Orchestrating an interoperable sovereign federated Multi-vector Energy data space built on open standards and ready for GAia-X

D5.1 Marketplace Design

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List of Acronyms

Abbreviation / acronym	Description
AC	Alternate Current
API	Application Programming Interface
BIPV	Building-Integrated Photovoltaics
CA	Certificate Authority
CAPEX	Capital Expenditure
CSDM	Common Semantic Data Model
DAPS	Dynamic Attribute Provisioning Service
DC	Direct Current
DER	Distributed Energy Resources
DID	Decentralised Identifiers
dhi	diffuse horizontal irradiance
dni	direct normal irradiance
DSBA	Data Spaces Business Alliance
DSSC	Data Spaces Support Center
Dx.y	Deliverable number y belonging to WP x
DSO	Distribution System Operator
EMSP	eMobility Service Provider
EMRSP	e-Mobility Roaming Service Provider
ESCO	Energy service company
Flex	Flexibility
GHI	global horizontal irradiance
GUI	Graphical User Interface
ID	Identifier
IDSA	International Data Spaces Association
Imp	current at maximum power
Isc	open circuit current
kWh	kilowatt-hour

Abbreviation / acronym	Description
LEC	Local Energy Community
MPPT	Maximum Power Point Tracking
OPEX	Operational Expenditure
O&M	Operation & Management
PoA	Plane of Array
PV	Photovoltaics
REN	Renewable
SD	Self-Description
SSI	Self-sovereign identity
SUS	System Usability Scale
TNO	Toegepast Natuurwetenschappelijk Onderzoek
Tx	Task x
UC	Use Case
UCF	Use Case Family
UX	User Experience
VC	Verifiable Credentials
Vmp	Voltage at maximum power point
Voc	Voltage at open circuit
vx	Version x
WPx	Work Package x

Executive Summary

This report is the first of three versions dedicated to describing the Marketplace of the OMEGA-X project. More specifically, the report addresses three aspects of the OMEGA-X project: the Marketplace User Interface (UI) (including the architecture and the supporting services that enable its operation), the analytical services and digital twins enabled by the Marketplace and an introduction on the identity management, security, vocabulary and infrastructure monitoring services.

One of the main focuses of this report is the description of the preliminary version of the data and services Marketplace, describing its different functionalities and architecture. The graphical user interface (GUI) of the Marketplace is presented via a set of high-fidelity wireframes, its functionalities in the form of use cases and its architecture in the form of a high-level component diagram. The design of the Marketplace was created following a three-step methodology:

- A literature review was conducted, investigating similar energy marketplaces and Data Space initiatives, which led to the identification of a set of main functionalities that would be incorporated into an initial static version (static mock-ups) of the OMEGA-X Marketplace and the creation of the Marketplace's architecture.
- Secondly, meetings were held with OMEGA-X stakeholders (data providers, service providers and other partners) in order to identify their specific needs and any adaptations needed on the basis of the mock-ups. This step led to the refinement of the design of the GUIs and the creation of the prototype (interconnected mock-ups) of the Marketplace.
- The final step was to conduct a User Experience (UX) study, where partners tested an interconnected version. The results of this study led to the creation of the preliminary version of the Marketplace GUI design, which can be seen in Annex A. In parallel, the final description of the Use Cases was formulated, and the architecture was refined, revisiting recent advancements in Data Spaces Initiatives (especially Data Spaces Support Center - DSSC) and the overall architecture of the project.

Another objective of this report is to further detail analytic services and digital twins enabled by the OMEGA-X Marketplace. These are presented on the basis of the different Use Case (UC) Families (i.e Renewables, Local Energy Communities (LEC), Electromobility, Flexibility) and provide the category, service provider, data provider, model serving type and end user of each service. In total, this report presents 13 services of the Flexibility UC Family, 10 of the LEC UC Family, 2 of the Electromobility UC Family and 8 of the Flexibility UC Family.

Finally, a preliminary analysis of different components enabling the operations of the Marketplace, pertinent to the above Tasks is presented, namely: identity management and security, the Vocabulary Hub, and infrastructure monitoring services of the Marketplace.

The next iteration of this report will further detail its elements of interest. More specifically there will be more details on the backend infrastructure of the Marketplace, together with a functional first version of the Marketplace GUI. There will also be more details on the Marketplace as a part of the whole OMEGA-X data space, with more details on identity, self-descriptions, connector etc.

1 Introduction

1.1 Purpose of the document

The goals of this report are to present the primary version of the OMEGA-X Marketplace for data and services, provide a detailed overview of the functionalities included in this primary version, analyse the Marketplace architecture and provide a second iteration on the data analytic services and digital twins. Furthermore, this report includes a presentation of the identity management and security of the Marketplace, an introduction to the vocabulary that will be employed within the Marketplace and an introduction to the underlying infrastructure monitoring services.

This report is the outcome of the following OMEGA-X tasks:

- T5.1: Development of analytic services
- T5.2: Digital twins
- T5.3: Development of data and services marketplace

The report is divided into the following main parts:

- Presentation of how the primary version of the Marketplace was created, as well as a presentation of the Marketplace architecture.
- Presentation of the analytic services and digital twins that will be offered through the Marketplace by the end of this project.
- Presentation of the identity management and security of the Marketplace, introduction to the vocabulary in relation to the Marketplace and presentation of the underlying infrastructure and monitoring services of the Marketplace.

1.2 Relation to another project work

This deliverable deals with the Marketplace and the Analytic services and digital twins, which are all core elements of the project. Therefore, the work done for this report is influenced and is influencing, in return, many other tasks and work packages of the project. More specifically:

- The design and architecture of the Marketplace are influenced by sister projects, data space initiatives and standards, and other data energy services marketplaces. Therefore, input was received from WP2 “Cooperation” in order to be aligned with other projects. There was also alignment with T2.4 “Integration of sister projects functionalities” regarding the technology and tools.
- There is a great influence on the design and architecture of the Marketplace from WP3 regarding the use cases (T3.1 “Use case identification”), the non-functional requirements (T3.3 “Analysis of requirements for interoperability, security, privacy and data sovereignty and certification”) and the reference architecture of the OMEGA-X data space (T3.4 “Full system architecture and building blocks”). WP3 also includes the first definition and requirements regarding the analytic services and digital twins.
- T5.4 “APIs and standards to guarantee interoperability” is dealing with APIs and therefore relies on the Marketplace implementation, since it will build an interoperability layer on top of it.

- The work from the tasks mentioned in this report will influence WP6 “Demonstration” since the developed analytics services and digital twins will be validated in the corresponding pilots during WP6. The Marketplace implementation and user feedback are also influencing WP6.
- WP7 “Communication and Business” can utilise this work for dissemination purposes and for business models.

1.3 Structure of the document

This document is structured in 6 major chapters.

Chapter 1 is the introduction to this report, describing the following chapters.

Chapter 2 presents the mock-up version of the OMEGA-X Marketplace, the user experience (UX) study that was done on members of the consortium in order to test the usability of this version and the changes that were done and will be done in the first Marketplace release. The chapter also describes the architecture of the OMEGA-X Marketplace, based on the architecture of the OMEGA-X data space presented in OMEGA-X_D3.1 “Use Cases and Architecture living report” [1].

Chapter 3 presents all the analytic services and digital twins that will be offered through the Marketplace, mentioning their category, service provider, data provider, model serving type and end user.

Chapter 4 presents how identity management will be implemented, as well as details on the security of the Marketplace.

Chapter 5 introduces some details regarding the Vocabulary from the perspective of the Marketplace.

Chapter 6 presents an introduction to the underlying infrastructure and monitoring services of the Marketplace, focusing on hosting of the Marketplace, implementation of readiness and liveness probes and logging and monitoring.

1.4 Glossary adopted in this document

- **Actor.** A role played by an external entity that interacts with the subject (i.e. a system). This entity can be a human user of the designed system or another organisation, system, application or device.
- **Data Space.** According to Gaia-X “the term ‘Data Space’ refers to a type of data relationship between trusted partners who adhere to the same high standards and guidelines when it comes to data storage and sharing.” According to IDSA “a ‘Data Space’ is defined as an ecosystem for a secure and sovereign data sharing, exchange, and value creation. According to the design principles for Data Spaces, “Data Spaces are defined as a decentralised infrastructure for trustworthy data sharing and exchange in data ecosystems based on commonly agreed principles [2].
- **Use Case:** The specification of a set of actions performed by a system, which yields an observable result that is, typically, of value for one or more actors or other stakeholders of the system (ISO/IEC 19505-2:2012).

2 OMEGA-X Marketplace

2.1 Marketplace Actors

The OMEGA-X Marketplace actors were inspired by the Gaia-X specifications about the Gaia-X portal [3]. However, they were adapted to the needs of the OMEGA-X project. The Marketplace Actors that will be used in the current version of the Marketplace are:

- Marketplace Federator (or Federator): An entity entitled to manage a set of Marketplace functionalities. Their responsibilities include:
  - Inviting Admins
  - Approving the registration of Users
  - Accepting offering descriptions uploaded by Users
  - Accepting the deletion of offerings
- Admin (or Organisation Admin): a legal person/entity that is the employee of an organisation that wishes to be a member of the Marketplace. The Admin is the first person to register in the Marketplace and is responsible for managing other Users belonging to their organisation (inviting them to the Marketplace and deleting them from it), as well as for managing their organisation's description on the Marketplace. The Admin is also a User.
- User: a legal person/entity that is a member of the Marketplace. In this iteration of the Marketplace, Users should be members of Organisations that participate in the Marketplace, not natural persons who want to register independently. A User can be both a Provider (provide Data/Service offerings) and a Consumer (search and contract Data/Service offerings).
- Visitor: a legal person/entity that is not registered in the Marketplace. A Visitor can access the landing page of the Marketplace, which contains information about the project and the Marketplace. A Visitor can also access the search page and see information on all the offerings of the Marketplace (but not request a contract).

