing in the SYNERGIES Marketplace) in the final release.
DLTE_2 "Revision of active data sharing contracts"	The functionality to trigger the cancellation of a data sharing contract once breaches are observed is planned to be added in the final release.
CSE_1 "Settle data bartering agreements"	Since the federated sharing aspects are planned for the final release, the settlement of a contract through bartering shall be also complemented accordingly.
CSE_2 "Settle monetary transactions of data sharing agreements"	Since the federated sharing aspects are planned for the final release, the settlement of a monetary contract shall be also complemented

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Feature	Notes
	accordingly. In addition, in the case of derivative assets, a reimbursement mechanism to all involved data providers shall be delivered.
CSE_3 "Monitor any active contract to ensure compliance with the agreed terms"	The contract terms shall be extended to additional data quality aspects that shall be monitored. In addition, custom alerts for contracts shall be sent via email and in the cloud coordination platform in the final release.
DSS_1 "Transferring of acquired data that reside centrally to the data consumer's energy data space based on the contract terms"	The underlying secure transferring of data assets between centralized cloud data spaces, shall be extended to accommodate the transfer of data assets from a centralized cloud data space of the data provider to a federated (private cloud/server) data space of a data consumer in the final release. In addition, the transferring of acquired data assets will embrace derivative assets as well.
DSS_2 "Transferring of acquired data in a peer-to-peer manner to the data consumer's energy data space based on the contract terms"	In the final release, the federated data sharing mechanisms that allow the direct, peer-to-peer exchange of data between the federated data spaces of the data provider and the data consumer shall be delivered.
DSS_3 "Access to the acquired data in the data provider's energy data space based on the contract terms"	In cases when the contract terms do not allow an acquired data to leave the federated energy data space of its data provider, the underlying mechanisms to ensure that controlled view-access (e.g. to run an analysis) in the data provider's energy data space will be provided in the final release.

Table 9: Planned features in the Final Release of the SYNERGIES Trusted Data Sharing Block

2.4 Data Value Accrual Block

2.4.1 Overview

As described in deliverable D2.1 [2], the Data Value Accrual Block includes: (a) the Secure Data Serving Service, and (b) the Interactive Data Exploration Service.

The **Secure Data Serving Service** serves data in 2 fundamental ways: (a) by generating custom API endpoints automatically, enabling users to self-serve the data through programmatically accessible interfaces, according to their preferences for data retrieval and provisioning, tailoring the output to meet their specific requirements; (b) by downloading (once or based on a schedule) the selected slice for "sensitive" data according to their preferences and the license/contract terms (in case of an acquired dataset, for example) as an encrypted file. In general, a data slice can be an extract of a dataset (that is the outcome of a data check-in pipeline) or a result (that is considered as a derivative data extract generated by a data analytics pipeline). It allows users to retrieve the data during runtime, performing basic functions on-demand such as selection, filtering and ordering, to retrieve only the data they need for their applications.

The **Interactive Data Exploration Service** provides interactive and user-friendly visualizations that facilitate a deeper exploration of the selected data assets, aiding in the identification of valuable candidates for acquisition or further analysis. By utilizing this service, users can actively engage with the data, applying filters and focusing on specific subsets of interest for the fields that the data provider has allowed. They have access to a variety of visualization options, which effectively portray detailed data relationships and trends. These visual representations are crucial for recognizing patterns, correlations, and anomalies, empowering users to extract valuable insights and make well-informed decisions. Moreover, the Interactive Data Exploration Service supports interactive searching

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and exploration within the data, enabling users to dynamically investigate different aspects of the dataset.

2.4.2 Implemented Features

The draft release of the Data Value Accrual Block implements a set of features of its associated components, following the development roadmap of the different services and components that comprise the SYNERGIES Energy Data Space, as documented in the SYNERGIES Internal Deliverable ID3.1 [1]. The following table presents the implementation status of the Data Value Accrual Block in its first release on M18 of the SYNERGIES project.

Feature		Status	Notes
SDSS_1	API-based Data Retrieval	Partially Implemented	The configuration of API-based data retrieval queries for datasets that reside in the cloud, centralized data spaces is possible both for the datasets that an organization owns and for the datasets that an organization has acquired. The user can view the list of retrieval queries that he/she has configured and perform actions (view, edit, delete) over each retrieval query. The user can also search for specific retrieval queries and filter or sort the results. Access policies are enforced on retrieval queries: any moment access to an asset is revoked, the related retrieval queries are deleted while if a contract has expired, its related retrieval queries also become inactive.
SDSS_2	File-based Data Retrieval	Partially Implemented	The configuration of a file-based retrieval query is currently in progress. Any "sensitive" data that resides in the centralized cloud data space shall be downloaded as encrypted files.

Table 10: Implemented features in the draft release of SYNERGIES Data Value Accrual Block

2.4.3 Technologies & Implementation Tools

As presented in the SYNERGIES Deliverable D2.1, the Data Value Accrual Block leverages the underlying technologies developed in the H2020-SYNERGY project, i.e. the Secure Data Serving Service extends the functionalities provided in the H2020-SYNERGY Platform. On the contrary, the Interactive Data Exploration Service shall be developed from scratch.

As depicted in the following table, the overall Data Value Accrual Block builds on a number of open-source technologies and is developed based on TypeScript as the underlying programming language. Since the deliverable at hand is a public deliverable, the exact versions are not provided for certain technologies due to security reasons.

Library	Version	License
NodeJS	18	MIT
Vue.js	2.7	MIT
TailwindCSS	2	MIT
PostgreSQL	-	PostgreSQL License (similar to BSD/MIT)
Redis	-	3-clause BSD License
MinIO	-	Apache License 2.0
MongoDB	-	Apache License 2.0

Library	Version	License
Vault	-	Mozilla Public License 2.0

Table 11: Technology Stack used in the development of SYNERGIES Data Value Accrual Block

2.4.4 Assumptions & Restrictions

In the first release of the Data Value Accrual Block, the following assumptions have been made, which in turn may pose restrictions in the capabilities offered by the SYNERGIES Energy Data Space:

- The retrieval queries are configured per user and are not shared at the organization level for security reasons, i.e. due to the access tokens (with "retrieve" scope) that are stored in an encrypted form per user.
- The retrieval queries refer only to datasets that are stored in the centralized cloud data space environments at the moment.
- The retrieval API-based data retrieval offers both pagination and sorting options. In case the expected results are significant, it is recommended to use the lastRecordId as a parameter, to paginate data instead of using page as a parameter, for performance reasons especially when multiple datasets are selected to be returned in a single retrieval query.
- The file-based data retrieval requires the presence of the private server data space environment on the side of the data consumer since the encrypted file is downloaded and can be only decrypted with the use of the services of the declared environment.