2.2 Marketplace Functionalities

2.2.1 Marketplace Enrolment

2.2.1.1 Organisation Admin Registers at Marketplace

Organisation Admin Registers at Marketplace
Objectives
To present the procedure of an Organisation Admin registering at the Marketplace.

Organisation Admin Registers at Marketplace
Short narrative
The Marketplace Federator invites an Organisation Admin to register in the Marketplace. The Admin receives the invitation, and if they wish to register via SSI, they follow the instructions provided in the e-mail. The Admin then accesses the Marketplace and navigates to the "Register" page. The Admin chooses whether they wish to register via e-mail or via SSI, by clicking on the appropriate button (either "Register via e-mail" or "Register via SSI"). The Admin then follows the steps of the registration wizard. After registration, Users must create and upload their personal and organisation self-descriptions to the Marketplace.
Steps
1. The Marketplace Federator invites an Organisation Admin to register in the Marketplace. 2. The Organisation Admin receives an e-mail with the Marketplace invitation. 3. (optional) The Organisation Admin follows the instructions in order to set up the SSI. 4. The Organisation Admin accesses the Marketplace and navigates to the Register page. 5. The Organisation Admin chooses whether they wish to register via e-mail or SSI by clicking on the appropriate button. 6. The Organisation Admin follows the registration wizard of the Marketplace 7. The Organisation Admin creates a self-description for themselves and their company and uploads it on the Marketplace.
Preconditions
The Organisation Admin is not registered at the Marketplace.
Post conditions
The Organisation Admin is registered at the Marketplace.
Comments
-

2.2.1.2 Organisation Admin Invites User at Marketplace

Organisation Admin Invites User at Marketplace
Objectives
To present the procedure of an Organisation Admin inviting a User of their Organisation at the Marketplace.

Organisation Admin Invites User at Marketplace
Short narrative
The (registered and logged-in) Organisation Admin navigates to the Admin page of the Marketplace. The Admin clicks on the “Add User” button, and a new window appears. The Admin fills in the form on the new window with the personal information (name, e-mail, etc.) of the User (a person who is an employee of the Admin’s Organisation) and clicks on the “Submit” button. The invited User receives an e-mail with the invitation and instructions about registering at the Marketplace.
Steps
1. The Organisation Admin navigates to the Admin page of the Marketplace. 2. The Organisation Admin clicks on the “Add User” button. 3. The Organisation Admin fills in the form with the information of the User (a person from their Organisation) they wish to invite and presses the “Submit” button. 4. The invited User receives an e-mail with the invitation to register at the Marketplace.
Preconditions
• The Organisation Admin is registered at the Marketplace. • The User is not registered at the Marketplace. • The User is not invited yet to register at the Marketplace. • The User is a member of the Organisation Admin’s organisation. • The User is not the Organisation Admin.
Post conditions
The User is invited to register at the Marketplace.
Comments
-

2.2.1.3 User Registers at Marketplace

User Registers at Marketplace
Objectives
To present the procedure of an invited User registering in the Marketplace.
Short narrative
The User receives via e-mail an invite from their Organisation Admin to register at the Marketplace. If the User decides to register via SSI, they follow the instructions to set up their SSI. The User then accesses the Marketplace and navigates to the Register page. The User chooses whether they wish to register via e-mail or via SSI, by clicking on the appropriate button (either “Register via e-mail” or “Register via SSI”). The User then follows the steps of the registration wizard. After the registration is complete, the User has to create their personal self-description and upload it on the Marketplace.

User Registers at Marketplace
Steps
1. The User receives an e-mail with the invitation to register at the Marketplace. 2. (optional) The User follows the instructions in order to set up the SSI. 3. The User accesses the Marketplace and navigates to the Register page. 4. The User chooses whether they wish to register via e-mail or SSI by clicking on the appropriate button. 5. The User follows the registration wizard of the Marketplace. 6. The User creates their own self-description.
Preconditions
• The User is not registered at the Marketplace. • The User is invited by their Organisation's admin to register the Marketplace.
Post conditions
The User is registered at the Marketplace.
Comments
-

2.2.2 Log in

User Logs in at Marketplace
Objectives
To present the procedure of a registered User logging in the Marketplace.
Short narrative
A registered User accesses the Marketplace and clicks on the "Log In" button. The User chooses whether they wish to log in via e-mail or SSI by clicking on one of the two buttons ("Log in via e-mail" or "Log in via SSI"). The User then follows the instructions of the login wizard.
Steps
1. The User accesses the Marketplace and navigates in the Log in page. 2. The User chooses whether they wish to Log in via e-mail or SSI by clicking on one of the two buttons ("Log in via e-mail" or "Log in via SSI"). 3. The User logs in the Marketplace by following instructions of the log in wizard.

User Logs in at Marketplace
Preconditions
• The User is registered at the Marketplace. • The User is not logged in at the Marketplace.
Post conditions
The User is logged in at the Marketplace.
Comments
"User" here can mean all roles: "User", "Admin" and "Federator".

2.2.3 Search Offering

User Searches for Offering
Objectives
To present the procedure of searching for an offering.
Short narrative
A User or a Visitor access the Marketplace and navigates to the Search page. The User/Visitor can use filters to narrow down their search. The User/Visitor clicks on the "Search" button. If they wish to see more information on an offering, they click on the "View more" button of an offering.
Steps
1. The User accesses the Marketplace. 2. The User navigates to the Search page. 3. (optional) User uses filters to narrow down search options. 4. The User clicks on the "Search" button. 5. (optional) The User selects an offering and clicks on the "View More" button to view more information on the offering.
Preconditions
The User not logged in.
Post conditions
Information presented to the User.
Comments
-

2.2.4 Begin Contract Negotiation

User Begins Contract Negotiation
Objectives
To present the procedure of starting the negotiation of an offering contract.
Short narrative
A (registered and logged in) User finds an offering they wish to contract and clicks on the “Request Contract” Button. A new window appears, requesting more information (e.g. contract name, contract period, etc.). The User fills in the form and clicks on the “Request Contract” button. A notification is sent to the User that provides the offering that a contract is being requested.
Steps
1. The User navigates to the offering of interest and clicks on the “Request Contract” button. 2. The User fills in the form on the contract page, specifying the requested details (contract name, payment type, etc.). 3. The User clicks on the “Request Contract” button.
Preconditions
The User is logged in the Marketplace.
Post conditions
The Provider of the offering is notified about the contract request.
Comments
-

2.2.5 Add an offering description

User adds an Offering description
Objectives
To present the procedure of adding a new offering description on the Marketplace.
Short narrative
A (registered and logged in) User wants to add a new offering (Data or Service) to the Marketplace. While being logged in the Marketplace, they navigate to the “Provide” page, choose whether they wish to provide a data or Service offering and then fill in the form on the Marketplace and upload the files that are requested by the form. When (at least) the required fields of the form are filled in, the User can press the “Submit” button.

User adds an Offering description
Steps
1. The User navigates to the Provide page. 2. The User chooses what kind of offering they wish to upload (either “Data” or “Service”). 3. The User fills in the form and uploads whatever file is needed (self-description, documentation, sample data file). 4. The User presses the “Submit” button.
Preconditions
The User is logged in the Marketplace.
Post conditions
A notification about a new offering added is created for the Federator.
Comments
-

2.2.6 Manage offering

2.2.6.1 User Edits a Data/Service offering in the Marketplace

User Edits a Data/Service offering in the Marketplace
Objectives
To present the procedure of editing an offering that has already been published in the Marketplace.
Short narrative
The (registered and logged in) User navigates to the Dashboard page and finds the tab with the kind of offering they wish to edit (either “My Provided Data Sources” or “My Provided Services”). They find the offering they wish to edit and click on the “Edit” button. The User then makes the changes they wish (not all fields will be editable) and then clicks on the “OK” button.
Steps
1. The User navigates to Dashboard page. 2. The User navigates to the “My Provided Services” or “My Provided Data Sources” tab (depending on the kind of offering they wish to edit) and finds the offering they wish to edit. 3. The User clicks on the “Edit” button. 4. The User makes the change they wish. 5. The User clicks on the “OK” button.

User Edits a Data/Service offering in the Marketplace
Preconditions
• The User is logged in the Marketplace. • The User has uploaded an offering description in the Marketplace.
Post conditions
• A notification about a new offering edited is created for the Federator. • All Users that have contracted the offering are notified that it has been edited.
Comments
-

2.2.6.2 User Deletes Data/Service offering from the Marketplace

User Deletes Data/Service offering from the Marketplace
Objectives
To present the procedure of deleting an uploaded offering.
Short narrative
The (registered and logged in) User navigates to the Dashboard page and finds the tab with the kind of offering they wish to delete (either “My Provided Data Sources” or “My Provided Services”). They find the offering they wish to delete and click on the “Delete” button. A pop-up window asks if they are sure they want to delete the offering, and the User clicks on the “OK” button.
Steps
1. The User navigates to the Dashboard page. 2. The User navigates to the “My Provided Services” or “My Provided Data Sources” tab. (depending on the kind of offering they wish to delete) and finds the offering they wish to delete. 3. The User clicks on the “Delete” button. 4. The User clicks on the “OK” button of the pop-up window that ensures they indeed want to delete the offering.
Preconditions
• The User is logged in the Marketplace. • The User has uploaded an offering description in the Marketplace. • The offering has no active contracts.