2.4.5 Planned Features for the Next Release

In continuation of the development activities during the second half of the SYNERGIES project, the first release of the Data Value Accrual Block will be enhanced by the following features, which will be implemented, or enriched, in the final release planned for M36, as shown in the following table.

Feature	Notes
SDSS_1 "API-based Data Retrieval"	The configuration and execution of API-based data retrieval queries shall be extended to support the retrieval of results from centralized cloud data spaces, but also to support the retrieval of both datasets and results directly from the federated data spaces of the data provider.
SDSS_2 "File-based Data Retrieval"	The functionality for retrieving data (and eventually results) as encrypted files will be integrated for the centralized cloud data spaces and extended to federated data spaces of the data provider in the final release.
IDES_1 "Visual Exploration of Data"	The functionality related to the visual exploration of data has been directly planned for the final release.
IDES_2 "Data in-depth Search"	Advanced search within the values of a dataset or a result has been directly planned for the final release.

Table 12: Planned features in the Final Release of the SYNERGIES Data Value Accrual Block

2.5 Data Space Management Services
2.5.1 Overview

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As described in deliverable D2.1 [2], the Data Space Management Services include: (a) the CIM Network Manager, (b) the Data Spaces Environments Manager, (c) the Master Controller, (d) the Orchestration Engine, and (e) the Runner.

The **CIM Network Manager** is a component in the Data Mesh Coordination Platform that oversees the smooth operation of the network of cross-sectorial Common Information Models (CIM) as defined in SYNERGIES project. At first, the CIM Network Manager is responsible for effectively maintaining and managing the lifecycle of the different (cross-sectorial) data models, starting from the detailed specification of the relevant concepts, handling the different updates on the concepts while further managing concepts' deprecation as the project evolves. The component includes an appropriate evolution mechanism to ensure backwards compatibility to the extent possible and to migrate all changes to the CIM in all services and components that use it, enhancing that way the integrity and robustness of the data models within the project as it evolves over time.

The **Data Spaces Environments Manager** allows data providers to register, configure and manage their dedicated Energy Data Spaces according to their preferences. The component foresees different federated Data Fabric Environments (e.g., multiple edge environments in each gateway, server environments and/or private cloud) or centralized Data Fabric Environments which can be linked to and managed by each stakeholder (with any potential limits applied at the organization level). In addition, the Data Spaces Environments Manager gathers and displays the necessary information to monitor, manage, and assess the performance of the different Data Fabric Environments.

The **Master Controller** is a component that resides centrally on the SYNERGIES Data Mesh Coordination Platform and is responsible for orchestrating the different services that are executed in the SYNERGIES Data Space centrally or in a federated manner. The Master Controller functions as a scheduler, automating the execution of the various services associated with data check-in and analytics processes according to the predetermined schedules set by the data provider or data consumer. Additionally, it undertakes the scheduling of any platform operations that need to run under the hood, e.g. running cronjobs in specific timeslots that the platform use is low, applying the backup policy. Finally, the Master Controller is responsible for provisioning the necessary resources (in terms of memory, compute and storage capacity) and providing them with the exact information that is needed to perform their tasks through a real-time messaging mechanism.

The **Orchestration Engine** acts as a federated, equivalent version of the Master Controller, responsible for the orchestration of services in the SYNERGIES Private Cloud/Server Data Fabric, allocating the necessary resources for the seamless operation of the federated Energy Data Spaces. More specifically, the Orchestration Engine aims at ensuring the optimal allocation and use of the overall resources available in SYNERGIES Private Cloud/Server Data Fabric while flexibly sharing them based on dynamic configurations in order for all federated services to run seamlessly and efficiently.

The **Runner** is a stand-alone environment (e.g., for Windows, Linux, MacOS, ARM releases) that is intended to be installed either in a server (SYNERGIES Federated Private Server Data Fabric) or in gateways (SYNERGIES Edge Data Fabric), always on the premises of the energy data value chain stakeholders. The SYNERGIES Runner establishes a direct communication with the SYNERGIES Data Mesh Coordination Platform or alternatively with the stakeholder's Federated Private Cloud Data Fabric in order to facilitate the execution of the data check-in, data sharing and data analysis tasks locally using Docker containers.

2.5.2 Implemented Features

The draft release of the Data Space Management Services implements a set of features of its associated components, following the development roadmap of the different services and components that comprise the SYNERGIES Energy Data Space, as documented in the SYNERGIES

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Internal Deliverable ID3.1 [1]. The following table presents the implementation status of the Data Space Management Services in its first release on M18 of the SYNERGIES project.

Feature		Status	Notes
CNM_1	Management of the Sectorial Data Models Network	Implemented	The set of Sectorial Data Models (Energy, Building, Electromobility, General as described in Annex II) that conceptually belong in the SYNERGIES Network can be fully managed by a dedicated user role (CIM administrator): concepts or fields can be created, read, updated, deleted; relations between concepts of separate models can be established; any updates in a concept/field are appropriately propagated. All users can view the details of each sectorial data model and can provide their suggestions for updates or additions. Such suggestions are communicated (through a notification) to the CIM administrator to decide whether to accept or reject them.
CNM_2	Concepts and Fields Metadata Management and Version Control	Partially Implemented	An appropriate metadata schema for the concepts and fields of each data model is in place and persists all necessary information for managing each sectorial data model and handling the relations of each concept/field with the state-of-the art data models/ontologies/standards. In addition, an appropriate version control mechanism has been implemented to track any major/minor change performed to each Sectorial Data Model and propagate it to the other Sectorial Data Models whenever needed.
CNM_3	Data Harmonization Configuration	Partially Implemented	All users can view all necessary details of the underlying data model they have selected during the mapping step configuration. Any localization settings and transformation rules, depending on the data type, are compulsory to be provided by the user (data provider) at the time the data are checked in to ensure that the data are properly harmonized according to the provisions of the selected data model prior to their check-in to the corresponding centralized cloud data space.
DSEM_1	Advanced Data Space Configuration	Partially Implemented	Each organization can have a single centralized cloud energy data space and as many federated data spaces as needed. Each user can link a private server/edge (federated) data space environment following the instructions provided (to ensure its secure registration) and can unlink it (delete) at any time from the organization's account in SYNERGIES.
DSEM_2	Advanced Data Space Monitoring	Partially Implemented	For each energy data space modality that is available at organization level, a basic monitoring functionality (including the number of data check-in pipelines and assets that are currently available) is provided.
MC_1	Scheduled execution of data check-in and data analytics pipelines	Partially Implemented	The execution of data check-in pipelines is triggered according to the configuration that the user who has created the pipeline has defined: (a) based on a schedule or a predefined frequency (within a reference time period) – this is applicable for certain data ingestion options (i.e. large file upload, API data ingestion), (b) at real-time within the reference period for streaming data ingestion.
MC_2	Scheduled execution of	Implemented	The execution of different services is triggered on demand, according to a schedule or based on events, in the SYNERGIES