User Deletes Data/Service offering from the Marketplace
Post conditions
• A notification about a new offering deleted is created for the Federator. • The offering description is removed from the Marketplace.
Comments
-

2.2.6.3 User Discontinues Data/Service offering from the Marketplace

User Discontinues Data/Service offering from the Marketplace
Objectives
To present the procedure of discontinuing an uploaded offering (active contracts continue to be valid, but the offering is not available for new contracts).
Short narrative
The (registered and logged in) User navigates to the Dashboard page and finds the tab with the kind of offering they wish to discontinue providing (either “My Provided Data Sources” or “My Provided Services”). They find the offering they wish to discontinue providing and click on the “Discontinue” button. A pop-up window asks if they are sure they want to discontinue providing the offering, and the User clicks on the “OK” button.
Steps
1. The User navigates to the Dashboard page. 2. The User navigates to the “My Provided Services” or “My Provided Data Sources” tab. (depending on the kind of offering they wish to discontinue) and finds the offering they wish to discontinue. 3. The User clicks on the “Discontinue” button. 4. The User clicks on the “OK” button of the pop-up window that ensures they indeed want to discontinue the offering.
Preconditions
• The User is logged in the Marketplace. • The User has uploaded an offering description in the Marketplace.

User Discontinues Data/Service offering from the Marketplace
Post conditions
• A notification about a new offering discontinued is created for the Federator • The offering description is removed from the Marketplace • All Users that have contracted the offering are notified that it is now discontinued, but their contracts are still valid.
Comments
-

2.2.7 Manage Contract

2.2.7.1 User Accepts a Contract

User Accepts a Contract
Objectives
To present the procedure of accepting a contract.
Short narrative
The (registered and logged in) User receives a notification that another User wishes to contract one of their offerings. The User navigates to the Notifications page and finds the contract request that needs action. The User clicks on the “Accept” button.
Steps
1. The User receives a notification about a new contract on an offering they are providing. 2. The User navigates to the Notifications page and finds the contract request 3. The User clicks on the “Accept” button.
Preconditions
• The User is logged in the Marketplace. • The User has (at least) one active offering. • Another User has made a contract request about one offering of the User.
Post conditions
• The User has an active contract on one of their offerings. • The User that requested the contract is notified about the acceptance.
Comments
-

2.2.7.2 User Declines a Contract

User Declines a Contract
Objectives
To present the procedure of declining a contract.
Short narrative
The (registered and logged in) User receives a notification that another User wishes to contract one of their offerings. The User navigates to the Notifications page and finds the contract request that needs action. The User clicks on the “Decline” button.
Steps
1. The User receives a notification about a new contract. 2. The User navigates to the Notifications page and finds the contract request. 3. The User clicks on the “Decline” button.
Preconditions
• The User is logged in the Marketplace. • The User has (at least) one active offering. • Another User has made a contract request about one offering of the User.
Post conditions
• Contract request is refused. • The User that requested the contract is notified about the cancellation.
Comments
-

2.2.7.3 User cancels an active Contract

User cancels an active Contract
Objectives
To present the procedure of cancelling an active contract.
Short narrative
The User navigates to the “Contracts” page and finds the active contract that they wish to cancel. The User clicks on the “Cancel” button. A pop-up window appears asking if they are sure they want to cancel this contract. The User clicks on the “OK” button. All other Users involved are notified that the contract is now cancelled.

User cancels an active Contract
Steps
1. The User navigates to the Contracts page and finds the contract they wish to cancel. 2. The User clicks on the “Cancel” button. 3. The User clicks on the “OK” button on the pop-up that asks if they are sure they want to cancel.
Preconditions
• The User is logged in the Marketplace. • The User is a Consumer of a contract. • The User has (at least) one active contract on one of their offerings. • Cancelling the contract is according to the Terms and Conditions.
Post conditions
• The contract is cancelled. • The Provider of the offering receives a notification that the contract is cancelled.
Comments
-

2.2.7.4 User suspends a contract

User suspends an active Contract
Objectives
To present the procedure of suspending a contract for a period of time, with the option to resume the contract later.
Short narrative
The User navigates to the “Contracts” page and finds the active contract that they wish to suspend. The User clicks on the “Cancel” button. A pop-up window appears asking if they are sure they want to suspend this contract. The User clicks on the “OK” button. All other Users involved are notified that the contact is now suspended.
Steps
1. The User navigates to the Contracts page and finds the contract they wish to suspend. 2. The User presses the “Suspend” button. 3. The User clicks on the “OK” button on the pop-up that asks if they are sure they want to suspend.

User suspends an active Contract
Preconditions
• User is logged in the Marketplace. • User has (at least) one active contract on one of their offerings as a Consumer. • Resuming the contract is according to the Terms and Conditions.
Post conditions
• The contract is suspended. • All parties involved receive a notification about the suspension.
Comments
-

2.2.8 Use Service

2.2.8.1 User Downloads Service Image

User Downloads Service Image
Objectives
To present the procedure of downloading the Service image of a contracted Service.
Short narrative
The User navigates to the “Dashboard” page and the “My Contracted Services” tab. They find the Service offering that they wish to use. The User clicks on the “Download Service Image” button, and the Service image is downloaded on their environment.
Steps
1. The User navigates to the Dashboard page. 2. The User navigates to the “My Contracted Services” tab and finds the Service offering they wish to use. 3. The User clicks on the “Download Service Image” button.
Preconditions
• The User is logged in the Marketplace. • The User has an active contract with the Service. • The Service is offered as a downloadable Service.
Post conditions
The user has the Service image downloaded in their environment.

User Downloads Service Image
Comments
-

2.2.8.2 User uses Online Service

User uses Online Service
Objectives
To present the procedure of using a contracted Service online.
Short narrative
The User navigates to the “Dashboard” page and the “My Contracted Services” tab. They find the Service offering that they wish to use. The User clicks on the “Use online Service” button and is transferred to the external platform that hosts the Service.
Steps
1. The User navigates to the Dashboard page. 2. The User navigates to the “My Contracted Services” tab and finds the Service offering they wish to use. 3. The User clicks on the “Use online Service” button. 4. The User is transferred in the external platform that hosts the Service.
Preconditions
• The User is logged in the Marketplace. • The User has an active contract with the Service. • The Service is offered as an online Service. • The User has credentials (if needed) for the external platform.
Post conditions
The User can use the Service in the external environment.
Comments
-

2.3 Marketplace User Interface

2.3.1 Design Methodology

The prototype and the preliminary version of the OMEGA-X Marketplace were high-fidelity connected mock-up prototypes created with Figma [4].In order to create these versions, the following steps were followed:

- Research: projects similar to OMEGA-X were researched in order to identify the main functionalities a marketplace for energy data and services needs to have. The projects and marketplaces that were mainly analysed are BD4OPEM [5], PLATOON [6] and a project of ATOS called AGORA [7]. However, the main influence was the Gaia-X specifications about the Gaia-X portal [3] and Pontus-X, the Minimal Viable Gaia-X Portal [8].
- Define: After the research, the main functionalities and architecture of the OMEGA-X Marketplace were identified and discussed.
- Static version: A static version of mock-ups was created and presented to the consortium. This version included the processes of registration and log in (based on Pontus-X [8]), Dashboard, Search and Provide page (the page for uploading offers).
- Discussions: the static version was discussed during meetings with the consortium. There were also one-on-one meetings with Data providers and Service providers of the consortium in order to refine details on the Data and Service offerings, respectively.
- Prototype: after the discussions, the first high-fidelity connected mock-up version of the OMEGA-X Marketplace was created. That means that the static mock-ups had links to each other, creating the feeling of an actual website.
- User Experience (UX) Study: this first version was tested in a UX study with members of the consortium. The methodology and results of the UX study are analysed in section 2.3.3 of this document.
- Preliminary (see Annex A for the mock-ups): the results of the UX study led to some changes in the prototype. However, more substantial changes will be directly implemented in the first release of the Marketplace (see section 2.3.5).

2.3.2 OMEGA-X Marketplace Mock-ups (prototype)

The OMEGA-X Marketplace prototype included the following pages/procedures:

- Register: the OMEGA-X Registration was based on the Pontus-X [8] registration wizard. There were the options “Register via e-mail” or “Register via DID”.
- Log in: the OMEGA-X Log in was also based on the Pontus-X [8] registration wizard. There were the options “log in via e-mail” or “log in via DID”.
- Search: the Search page is open to all Visitors of the OMEGA-X Marketplace. Visitors and Users can search amongst the published Data offerings and Service offerings. There will be an Advanced Search option that is not yet implemented. The offerings have an image, the logo of the company acting as a Provider and a short description with the basic information. There is a “See more” button that leads to a pop-up window with a more detailed description. The registered and logged in Users can see a “Request Contract” button that leads to another pop-up page where they can fill in the contract details.
- Provide: the Provide page has two tabs, “Data Set” and “Service”. The User chooses which one they wish to Provide and fill in the form.

- Dashboard: in the first version of the OMEGA-X Marketplace, the Dashboard had a list with the latest transactions of the User and four other sections:
  - "My Provided Services", which included the Services that the User has uploaded (as a Provider)
  - "My Provided Data Sets", which included the data sets that the User has uploaded (as a Provider)
  - "My Contracted Services", which included the Services that the User has contracted (as a Consumer)
  - "My Contracted Data Sets", which included the Data sets that the User has contracted (as a Consumer)
- Admin page: this page is accessible only by the Organisation Admin. It contains the information of their company and a list of the Users that belong to it. There is also the button "Add User" which leads to a pop-up form where the Admin fills in the information of the new User (an employee of their company) that they wish to invite to the OMEGA-X Marketplace.
- Federator page: in this first version of the Marketplace, the Federator page is only a list of notifications for the Federator to approve that can be filtered according to categories (e.g. participant credentials, approve Data set, approve Service etc.)

2.3.3 User Experience (UX) study

2.3.3.1 Methodology

During the unmoderated usability study, the participants performed 7 scenarios according to the main role they will have in the Marketplace, either Data Provider or Service Provider.

- Service Provider
  - Scenario 1: Register via DID - Complete your registration to the OMEGA-X Marketplace via DID.
  - Scenario 2: Log in via DID.
  - Scenario 3: Add new user.
  - Scenario 4: Search for a Data Offering and Contract it - Find the Data Offering *Aggregated energy at the substation level* offered by EyPESA and contract it.
  - Scenario 5: Use Data - Use the Data Offering *Smart Meter in the District Heating network* offered by Astea that you have already contracted.
  - Scenario 6: Provide a new Service Offering - Submit the description for a new service offering.
  - Scenario 7: Delete own Service Offering - Find the Service *Energy services for prosumers* offered by ICOM and delete it.
- Data Provider
  - Scenario 1: Register via e-mail - Complete your registration to the OMEGA-X Marketplace via e-mail uploading Self-Description.
  - Scenario 2: Log in via e-mail.
  - Scenario 3: Add new user.
  - Scenario 4: Search for Service and Contract it - *Find the Service Gamification for electrical energy savings* offered by Revolt and contract it.

- Scenario 5: Use Service - Use the Service *Energy services for prosumers* offered by Tecnalia that you have already contracted.
- Scenario 6: Provide new Data Offering - Submit the description for a new data offering.
- Scenario 7: Delete own Data Offering - Find the Data Offering *Smart Meter Measurements* offered by ICOM and delete it.

All participants completed these scenarios during online interviews conducted by a facilitator and assisted by a front-end developer. There was first a brief presentation of the project and a description of how the test would happen. The participant was instructed that there are only specific connections between the pages and there is no option to fill in forms or upload files. Then, the facilitator asked the participant to complete each scenario and kept notes of difficulties or comments (see Figure 1 for an example of the note-taking spreadsheet). In the end, participants gave their general opinion on the Marketplace.

Role: Data Provider				
Task	**Click Path Deviations**	**Observations**	**Quotes**	**Task Completion**
Write the task number and directions here.	Record any path deviations the participant took to complete the task.	Note down behaviors, opinions, and attitudes along with any errors, issues, or areas of confusion.	Note any significant quotes (positive and negative).	Choose if the task was: 1 - easy to complete 2 - completed but with difficulty 3 - not completed
Scenario 1: Register via email			Maybe on top write the title of the steps - DID button is confusing	1
Scenario 2: Login via email				1
Scenario 3: Add new user			maybe mark with * the fields that are mandatory	1
Scenario 4: Search for a Service Offering and Contract it	filtered for services	didn't like the word Contract, since the SP has to accept	"Contract" is a strong word	1
Scenario 5: Use Service			Maybe add a filter in the dashboard	1
Scenario 6: Provide a new Data Offering	searched the whole menu	couldn't find where to go, even after asked to expand, didn't get the Provide	is the sample file only json? - SD should be explained	2
Scenario 7: Delete own Data Offering	again lost in the menu			2
Notes	*Provide icon is difficult to understand* *Also dashboard icon could be different*			

Figure 1 Example of note-taking spreadsheet that was used in the UX study

After the end of the session, participants were given a link to a form with the System Usability Scale [9] (SUS). The SUS is a reliable tool that is being widely used in order to measure the usability of a website or app. It consists of 10 statements that are being answered on a 5-level Likert Scale, from “Strongly Disagree” to “Strongly Agree”. The questions are the following:

- I think that I would use this Marketplace frequently.
- I find the Marketplace unnecessarily complex.
- I think the Marketplace is easy to use.
- I need the support of a technical person to be able to use this Marketplace.
- I find the Marketplace easy to navigate.
- There is inconsistency within the Marketplace.

- I imagine that most people would learn to use this Marketplace quickly.
- I found the OMEGA-X marketplace inconvenient to use.
- I feel confident using the Marketplace.
- I need to learn a lot of things before I can start using this Marketplace.

2.3.3.2 Participants

For the scenarios of the Service Providers, three participants were tested: one from REVOLT, one from SENER ING and one from Tecnalia. For the scenarios of the Data Providers, three participants were tested: one from IMPULSA, one from EyPESA and one from ATOS.

2.3.3.3 Results

Participants had no major issues navigating through the Marketplace. However, none of them were familiar with SSI, and even though it was a simulated SSI registration and log in, extra explanation was needed in all cases. All participants were very pleased with the appearance and aesthetic of the prototype.

The questions of the SUS [10] are generic in order to fit most platforms. A SUS score above 68 is considered an above-average result. A SUS score below 68 is below average [10]. The SUS score of this first OMEGA-X UX study is 80.4, therefore a good result.

The following appearance comments were made by more than one participant:

- Almost all participants had a comment about the side menu. They commented that when the side menu is not expanded, it is not clear what the icons mean. One participant also commented that the “Provide” and “Dashboard” icons are not representative, and another one suggested having the name of each page shown when the pointer is hovering over the icon.
- Two participants commented that it would be more user-friendly if the Dashboard had the different sections (“My Provided Services”, “My Provided Data Sets”, “My Contracted Services”, “My Contracted Data Sets”) in some kind of submenu.
- Two participants suggested that the registration should also have two buttons in the beginning: “Register via DID” and “Register via e-mail”.
- One participant suggested including names for each step of the Registration and the Log in wizard.
- One participant commented that it would be better to see their transactions and balance in graph form in the Dashboard.

2.3.4 Functionality changes on the OMEGA-X Marketplace prototype

There were also some comments on more functional issues that were discussed mostly during one-on-one meetings with data providers and service providers. There were discussions about search filter options for both data and service offerings. Based on OMEGA-X_D3.4 [11], the search filters for the Service Offerings will be “Category” and “Provided to”. “Provided to” means the type of clients this Service Offering is addressed to, e.g. Distribution System Operator (DSOs), Local Energy Communities (LECs), etc. ”Category” will be one of the following:

- Renewable Energy Generation – Operation and Maintenance
- Smart grid data-driven services
- PV smart grid integration

- Planning services
- Gamification services
- Optimisation services
- State estimation and predictive services
- Flexibility management services
- Planning tool for energy community creation
- Other

The search filters for data offerings will be “Geographical location” and “Category”. This last will have two levels, as seen in the list below:

- Generation
  - Maintenance data
  - SCADA
  - HF data
  - Other
- Distribution & Transport
  - Maintenance data
  - SCADA
  - Energy Market Data
  - Other
- Prosumer
  - Smart meter
  - EV
  - HVAC
  - Other
- Non-energy data
  - Weather data
  - Energy tariffs
  - Other

Apart from these filters, the offerings will also be filtered by the Provider that offers them. These filter options will be implemented directly in the Marketplace first release.

Another change discussed was that the Provide section of a Service offering should have the option “Download” (if the Service will be offered with the option to download its’ image on the Users’ connector) or “Compute” (if the Service will be offered online and the User will be redirected in an external environment in order to use the Service). This change was implemented in the preliminary version of the Marketplace, which can be found in Annex A of this document.

The mock-ups showed already that the offerings had the option to be deleted by the Provider. It was discussed, however, the possibility to offer a “Discontinue” option. That means that the offering would continue to exist in the Marketplace for the Users that have already contracted

it, but stop being offered for new contracts. Therefore, a “Discontinue” button will be added to the Dashboard for the Providers.

One more change that was discussed was that the data offerings should have a link to the Vocabulary that it is using (for more details, see section 5 of the current document). This link was added in the preliminary version, both on the Provide page and on the description of the published offering.

2.3.5 Plans for first Marketplace Release

There are pages that had not been implemented in the mock-up version and will be directly introduced in the 1st Marketplace release. These pages are:

- Advanced Search (with the filtering options mentioned in section 2.3.4)
- User Notifications
- User Profile/Settings

Another addition to the 1st Marketplace release will be the implementation of self-descriptions (SDs) [12]. Users will need to upload SDs for themselves, their organisation and their offerings. The official Gaia-X Self-Description Wizard [13] will be used in the OMEGA-X Marketplace.

As the implementation progresses, there will definitely be more aspects of the OMEGA-X Marketplace that will need refinement (e.g. the SSI that will be used) and more functionalities will need to be implemented (e.g. related to the Connector).

2.4 Marketplace Architecture

This section presents the first iteration of the OMEGA-X Marketplace architecture. The work is based on the general OMEGA-X Data Space Architecture, as explained in OMEGA-X_D3.1 [1]. To facilitate convergence with other initiatives within the Data Space ecosystem, the architectural design is heavily influenced by the Blueprint of Data Spaces Support Center (DSSC) [14]. Towards this, this version of the architecture focuses on presenting the building blocks of the Data & App Marketplace and the Data Exchange Services (see Figure 2), updating the initial work presented in OMEGA-X_D3.1.