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Feature		Status	Notes
	operations in the SYNERGIES centralized cloud data fabric		centralized cloud data fabric, e.g. in order to ensure the seamless operation and address any underlying failures to the extent it is possible (by automatically retrying the execution of a specific operation).
MC_3	Manage the secure transfer of data among the different Energy Data Spaces	Partially Implemented	In this release, the secure transfer of data from a federated data space to a centralized data space owned by the same stakeholder is possible at the data check-in time only.
MC_4	Dynamic management of resources	Partially Implemented	The mechanism for dynamic management of the available resources is in place, ensuring that the centralized cloud data spaces of the different organizations have equivalent resources and that all underlying services have sufficient resources. Heartbeats at the services levels in different forms (e.g. queued messages are above a threshold) and automated alerts for the storage layer (e.g. reaching 70% of capacity raises a yellow alert) are in place. It is also possible to auto-scale the resources (to allocate additional nodes with extra memory, CPUs) within the thresholds set.
RUN_1	Runner Execution in the SYNERGIES Federated Private Server Data Fabric	Partially Implemented	The execution of data check-in pipelines on-premise is possible through the Private Server Energy Data Space environment (also referred to as Runner component) that ensures that all services that need to run "locally" are downloaded and are available at the time of the execution. The resulting dataset may be stored on-premise (in the Private Server Energy Data Space environment) or may be transferred to the centralized cloud data space of the organization, according to the configuration of the data check-in pipeline.
RUN_2	Runner Execution in the SYNERGIES Federated Edge Data Fabric	Partially Implemented	An experimental version of the Federated Edge Data Space environment is available to be installed and registered in order to run data check-in pipelines in the gateways that the user has selected.

Table 13: Implemented features in the draft release of SYNERGIES Data Space Management Services

2.5.3 Technologies & Implementation Tools

As presented in the SYNERGIES Deliverable D2.1, the Data Space Management Services leverage a set of underlying technologies developed in the H2020-SYNERGY project: (a) the CIM Network Manager, and (b) the Runner extend the functionalities provided in the H2020-SYNERGY Platform. On the contrary, the Master Controller, the Data Spaces Environments Manager and the Orchestration Engine are developed from scratch.

As depicted in the following table, the overall Data Space Management Services build on a number of open-source technologies and is developed based on TypeScript as the underlying programming

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language. Since the deliverable at hand is a public deliverable, the exact versions are not provided for certain technologies due to security reasons.

Library	Version	License
NodeJS	18	MIT
Vue.js	2.7	MIT
TailwindCSS	2	MIT
Kybernetes	-	Apache License 2.0
KEDA	-	Apache License 2.0
Prometheus	-	MIT
Grafana	9.5.16	GNU Affero GPL, v3.0
Kafka	-	Apache License 2.0
PostgreSQL	-	PostgreSQL License (similar to BSD/MIT)
Redis	-	3-clause BSD License
MinIO	-	Apache License 2.0
MongoDB	-	Apache License 2.0
Vault	-	Mozilla Public License 2.0

Table 14: Technology Stack used in the development of SYNERGIES Data Space Management Services

2.5.4 Assumptions & Restrictions

In the first release of the Data Space Management Services, the following assumptions have been made, which in turn may pose restrictions in the capabilities offered by the SYNERGIES Energy Data Space:

- Any changes in the concepts and/or fields of the sectorial data models may take up to 15 minutes to propagate since the data models are cached for performance reasons.
- The resources are allocated per organization in a democratic/flat manner yet such an allocation shall be reconsidered depending on the actual use.

2.5.5 Planned Features for the Next Release

In continuation of the development activities during the second half of the SYNERGIES project, the first release of the Data Space Management Services will be enhanced by the following features, which will be implemented, or enriched, in the final release planned for M36, as shown in the following table.

Feature	Notes
CNM_2 "Concepts and Fields Metadata Management and Version Control"	The metadata management functionalities will be extended in the final release, through the support of vocabularies and code lists for certain fields, whenever applicable. It needs to be noted that emphasis will be laid on standardized vocabularies and code lists (that are endorsed and promoted by standardization organizations). In addition, support for abbreviation lists per sectorial data model will be added.

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Feature	Notes
CNM_3 "Data Harmonization Configuration"	The underlying requirements for the transformation and harmonization rules will be extended to support vocabularies and code lists in alignment with CNM_2, in the final release.
DSEM_1 "Advanced Data Space Configuration"	The data space management functionalities will be extended to support the configuration and registration of private cloud data space environments under an organization in the final release.
DSEM_2 "Advanced Data Space Monitoring"	The data space monitoring functionalities will be extended to allow monitoring of more "real-time" aspects regarding each data space environment, e.g. how many pipelines are executed, how many assets are shared, etc. In addition, the data space monitoring functionalities will also include the rest of the data space modalities.
MC_1 "Scheduled execution of data check-in and data analytics pipelines	The underlying execution functionalities will be extended to embrace the scheduled, event-based and API-triggered execution of data analytics pipelines in the final release.
MC_3 "Manage the secure transfer of data among the different Energy Data Spaces"	The coordination of the secure transfer of datasets will be extended to results and will also accommodate the necessary transfers directly between the various federated data spaces to support federated data sharing across different organizations when an active contract is in place.
MC_4 "Dynamic management of resources"	Constant performance improvements in order to optimize the dynamic allocation of resources based on the consumption patterns that will be extracted during the EDS operation.
OE_1 "Allocation of resources in the SYNERGIES Private Cloud/Server Data Fabric"	The necessary mechanisms to ensure the setup and orchestration of all containerized services of the full release of the SYNERGIES Private Cloud/Server Data Fabric are to be designed and implemented in the final release.
OE_2 "Dynamic management of resources for executing the services in the SYNERGIES Private Cloud/Server Data Fabric"	The dynamic allocation of the available resources across the tasks/services that are running on-premise (in the private cloud/server data space environment) will be supported in the final release when the private cloud data space is expected to be available.
RUN_1 "Runner Execution in the SYNERGIES Federated Private Server Data Fabric"	The federated private server environment will be complemented with the execution of data analytics pipelines (in collaboration with the AI Analytics On-Demand Platform delivered in WP4) and with additional resources management functionalities (related to OE_1 and OE_2).
RUN_2 "Runner Execution in the SYNERGIES Federated Edge Data Fabric"	The federated edge environment will be fully operational, complemented with the data minimization services, in the final release.