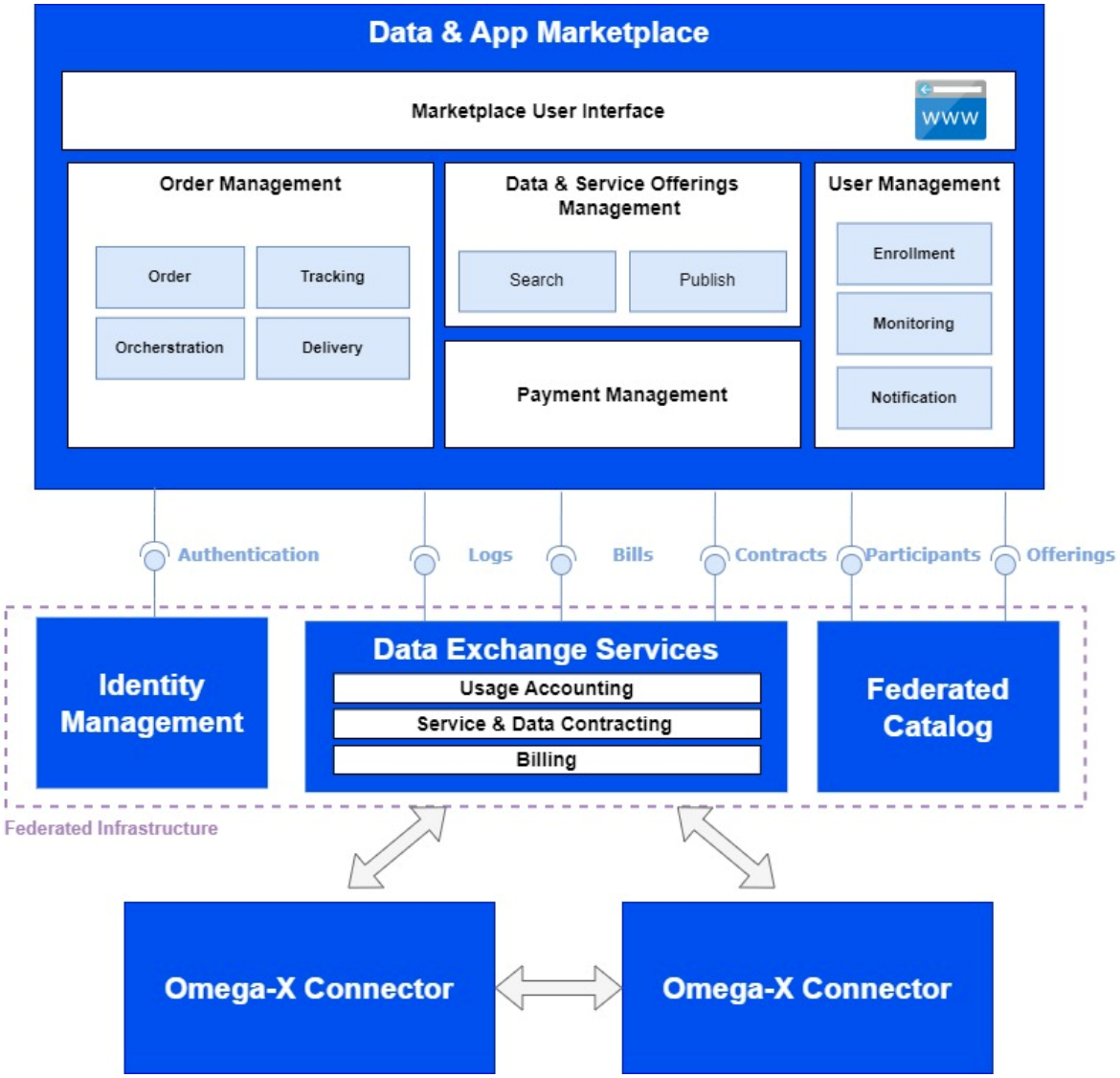

Figure 2 OMEGA-X Marketplace Architecture

The Data & App Marketplace is comprised of the elements shown in Table 1.

Table 1. Data & App Marketplace Components

Component	Description
Marketplace User Interface (UI)	A Graphical User interface enabling the intuitive communication of the user and Data Space. It allows users to search available offerings (Service and Data) in the OMEGA-X Data Space, create and manage offerings/contracts, and manage financial-related activities in the Marketplace. It also provides a channel for users to share their feedback.
Order Management	In charge of the orchestration of an offering (either Service or Data) order, enabling the tracking of the different steps until delivery

Component	Description
Data & Service Offerings Management	It offers users the ability to add, edit and delete Data and Service offerings. The component should provide the ability to set different visibility options for an offering (product) and pricing models.
User Management	This module enables and orchestrates the registering procedure of organisations and the onboarding procedure of new users. It is also responsible for managing all participants of the Data Space as well as their “offboarding”.
Payment Management	Responsible for the payment of an order, on the basis of a usage bill.

The Data Exchange Services are comprised of the elements shown in Table 2.

Table 2. Data Exchange Services Components

Component	Description
Service & Data Contracting	Responsible for managing the contracting of Data and Service offerings among users and providers. It provides a process to allow the tracking the different steps of finalizing or amending a contract.
Usage accounting (ex. Monitoring and Logging)	This module tracks Data transmitted/received with respect to a contract, as well as that the honouring of the usage policies has been respected.
Billing and Settlement	Responsible for managing the settlement and billing of transactions taking place in the ecosystem

3 Analytic Services and Digital Twins

In deliverable OMEGA-X_D3.4, 34 data analytics services and digital twins have been defined. These services are grouped into different use case families.

All the services will be published in the marketplace under certain usage policies.

As part of WP5 the services defined in OMEGA-X_D3.4 “Data analytic services and requirements related to interoperability, security, privacy and data sovereignty” have been reviewed and redefined where necessary. These services are currently being developed as part of WP5 and the first version of the developed solutions and offline validation will be presented as part of OMEGA-X_D5.2 “OMEGA-X Marketplaces release. First release”.

The following section contains an updated list of the data analytics services and digital twins. A detailed explanation of each service is included as part of Annex A.

3.1 Renewables

Table 3 contains the data analytics services and digital twins for renewables (REN) use case family.

Table 3. List of Data Analytics Services - Renewable Use Case family.

Service	Category	Service Developers (SDs)	Data Providers (DPs)	Model Serving Type	End User
Predictive Maintenance for large PV plants	Ren-PV O&M optimisation	Tecnalia	MAG, EyPESA and EDF	Software as a Service	PV asset manager
Benchmarking	Ren-PV O&M optimisation	Tecnalia	MAG, EyPESA and EDF	Software as a Service	PV asset manager
Compare actual production versus expected	Ren-PV O&M optimisation	SENER ING	EDF, EyPESA and MAG	Software as a Service	Plant Operator
PV Cleaning Advisor	Ren-PV O&M optimisation	SENER ING	EDF, EyPESA and MAG	Software as a Service	Plant Operator
Shading Analysis	Ren-PV O&M optimisation	SENER ING	EDF, EyPESA and MAG	Software as a Service	Plant Operator
Tracking algorithm check	Ren-PV O&M optimisation	SENER ING	EDF, EyPESA and MAG	Software as a Service	Plant Operator
Detect measurement errors	Ren-PV Smart Grid Integration	UPC	EyPESA	Software as a Service	DSO, PV plant operator

Service	Category	Service Developers (SDs)	Data Providers (DPs)	Model Serving Type	End User
Detect non-technical losses	Ren-PV Smart Grid Integration	UPC	EyPESA	Software as a Service	DSO
Congestion detection	Ren-PV Smart Grid Integration	UPC	EyPESA	Software as a Service	DSO
Behind-the-meter PV disaggregation	Ren-PV Smart Grid Integration	UPC	EyPESA	Software as a Service	DSO
Plan grid reinforcements for future renewable scenarios	Ren-PV Smart Grid Integration	UPC	EyPESA	Software as a Service	DSO
Energy Generation Forecast	Ren-PV Smart Grid Integration	METEO	EyPESA	Software as a Service	DSO, PV plant operator
Digital Twin BIPV Self Consumption Systems in Buildings	Ren-PV Smart Grid Integration	Tecnalia	EyPESA	Software as a Service	PV asset manager

3.2 Local Energy Communities

Table 4 contains the data analytics services and digital twins for the Local Energy Communities (LEC) use case family.

Table 4. List of Data Analytics Services – Local Energy Communities UCF.

Service	Category	Service Developers (SDs)	Data Providers (DPs)	Model Serving Type	End User
Thermal Losses Detection and Benchmarking at LEC level	LEC O&M optimisation	REVOLT	ASTEA	Software as a Service	Prosumer, ESCO, Local Energy Community manager

Service	Category	Service Developers (SDs)	Data Providers (DPs)	Model Serving Type	End User
Water Losses Detection and Benchmarking at LEC level	LEC O&M optimisation	REVOLT	ASTEA	Software as a Service	Prosumer, ESCO, Local Energy Community manager
Gamification for electrical energy savings	LEC Energy Consumption Optimisation through prosumer engagement	REVOLT	EDP, ASTEA	Software as a Service	Prosumer
Local Energy Communities Designer	LEC Energy Consumption Optimisation through prosumer engagement	REVOLT	EDP, ASTEA	Software as a Service	Prosumer, ESCO, Local Energy Community manager
Electrical losses detection and benchmarking at LEC level	LEC O&M optimisation	UPC	EyPESA, EDP	Software as a Service	Prosumer, ESCO, Local Energy Community manager
Reinforcement Plan of LEC for future renewable scenarios	Planning	UPC	EyPESA, ASTEA	Software as a Service	Local Energy Community manager
Optimizing self-consumption of renewable energy at LEC level	LEC Energy Consumption Optimisation through prosumer engagement	Tecnalia	EyPESA	Software as a Service	Prosumer, ESCO, Local Energy Community manager
Optimizing sharing coefficients in collective self-consumption	LEC Energy Consumption Optimisation through prosumer engagement	Tecnalia	EDP	Software as a Service	Prosumer, ESCO, Local Energy Community manager

Service	Category	Service Developers (SDs)	Data Providers (DPs)	Model Serving Type	End User
Planning services	Planning	Tecnalia	PUPIN	Software as a Service	Local Energy Community manager

3.3 Electromobility

Table 5 contains the data analytics services and digital twins for the Electromobility (EM) use case family.

Table 5. List of Data Analytics Services – Electromobility UCF

Service	Category	Service Developers (SDs)	Data Providers (DPs)	Model Serving Type	End User
EV Charge booker platform	Booking EVCI	AWG	EMRSP	Software as a Service	EMSP
CPO Open for booking	Booking EVCI	GIREVE	CPO	Software as a Service	EMRSP

3.4 Flexibility

Table 6 contains the data analytics services and digital twins for the Flexibility (Flex) use case family.

Table 6. List of Data Analytics Services – Flexibility UCF

Service	Category	Service Developers (SDs)	Data Providers (DPs)	Model Serving Type	End User
Grid observability and network analysis	Predictive services	Odit-e	MAIA / DSO	Software as a Service	DSOs
Grid validation platform, real-time	Flexibility management services	Odit-e	MAIA / DSO	Software as a Service	DSOs and Local Energy Community manager

Service	Category	Service Developers (SDs)	Data Providers (DPs)	Model Serving Type	End User
Flexibility platform for DER connection, planning	Flexibility management services	Odit-e	MAIA / DSO	Software as a Service	Public Institutions, RES & flexibility investors and DSOs
Passive consumption baseline prediction service	Predictive services	Tecnalia	MAIA / DSO	Software as a Service	Flexibility Service Provider and DSOs
Intermittent DER generation resource baseline prediction service	Predictive services	Tecnalia	Portfolio Manager (ISMAI)	Software as a Service	Flexibility Service Provider
Prosumer EMS internal optimisation service	Flexibility management services	Tecnalia	Portfolio Manager (ISMAI)	Software as a Service	Flexibility Service Provider
Flexibility order disaggregation service	Flexibility management services	Tecnalia	Portfolio Manager (ISMAI)	Software as a Service	Flexibility Service Provider
Aggregated flexibility offers optimisation service	Flexibility management services	Tecnalia	Portfolio Manager (ISMAI)	Software as a Service	Resource Aggregator and Flexibility Service Provider

Also, the information for some of the services has been updated in the corresponding templates available in Annex B.

4 Identity Management and Security

OMEGA-X will develop a Trust Anchor, which will include all the identity management and security requirements defined in deliverable OMEGA-X_D3.4 “Data analytic services and requirements related to interoperability, security, privacy and data sovereignty”.

The OMEGA-X Trust Anchor will be built reusing a previously existing IDSA Identity provider, which will be adapted to make it compatible with the Gaia-X Trust Framework. This approach will allow the reuse of previous work and also will allow legacy projects based on IDSA to be incorporated into the OMEGA-X Energy Data Space.

Following the IDSA reference architecture (Figure 3), the identity provider is formed of two main components: 1) Certification Authority (CA) and 2) Dynamic Attribute Provisioning Service (DAPS).

The Certification Authority issues X509 v3 digital certificates for all entities. These certificates are used for authentication between connectors. In particular, according to IDSA reference architecture, participants are registered with a digital identity (X.509 certificate) alongside other established external identifiers. An identity may have several attributes which are linked to that identity.

A Dynamic Attribute Provisioning Service is used to provide dynamic, up-to-date attribute information about Participants and Connectors. By means of the DAPS component, the reissuance of certificates is avoided whenever participant attributes are updated.

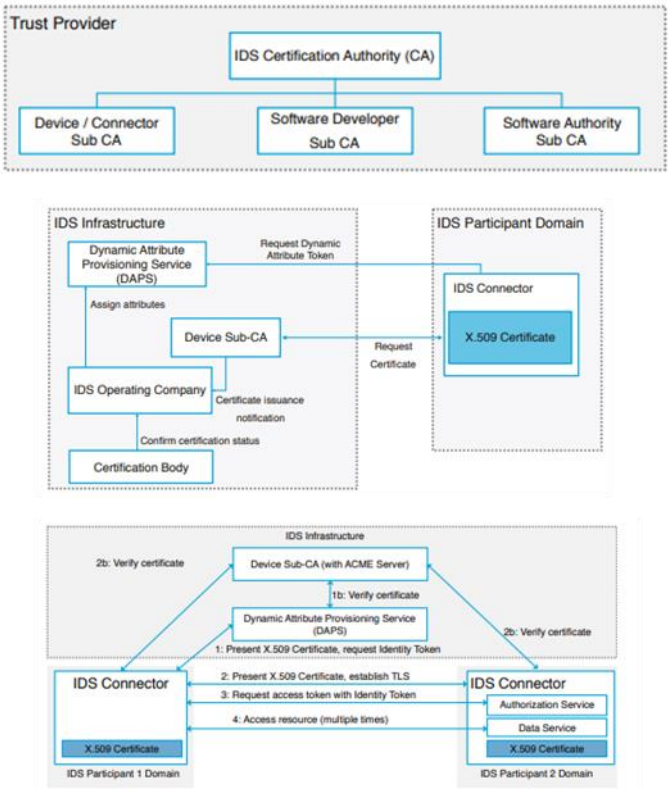

Figure 3 IDSA Reference Architecture: Identity Provider

However, the Gaia-X Trust Framework is based on the concept of self-sovereign identity. In this case, identity management and verification are decentralised from central identity providers. On the contrary, as explained before, IDS reference architecture is based on the use of federated central Identity Providers containing the information of every participant in the

ecosystem. Authentication and authorisation between connectors require the participation of these Identity Providers. In centralised identity management solutions, these components are crucial to providing Trust among participants in the ecosystem.

The change of paradigm imposed by the Gaia-X Trust Framework removes the necessity of central Identity repositories. However, Trust among participants is still needed, and this is where Gaia-X Trust Anchors come into play. Trust Anchors in Gaia-X are responsible for the issuance of Verifiable Credentials (VC) to the participants (holders). These VC issuers need to be registered into the Gaia-X Registry to be considered valid issuers of credentials inside the ecosystem. After the issuance of the credentials, the holders are responsible for securely managing these credentials. OMEGA-X's proposed identity management solution seeks compatibility with both Gaia-X and IDSA architectures. Compatibility is made possible thanks to the Certification Authority included in IDSA. OMEGA-X solution will issue certificates for IDSA connectors and register the required information in the DAPS on the one hand. On the other hand, it will issue Gaia-X compatible Verifiable Credentials based on X509v3 certificates. This approach is aligned with the Data Spaces Business Alliance (DSBA). This organisation is working actively in the convergence of the different existing European data spaces ecosystem and architectures. Regarding SSI Identity management, the proposal of the DSBA, described in their document "Technical Convergence. Discussion Document" [15], is to rely on identifiers already used in digital certificates for the issuance of Verifiable Credentials. Thus, it is possible to establish a bidirectional mechanism to derive DIDs (Decentralised Identifiers) from digital certificates. The adoption of this approach was the initial proposal of OMEGA-X identity management solution. It will allow to easily board on the Gaia-X ecosystem connectors containing IDSA certificates while their certificates are still valid in the IDSA ecosystem.

In the case of Gaia-X, the OMEGA-X credential issuer will be responsible for issuing Verifiable credentials based on X509v3 digital certificates. Therefore, the OMEGA-X Identity provider will contain a certification authority capable of issuing both IDSA and Gaia-X digital certificates. Besides, in the case of Gaia-X, OMEGA-X identity solution will also issue a Verifiable Credential, taking identifiers from the issued certificate. Afterwards, and prior to sending the VC to the holder, the OMEGA-X credential issuer will register the VC into the Gaia-X Registry.

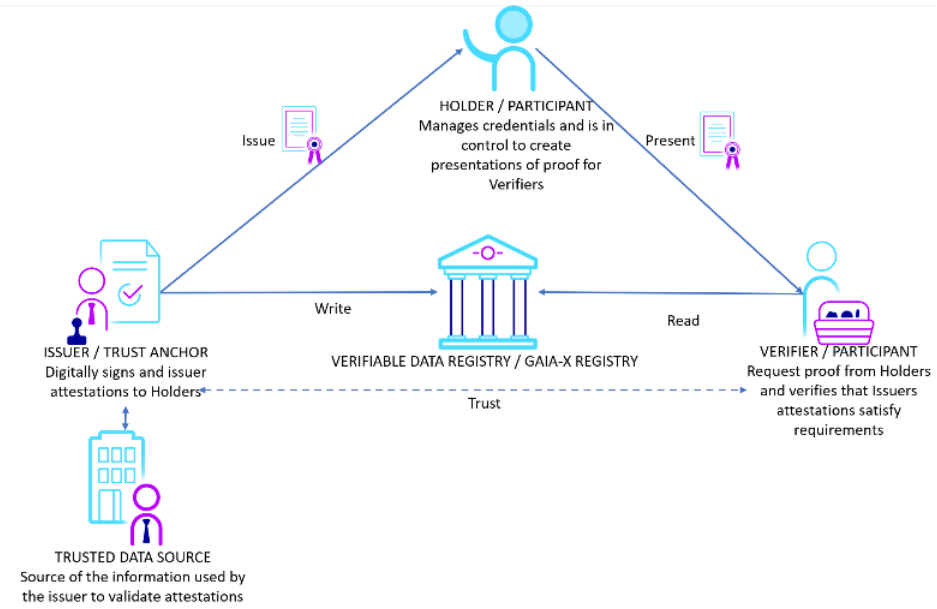

Figure 4 Gaia -X Trust Framework.

In this model (Figure 4), the Trust Anchors can be either:

- The entity in direct control of the Trusted Data Source
- An entity recognised by Gaia-X, also known as Notary, to translate Trusted Data Sources on behalf of the entity managing the Trusted Data Source into Verifiable Credentials.