Table 15: Planned features in the Final Release of the SYNERGIES Data Space Management Services

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3 SYNERGIES Reference Energy Data Space Release

This section refers to integration aspects of the Energy Data Space and presents a glimpse of the user experience and the user on-boarding mechanisms that are in place.

3.1 Status At a Glance

The main menu of the SYNERGIES Reference Energy Data Space delivered with the initial release on M18 of the project, includes the following items:

- **Home/Landing page** in which some basic statistics regarding the overall use of the SYNERGIES Energy Data Space by an organization is provided.
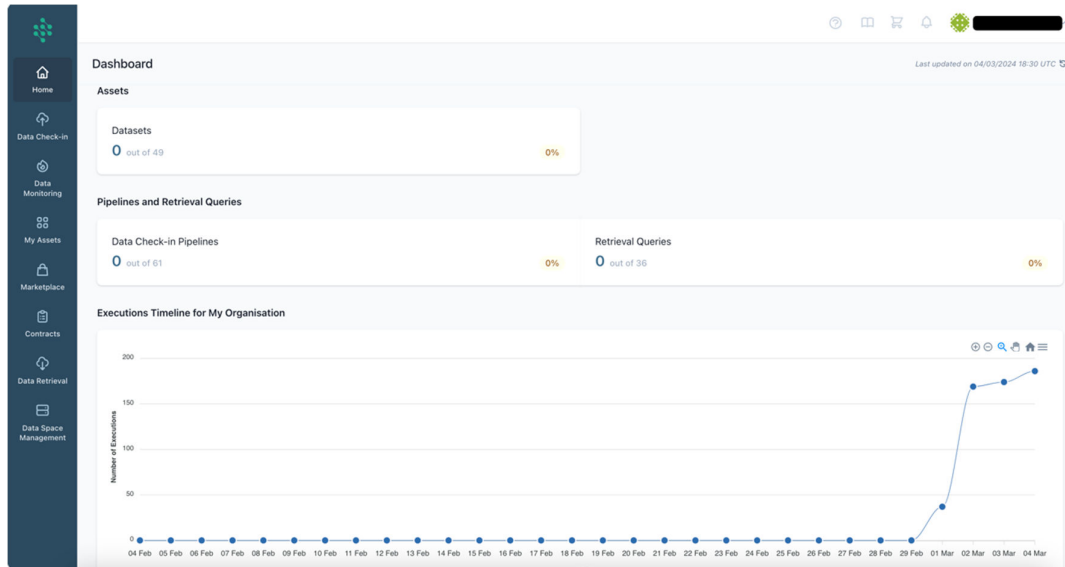
Figure 1: SYNERGIES Home Page

- **Data Check-In** where a user is able to view, search and filter/sort the data check-in pipelines belonging to his/her organisation, to configure a new data check-in pipeline from scratch, to edit, clone, or delete an existing data check-in pipeline, or to view the execution history of a particular data check-in pipeline.

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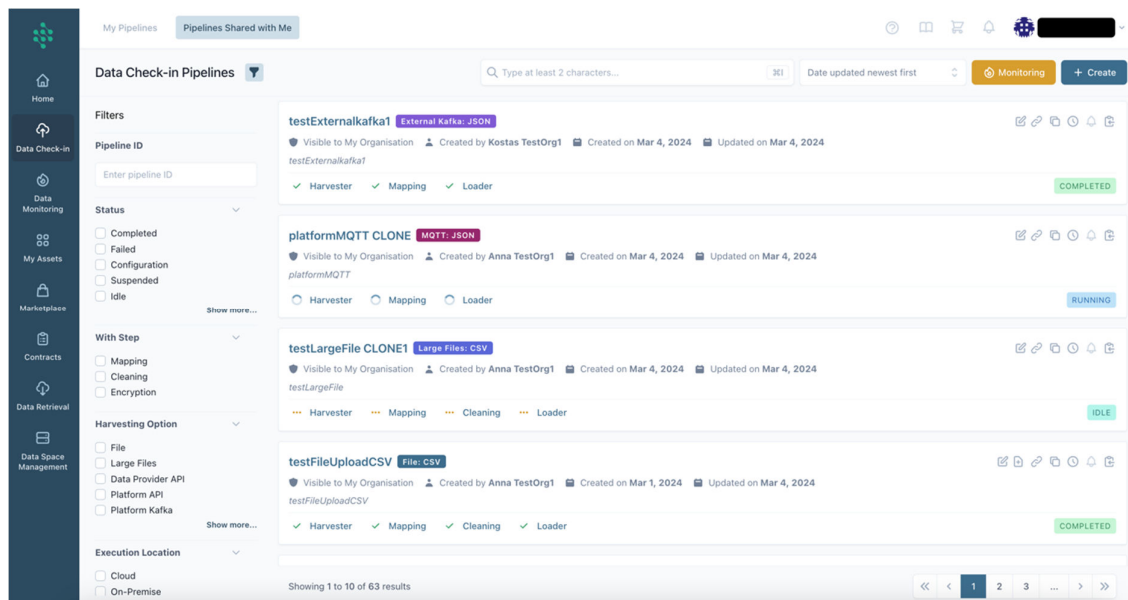
Figure 2: SYNERGIES Data Check-in