In summary, OMEGA-X will develop an IDSA and Gaia-X compatible credential issuer based on X509v3 certificates.

5 Vocabulary

According to the interoperability requirements defined in OMEGA-X_D3.4 “Data analytic services and requirements related to interoperability, security, privacy and data sovereignty“ and following the FAIR (Findable, Accessible, Interoperable and Reusable) data principles, the OMEGA-X marketplace will contain the metadata that describes the Data sets and the Services. The metadata will be annotated according to the Common Semantic Data Model (CSDM) (example seen in Figure 5) defined in deliverable OMEGA-X_D4.1 ”Data ingestion, Common Information Model and semantic interoperability“ [16].

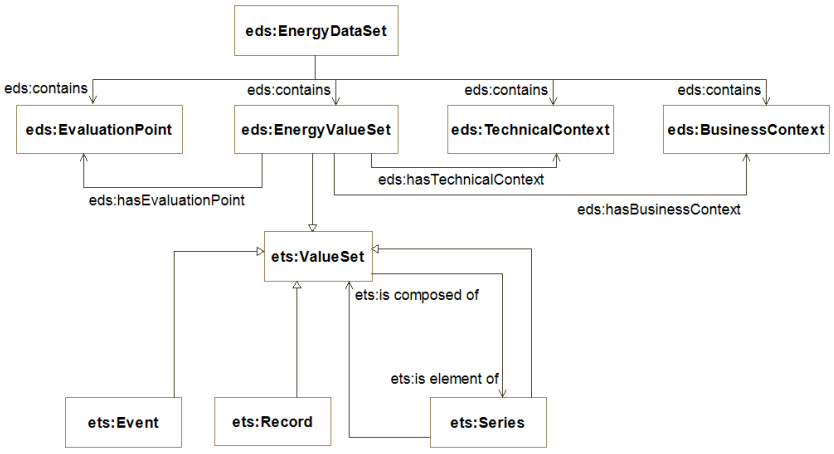

Figure 5 Overview of EnergyDataSetOntology [16]

In addition, the OMEGA-X Marketplace will include a link to the Energy Vocabulary Hub developed by TNO, where the OMEGA-X Common Semantic Data Model (CSDM) defined in deliverable OMEGA-X_D4.1 “Data ingestion, Common Information Model and semantic interoperability“ will be published along with other data models from other projects (e.g. ENERSHARE, PLATOON, BD4NRG, etc.) [17].

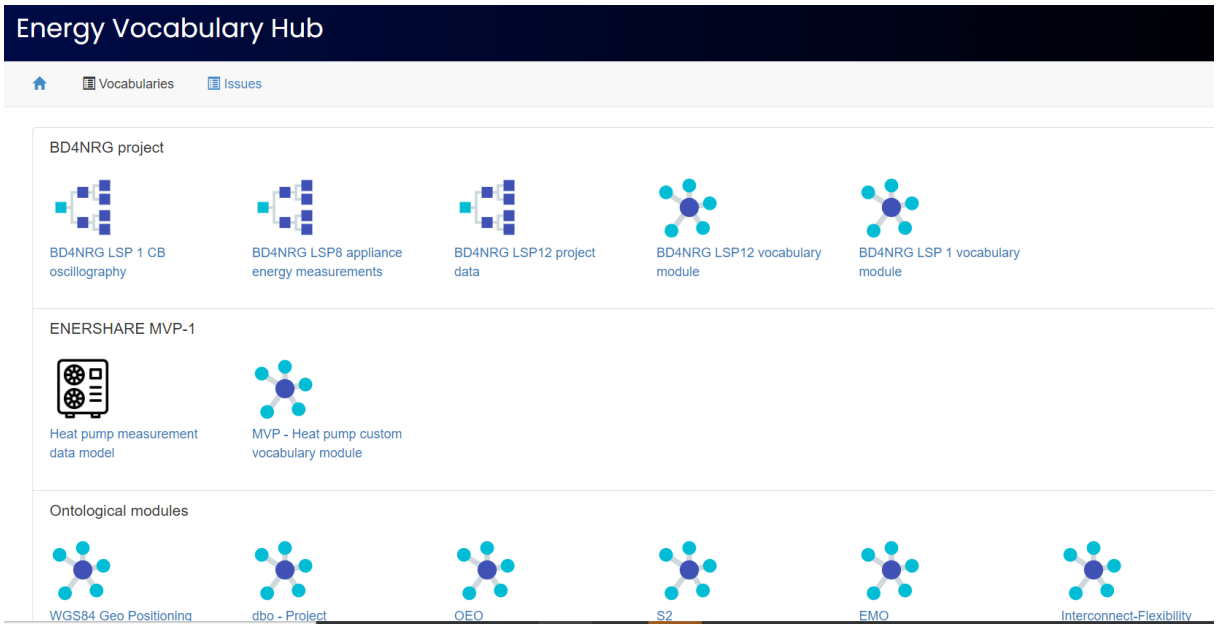

Figure 6 Energy Vocabulary Hub [17]

The Energy Vocabulary Hub (Figure 6) provides a graphical UI (example in Figure 7) that enables one to consult and visualise the different data models/ontologies in order to understand the meaning of the different concepts and properties and the relationships amongst them.

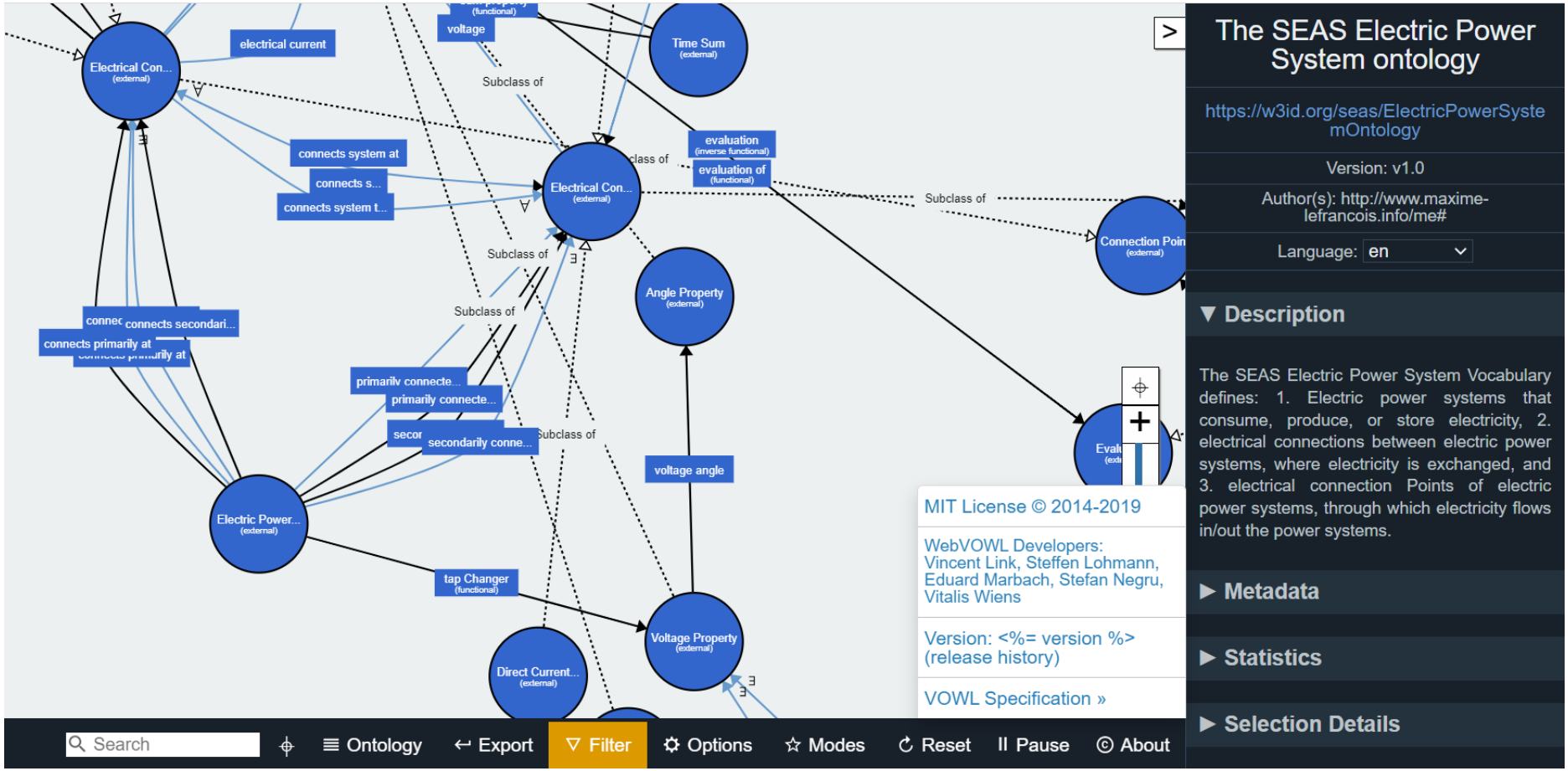

Figure 7 Energy Vocabulary Hub - Example visualisation of SEAS Electric Power System Ontology [17]

6 Infrastructure monitoring services

This section covers the infrastructure-related choices and options envisaged for OMEGA-X to apply.

It is worth noting that the discussion started here (and to be complemented in future deliverables such as OMEGA-X_D4.2 “Release of the Data Space federated implementation” [18]) applies only to the federated side of the OMEGA-X architecture, as detailed in OMEGA-X_D3.1 “Use Cases and Architecture living report. First release” [1]. This means the selection and description of the cloud environment and technologies do not apply to the data platforms selected to be used at a pilot site level but to the Data Space itself, covering both the Federation Services and the Marketplace.