- **Data Monitoring** where a user can view the incidents associated to the data check-in pipelines belonging to him/her or his/her organization, as well as the latest quality metrics of their associated datasets.
- **My Assets** where a user may view, search and sort the data assets which belong to or have been acquired by his/her organisation, to edit or delete an existing data asset, or to view the details of a particular data asset.
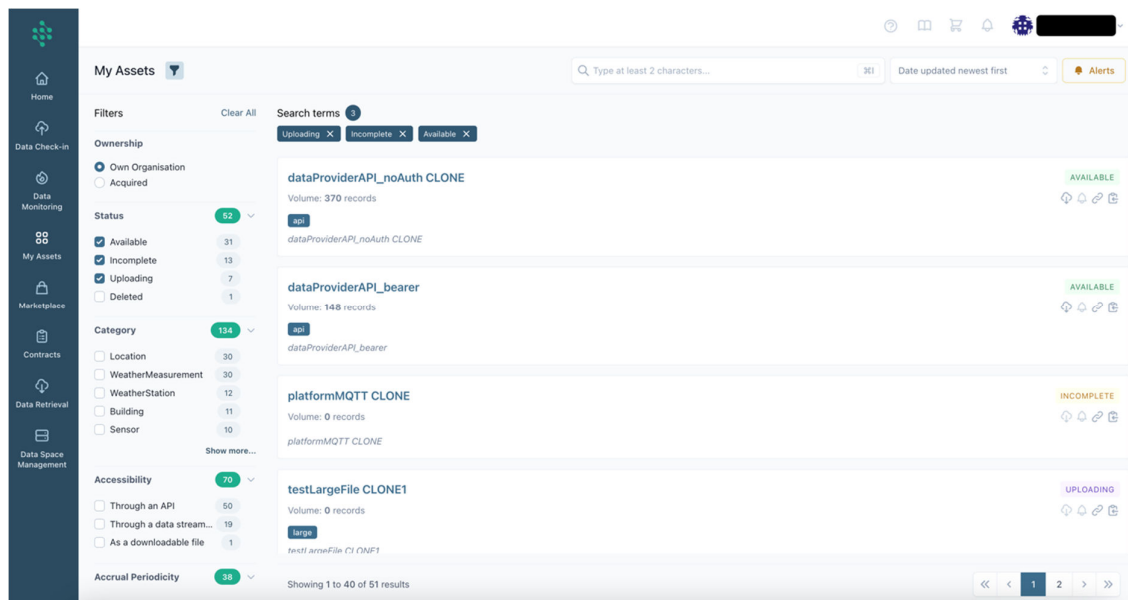
Figure 3: SYNERGIES My Assets

- **Marketplace** that allows a user to navigate through available data assets of interest, to view the details of a particular data asset to obtain deeper understanding of the data assets' contents and features (e.g., assessing their potential, their origin, their volume, etc.), or to initiate and negotiate a data sharing agreement.

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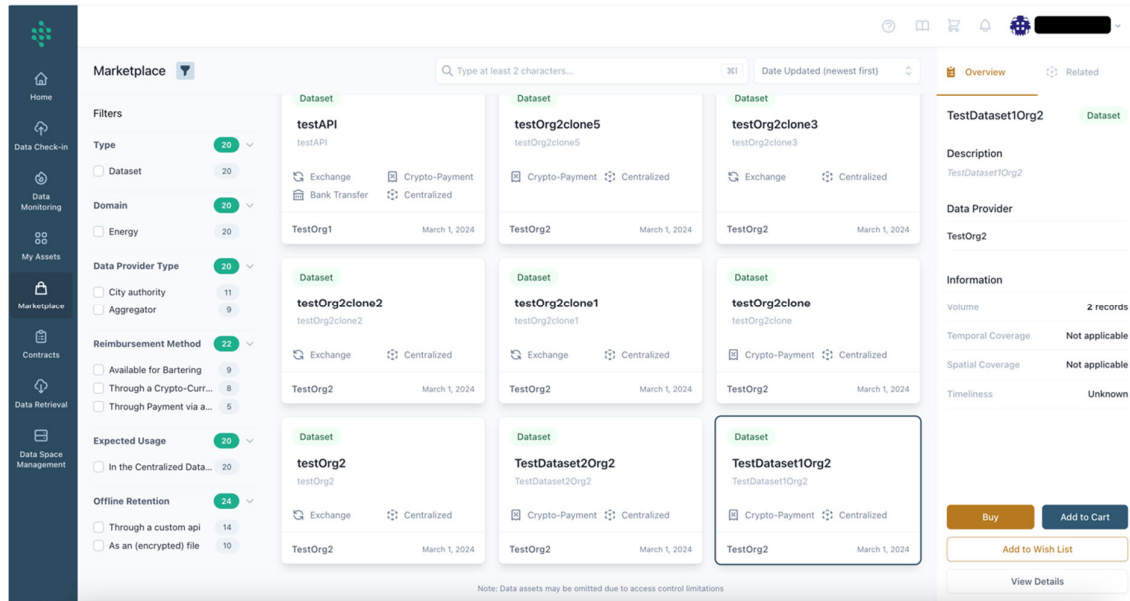
Figure 4: SYNERGIES Marketplace

- **Contracts** where a user may navigate to the contracts that his/her organization is involved as data provider or as data consumer.
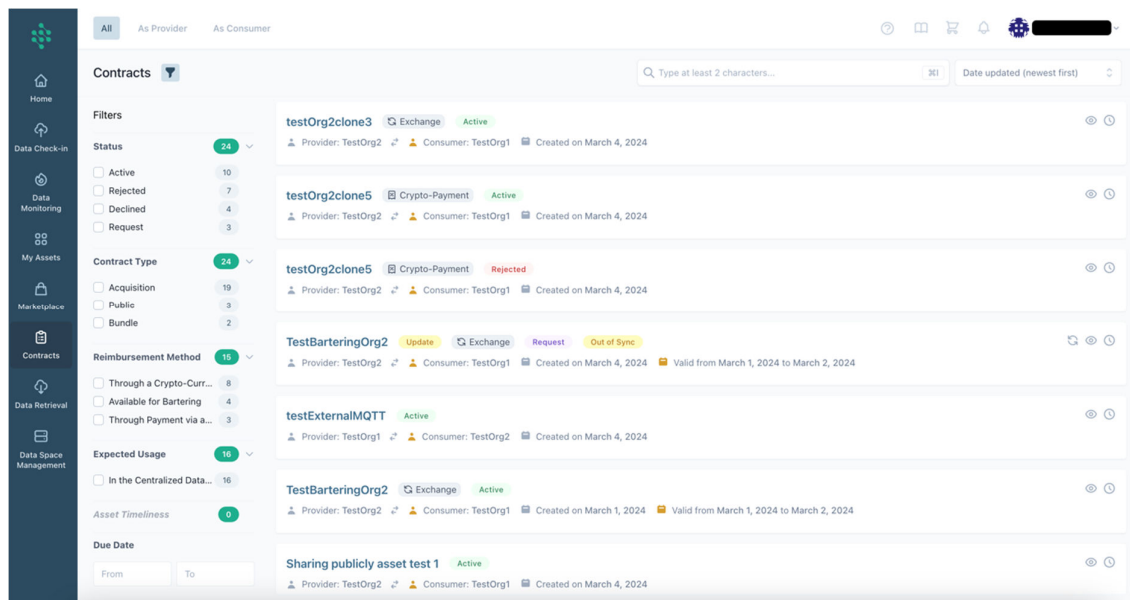
Figure 5: SYNERGIES Contracts

- **Retrieval**, allowing the user to view, search and sort the data retrieval queries belonging to his/her organisation, to configure a new data retrieval query, to edit or delete an existing data retrieval query, or to view the configuration of a particular data retrieval query.
- **Data Space Management**, where the user can view and configure the centralized cloud and federated data space environments that are available for his/her organization.

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Figure 6: SYNERGIES Data Space Management

3.2 Continuous Integration of the SYNERGIES Building Blocks

As described in Section 2, the SYNERGIES Reference Energy Data Space is a delicate combination of an extensive number of services and technologies that have been integrated in line with the SYNERGIES reference architecture described in section 8 of the SYNERGIES Deliverable D2.1 [2]. In order to successfully meet the software delivery challenges of a software project as complex as SYNERGIES, an agile integration approach has been applied based on the DevOps and GitOps practices:

- **Release design and planning**: the development teams of the involved partners, the WP3 leader, and the Technical Coordinator discuss on a bi-weekly basis the priorities and set/update the main milestones per development cycle.
- **Collaborative software development and testing**: It is organised in development sprints, typically lasting 4 weeks and actively involving the development teams in interactive cycles of: (a) coding (including the delivery of unit tests), (b) committing code to the respective component repo, (c) reviewing the code changes, (d) merging the new features and fixes included in the code, (e) running appropriate integration tests, and (f) executing the necessary test cases for each new functionality, but also the underlying regression tests.
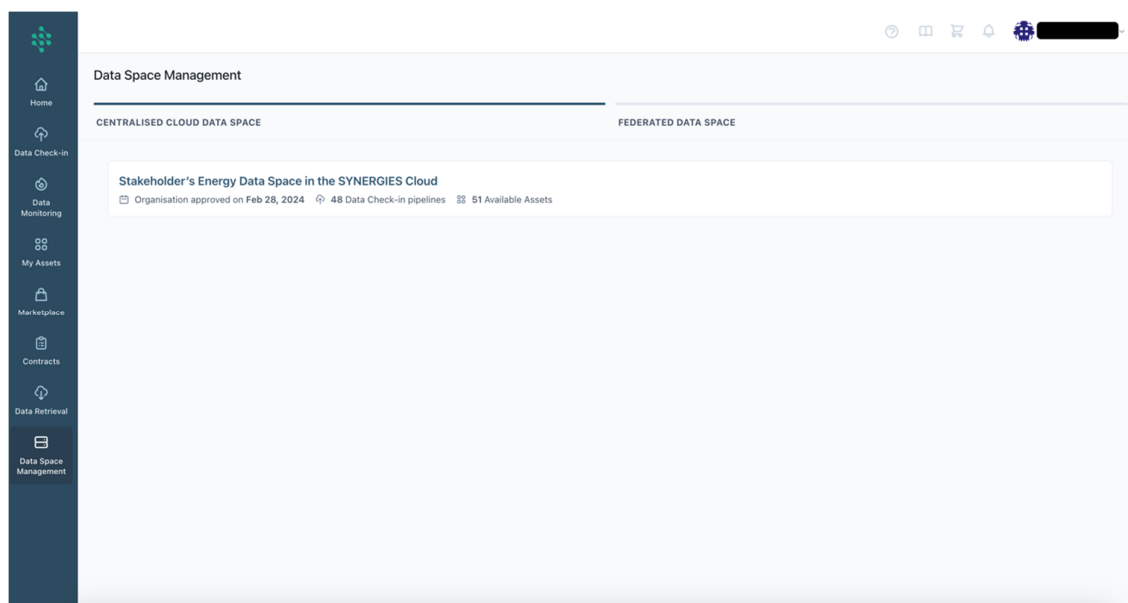- **Deployment in production environment**: Every major release and selected minor releases (for bug fixes or for prioritised features that need to be shipped earlier than the next major release) is deployed at the SYNERGIES production environment upon a relevant announcement to the consortium (at least 1 day earlier). Access to the production environment is available for all partners.

In particular, the techniques and open-source tools that have been selected to ensure collaborative and continuous planning, development and deployment cycles for each release are depicted in the following table.

Integration-related Activity	Tool
Source code versioning and issue tracking	Github
Automated build and testing	Github Actions

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Integration-related Activity	Tool
Error Tracking	Sentry
Deployment	Docker, Kubernetes
GitOps	Flux CD, KEDA

Table 16: SYNERGIES Integration Tools

3.3 Deployment Aspects

The SYNERGIES Reference Energy Data Space is deployed in its production environment at: https://synergies-eds.eu/

The SYNERGIES Reference Energy Data Space allows organisation-based access by-design: the manager of each participating organisation needs to create his/her account and then register the organisation. Once the registration of the organisation is approved by the SYNERGIES (cloud coordination platform) admin, then the organisation's manager can invite additional members to join the organisation, which receive an invitation code via email. The additional members include also the organisation's legal representative as a separate user role that is appointed by the SYNERGIES admin.

3.4 End-User On-Boarding and Support Mechanisms

For the on-boarding of end-users to the SYNERGIES Reference Energy Data Space, a detailed manual in the form of **online documentation** has been put in place and is available through the SYNERGIES EDS for registered users. The online documentation is compiled following the menu structure of the SYNERGIES Reference Energy Data Space, therefore describing, with the help of text and explanative screenshots, the steps an end-user needs to take in order to perform the basic platform functionalities.

With each release of the SYNERGIES EDS, **online training sessions** are organized in order to provide a hands-on demonstration of the delivered functionalities of the SYNERGIES Reference Energy Data Space. Such training sessions occur in the bi-weekly technical calls, but also during the face-to-face plenary meetings and are recorded in order to act as training material for easier onboarding of the end-users.

For the effective coordination of the SYNERGIES consortium when it comes to reporting, managing, and resolving defects and delivering releases, a private github repository (https://github.com/SYNERGIES-EDS/eds-support) has been configured under the SYNERGIES organization. In this github repo, any user can report: (a) bugs (e.g., defects, problematic behaviours) observed during the use of the SYNERGIES Reference Energy Data Space, and (b) enhancements (e.g. new feature requests, improvements on an existing feature) based on their experience.

The SYNERGIES Reference Energy Data Space Help Desk has been also set-up as a dedicated workspace "SYNERGIES-Support" in Slack[1], where end users can contact the help desk of the SYNERGIES technical partners to request support, post questions, report bugs, request new features, etc.

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[1] https://slack.com/

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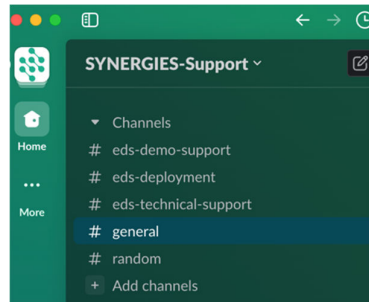
Figure 7: SYNERGIES Help Desk in Slack

It needs to be noted that neither issue reporting nor support requests are to be provided via email in order to keep track of all bugs and requests in a transparent manner for all users.

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4 Conclusions and Next Steps

This deliverable documented the progress achieved in the context of Work Package 3 "SYNERGIES Reference Energy Data Space Implementation", up until the deployment of the draft release of the SYNERGIES Reference Energy Data Space on M18 of the SYNERGIES project. Guided by the development roadmap which was laid down already in the SYNERGIES Internal Deliverable ID3.1 [1], the progress of each building block has been documented in a structured manner; for each feature identified per building block, the implementation status up to M18 was presented, together with the technology stack used during the development and the pertinent assumptions and restrictions.

The deliverable also reported the deployment URL of the initial release of the SYNERGIES Reference Energy Data Space and its online support documentation. Additionally, it described the integration approach aligned with the agile development methodology followed during the software delivery cycles, as well as the tools and support channels for successful collaboration of the development teams.

Furthermore, the deliverable presented, with the help of screenshots, the main menu of the SYNERGIES Reference Energy Data Space. As a high-level outline, this presentation referred to the main screens: Home/Landing page, Data Check-In, Data Monitoring, My Assets, Marketplace, Contracts, Data Retrieval, and Data Space Management. A detailed documentation is directly available online in the Help menu.

Finally, as the result of the work of Task 3.1 "SYNERGIES Network of Sectorial Data Models", in Annex II the deliverable at hand document the SYNERGIES Network of Sectorial Data Models (Energy, Building, EV, and General). The SYNERGIES Network of Sectorial Data Models is integrated in the initial release of the SYNERGIES Reference Energy Data Space and will be maintained and expanded through the available CIM Network management functionalities.

In the coming months of the project, all SYNERGIES data sharing-driven digital solutions and energy services marketplace (delivered in WP4) will be integrated with the Energy Data Space, adding the Energy Added-Value Services dimension. Subsequently, towards the final release of the SYNERGIES Reference Energy Data Space on M36, certain features which have been partially implemented in the draft release shall be enhanced, while other features which have been left out of the first release shall be implemented altogether according to the project's architecture described in deliverable D2.1 [2].In addition, the feedback by the technical partners that shall integrate their solutions in WP4 "SYNERGIES data sharing-driven digital solutions and energy services marketplace" and by the demo partners that proceed with the demonstration activities in WP5 "Demonstration and Impact Assessment" shall be leveraged to improve the provided features and the overall user experience.

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Annex I: References

[1]. SYNERGIES Project (2023a). Internal Deliverable ID3.1 "SYNERGIES Energy Data Space Release 1.00"

[2]. SYNERGIES Project (2023b). Deliverable D2.1 "1st version of SYNERGIES Requirements and Detailed Architecture Design"

Annex II: SYNERGIES Network of Sectorial Data Models

Energy Data Model

Concept	# Fields	# Related Concepts	Modelling based on Standards
ACLine	43	11	IEC CIM
Admittance	7	1	IEC CIM
Aggregator	8	14	Role Model
AggregatorPortfolio	13	25	Role Model
BalancingResponsibleParty	8	10	Role Model
BalancingServiceProvider	8	10	Role Model
Battery	32	12	IEC 61850, IEEE 2030.5-2018, DNP3
BatteryControlAction	10	12	IEC 61850, IEEE 2030.5-2018, DNP3
BiomassPlant	29	12	IEC 61850, IEEE 2030.5-2018, DNP3
Branch	16	6	IEC CIM
Breaker	16	7	IEC CIM
Bus	14	5	IEC CIM
CombinedHeatingPowerSystem	21	15	IEC 61850, IEEE 2030.5-2018, DNP3
ConnectivityNode	9	10	IEC CIM
Connector	16	7	IEC CIM
DCLine	18	9	IEC CIM
DemandResponseEvent	16	19	IEC 62746
DemandResponseEventSignal	20	21	IEC 62746
DemandResponseReport	14	22	IEC 62746
DemandResponseReportReading	12	23	IEC 62746
Device	21	14	IEC 61850, IEEE 2030.5-2018, DNP3
DeviceControlEvent	7	22	IEC 61850, IEEE 2030.5-2018, DNP3
DeviceControlEventAction	14	3	IEC 61850, IEEE 2030.5-2018, DNP3
DeviceControlStatus	9	23	IEC 61850, IEEE 2030.5-2018, DNP3
Disconnector	14	7	IEC CIM
DistributionSystemOperator	7	7	Role Model
DistributionSystemOperatorPortfolio	10	7	Role Model
Electrolyzer	30	12	IEC 61850, IEEE 2030.5-2018, DNP3
EnergyDemandMeasurements	46	27	SAREF4ENER
EnergyGenerationMeasurements	153	22	SAREF4ENER
EnergyMarket	26	18	IEC CIM
EnergyMarketOperator	8	4	Role Model

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Concept	# Fields	# Related Concepts	Modelling based on Standards
EnergyServiceCompany	8	4	Role Model
EnergyStorageMeasurements	23	5	SAREF4ENER
ExternalNetworkSegment	23	5	IEC CIM
Flexibility	15	26	USEF
FlexibilityMarket	26	18	Role Model
FlexibilityMarketOperator	8	4	Role Model
FuelCell	31	12	IEC 61850, IEEE 2030.5-2018, DNP3
Generator	18	10	IEC CIM
Grid	16	14	IEC CIM
HydrogenTank	16	12	IEC 61850, IEEE 2030.5-2018, DNP3
HydroPowerSystem	10	8	IEC 61850, IEEE 2030.5-2018, DNP3
Impedance	8	1	IEC CIM
Inverter	31	15	IEC 61850, IEEE 2030.5-2018, DNP3
Jumper	14	7	IEC CIM
Junction	16	8	IEC CIM
Load	16	3	IEC CIM
LoadResponse	12	6	IEC CIM
LocalEnergyCommunity	9	20	Role Model
NetworkSwitch	13	7	IEC CIM
Offer	6	10	USEF
OfferOption	9	4	USEF
Order	12	14	USEF
Outage	33	17	IEC CIM
OutageLog	9	16	IEC CIM
PhotovoltaicSystem	42	15	IEC 61850, IEEE 2030.5-2018, DNP3
PlantOperator	8	9	Role Model
PowerPlant	16	9	IEC CIM
PowerTransformer	56	6	IEC CIM
PowerTransistor	19	2	IEC CIM
RegulatingControl	10	5	IEC CIM
RenewableEnergySource	7	17	IEC 61850, IEEE 2030.5-2018, DNP3
RenewableEnergySourceOperator	8	13	Role Model
Request	9	8	USEF
Retailer	8	11	Role Model
RetailerPortfolio	8	24	Role Model
SCADA	9	4	IEC CIM
Settlement	15	9	USEF

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Concept	# Fields	# Related Concepts	Modelling based on Standards
ShuntCompensator	18	9	IEC CIM
Substation	15	12	IEC CIM
TransmissionSystemOperator	8	7	Role Model
VirtualPowerPlant	8	8	Role Model
WindTurbine	31	15	IEC 61850, IEEE 2030.5-2018, DNP3

Building Data Model

Concept	# Fields	# Related Concepts	Modelling based on Standards
AirConditioningSystem	34	15	SAREF4BLDG
AirConditioningSystemControlAction	28	9	-
AudioVisualAppliance	18	17	SAREF4BLDG
AudioVisualApplianceControlAction	10	10	-
AutomatedOperationProfile	12	12	SAREF4ENER
Boiler	31	16	SAREF4BLDG
BoilerControlAction	10	13	-
Building	49	25	IFC
BuildingMeasurements	12	0	IFC
BuildingSpace	19	28	IFC
BuildingStorey	15	9	IFC
BuildingZone	11	23	IFC
ChillerDevice	17	14	SAREF4BLDG
ChillerDeviceControlAction	10	8	SAREF4BLDG
Comfort	26	8	Role Model
CoolingTower	24	17	-
CoolingTowerControlAction	18	10	SAREF4BLDG
DomesticHotWaterSystem	13	16	Role Model
DomesticHotWaterSystemControlAction	10	8	-
ElectricAppliance	15	17	SAREF4BLDG
ElectricApplianceControlAction	9	10	-
Elevator	18	11	COBie
FacilityManager	8	5	Role Model
Gateway	9	5	SSN
HeatPump	19	16	SAREF4BLDG
HeatPumpControlAction	11	8	--
Humidifier	16	17	SAREF4BLDG
HumidifierControlAction	17	10	

Concept	# Fields	# Related Concepts	Modelling based on Standards
IndoorEnvironmentHealth	25	8	Role Model
LightingDevice	21	13	SAREF4BLDG
LightingDeviceControlAction	13	9	-
MedicalDevice	16	17	SAREF4BLDG
MedicalDeviceControlAction	9	10	-
Occupancy	18	4	IFC
Occupant	15	2	Role Model
Outlet	17	14	SAREF4BLDG, COBie
Prosumer	15	22	USEF
SensingMeasurement	30	12	SSN
Sensor	10	14	SSN
SmartAppliance	12	11	SAREF4BLDG
SmartApplianceControlAction	9	8	-
SolarThermal	23	17	SAREF4BLDG
SolarThermalControlAction	10	10	-
SpaceHeatingDevice	23	13	SAREF4BLDG
SpaceHeatingDeviceControlAction	11	8	-
VentilationSystem	17	13	SAREF4BLDG
VentilationSystemControlAction	10	8	-

EV Data Model

Concept	# Fields	# Related Concepts	Modelling based on Standards
ChargePointOperator	8	17	OCPP
ChargePointOwner	8	18	OCPP
ChargeSession	7	11	OCPP
ElectricVehicle	18	18	ISO/IEC 15118, IEC 61851-1, OCPP
EMobilityServiceProvider	8	15	OCPI, OCPP
EVChargingPlatform	8	12	OSCP
EVChargingProfileType	8	13	OSCP
EVChargingStation	24	16	OCPP
EVChargingStationControlAction	12	11	OCPP
EVConnector	12	11	ISO/IEC 15118, IEC 61851-1
EVFleetOperator	8	18	OSCP
EVOwner	8	10	OSCP
EVService	8	13	OCPP
EVSupplyEquipment	23	18	OCPP

SYNERGIES

Shaping consumer-inclusive data pathwaYs towards the eNERGy transItion, through a reference Energy data Space implementation

Concept	# Fields	# Related Concepts	Modelling based on Standards
EVUser	8	17	OSCP

General Data Model

Concept	# Fields	# Related Concepts	Modelling based on Standards
Address	21	3	UN/CEFACT CCTS
CityAuthority	7	5	-
Contact	13	3	UN/CEFACT CCTS
Contract	27	37	IEC CIM, USEF
Event	12	3	UN/CEFACT CCTS
Incident	15	11	IEC CIM
IncidentLog	6	11	-
KeyPerformanceIndicator	6	25	SAREF4CITY
KeyPerformanceIndicatorValue	11	2	SAREF4CITY
Location	33	3	UN/CEFACT CCTS
Measurement	9	21	SAREF, SSN
MeteringSystem	10	9	IEC CIM, SAREF
Period	33	5	UN/CEFACT CCTS
Schedule	9	12	IEC CIM
Status	18	2	UN/CEFACT CCTS
TariffProfile	14	5	IEC CIM
TroubleTicket	9	15	IEC CIM
WeatherMeasurement	33	3	-
WeatherStation	7	9	-