ATOS, as leader of the implementation of the Data Space, will host these services and maintain and operate them, providing the required access to all OMEGA-X parties in different roles, including other module integrators, Data/Service Providers and Data/Service Users.

In the following section, a first analysis is provided for the baseline technologies and choices to be made to materialise this Data Space. In future deliverables (including the aforementioned OMEGA-X_D4.2 and also the update of this report), the concrete implementation details of both the Federation Services (OMEGA-X_D4.2) and the marketplace (OMEGA-X_D5.2) will be included.

The discussion covers three primary topics: cloud environment selection (Section 6.1), the implementation of readiness and liveness probes (Section 6.2), and logging and monitoring solutions (Section 6.3). These components are vital for ensuring the reliability, performance, and security of the OMEGA-X infrastructure.

- Section 6.1 delves into the crucial decision of choosing between public and private cloud options for hosting OMEGA-X Services. It highlights the importance of data privacy and governance, particularly concerning European data principles.
- Section 6.2 focuses on the implementation of readiness and liveness probes within the OMEGA-X infrastructure. It discusses the significance of containerisation and introduces Kubernetes as a container orchestrator.
- Section 6.3 covers logging and monitoring solutions adopted by OMEGA-X. It investigates open-source monitoring services and discusses the importance of data visualisation tools.

6.1 Public versus Private cloud options

Recently, there has been a clear trend towards migrating all services to the cloud. However, behind the concept of cloud, there are some distinct approaches that result in significant differences when they are implemented. There are essentially two types of cloud providers: public and private. Public cloud providers offered by major tech companies such as Amazon (AWS), Microsoft (Azure), and Google (Google Cloud) are the most popular choices. Despite being less popular, some private cloud providers also offer interesting benefits compared to the public alternative.

First and foremost, from a data privacy standpoint, there is a significant interest in avoiding the use of American companies to host European data and services. Even though their physical infrastructure might be located in Europe, their governance is abroad, which might be a violation of the current data privacy and protection regulations. Moreover, from a strategic point

of view, there are also some valid concerns about paying the services of these American companies with the funds of European contributors.

On the other hand, there are multiple private cloud providers with both their infrastructure and governance based in European countries. For the OMEGA-X project a private cloud provider (Leaseweb [19]) located in the Netherlands was selected.

Among the multiple options the provider offers, for the context of the OMEGA-X project, it was selected to lease dedicated bare metal servers. This requires some extra steps to have the infrastructure fully working but pays off by offering total control over the data and services hosted.

6.2 Readiness & Liveness probes

From the software perspective, the services deployed in the infrastructure must be containerised. This adds an extra layer of security and robustness to the platform. Kubernetes is the open-source container orchestrator used. It is the state-of-the-art orchestrator engine and is the *de facto* standard. Orchestrating the containers not only means deploying, updating, or removing them, but it also has to do with preserving the state, monitoring, early identifying downtimes, and automatically executing the appropriate measures to solve those issues without any human interaction.

Kubernetes offers the possibility to create what they call readiness and liveness probes. These are some tests that can be configured to be executed periodically and can identify if the pod ("Pods are the smallest deployable units of computing that you can create and manage in Kubernetes." [20]) is working properly.

The liveness probe detects when a pod is in a deadlock state. This means that it is capable of identifying when the pod is not responding to any request for whatever reason despite being deployed. When the pod fails to reply to the liveness probe a certain number of times (this threshold is configured by the developer), the orchestrator kills the pod and starts the process of redeploying it.

Analogously, the readiness probes detect when a service is ready to start receiving traffic. This is extremely useful as it allows zero downtime when updating services.

Both probes together offer useful orchestrating capabilities and minimise the downtime as well as ensure high availability services.

6.3 Logging and Monitoring

Alongside the Kubernetes probes, there are more specific solutions that can help collect services logs and metrics, visualise them and set alarms that trigger automatically under predetermined circumstances.

A popular option for monitoring metrics is Prometheus [21]. It is an open-source monitoring service that collects all kinds of metrics from the services and can help to diagnose not only non-working services but also small inefficiencies or performance losses.

Prometheus follows a pull strategy for collecting the metrics. This means that the service that is being monitored must make its metrics available (typically over HTTP), but it is the Prometheus server which initiates the communication to get them. Although both approaches (push and pull) are valid, as they state in their frequent asked questions [22], the pull methodology might be slightly better in some scenarios.

Although the metrics collected by Prometheus might be valuable by themselves, it is usually recommended to feed them into some visualisation tools. These tools simplify data

management and help get better insights from the raw data. There are multiple visualisation tools available, each one tailored for a specific use case (e.g. Kibana [23] is a great alternative when it's used alongside Elasticsearch).

Grafana [24] is another open-source solution that provides metrics and logs visualisation capabilities and presents great integration with Prometheus. Compared with Kibana, Grafana offers a wider range of options that cover the whole data pipeline, from logs and metrics monitoring to aggregation and visualisation.

On top of all these functionalities, Grafana also benefits from an alerting system that opens the possibility to configure custom alerts and define actions that shall be triggered based on them. These alerts can be configured to use both the metrics and logs that are already inside Grafana and open data from The Internet or other public sources.

In summary, the end-to-end solution proposed for monitoring the marketplace (and the rest of the services) counts on cutting-edge containerisation and orchestration technologies and an open-source stack of tools for collecting metrics and logs, aggregating them, extracting the useful information through a web dashboard and launching alerts and jobs to notify unwilling behaviours.

6.4 Conclusions

This section outlines critical choices made within the OMEGA-X project's infrastructure monitoring services. These choices encompass the selection of a private cloud provider, the implementation of readiness and liveness probes using Kubernetes, and the adoption of Prometheus and Grafana for comprehensive logging and monitoring. These decisions collectively contribute to the project's goals of ensuring data privacy, maximizing system reliability, and effectively monitoring its infrastructure, ultimately supporting the success of OMEGA-X.

- OMEGA-X acknowledges the importance of data privacy and governance, particularly concerning European data hosted by American companies. A choice is made for a private cloud provider located in the Netherlands, emphasizing the advantages of this selection, such as enhanced control over Data and Services.
- Kubernetes, as the chosen container orchestrator, is a state-of-the-art orchestrator engine, which plays a pivotal role in automating deployment, updates, and issue resolution. Readiness and liveness probes are configured and utilised to ensure the proper functioning of pods and services, minimizing downtime and ensuring high availability.
- Prometheus is chosen as an open-source monitoring service, collecting metrics and diagnosing issues using a pull strategy for metric collection. Grafana's integration with Prometheus and its capabilities for metrics and logs visualisation is the more actionable choice.

7 Conclusions

This report documents the work performed under the WP5 tasks: *T5.1 - Development of analytic services*, *T5.2 - Digital twins* and *T5.3 - Development of data and services marketplace*. The document presents the preliminary version of the OMEGA-X Marketplace Design, detailing:

- The functionalities of the Marketplace, the design of its Graphical User Interface, and its high-level technical architecture
- The analytic services and digital twins that will be offered through the Marketplace.
- Supporting mechanisms of the Marketplace's operation, i.e. identity management and security, vocabulary and infrastructure monitoring services.

In the context of the analysis of the functionalities and UI design of the OMEGA-X Marketplace, a variety of existing marketplaces (e.g. BD4OPEM [5], PLATOON [6], AGORA [7]) were analysed, as well as reference work from Data Space initiatives (e.g. Gaia -X portal [3], Pontus-X [8], DSSC [14]). A preliminary design was made and validated with members of the consortium, resulting in a set of high-fidelity interconnected mock-ups, which will be used as a basis for the implementation phase. Leveraging the work of DSSC, a decomposition of the system was done in a high-level architecture, enabling a mapping of the different interfaces for further detailing the components.

All Services that will be offered through the Marketplace are presented by UC Family, detailing their category, the Service Developer/Data Providers/End Users that will be involved, along with details on how the Services will be offered through the Marketplace. Annex B of the report provides a more detailed description of each Service.

The identity management and security of OMEGA-X is heavily influenced by Gaia-X [25] and IDSA [26]. OMEGA-X will develop a Trust Anchor, which will be in line with the Gaia-X Trust Anchors. The credential issuer that will be used in the OMEGA-X project will be compatible with IDSA and Gaia-X and will be based on X509v3 certificates.

OMEGA-X Common Semantic Data Models (CSDM), defined in OMEGA-X_D4.1, will be utilised for modelling the metadata, whilst OMEGA-X Marketplace will be linked to the Energy Vocabulary Hub developed by TNO in the context of sister projects.

Regarding the underlying infrastructure monitoring services of the Marketplace, the document presents the reasons for the chosen cloud hosting solution and analyses the readiness and liveness probes for the infrastructure services of the Marketplace that will be created using Kubernetes [20] as an orchestrator. Prometheus [22] and Grafana [24] will be utilised for log monitoring.

This report is making the first presentation of the OMEGA-X Marketplace, further refining the Data Space architecture analysed in OMEGA-X_D3.1 [1] for the specific architectural element, creating a steady base for the development phase. In parallel with this first release of the Marketplace, prototyping of its different components has begun aiming for a Minimum Viable Product, which will uncover more details that need to be decided, more Marketplace functionalities that will need to be added or more clarifications that need to be made on the existing list of functionalities. The progress in regard to the design and implementation of the different building blocks of the marketplace will be documented in future iterations of this report.

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9 ANNEX A: Marketplace Design

A.1 Welcome page, Register and Login

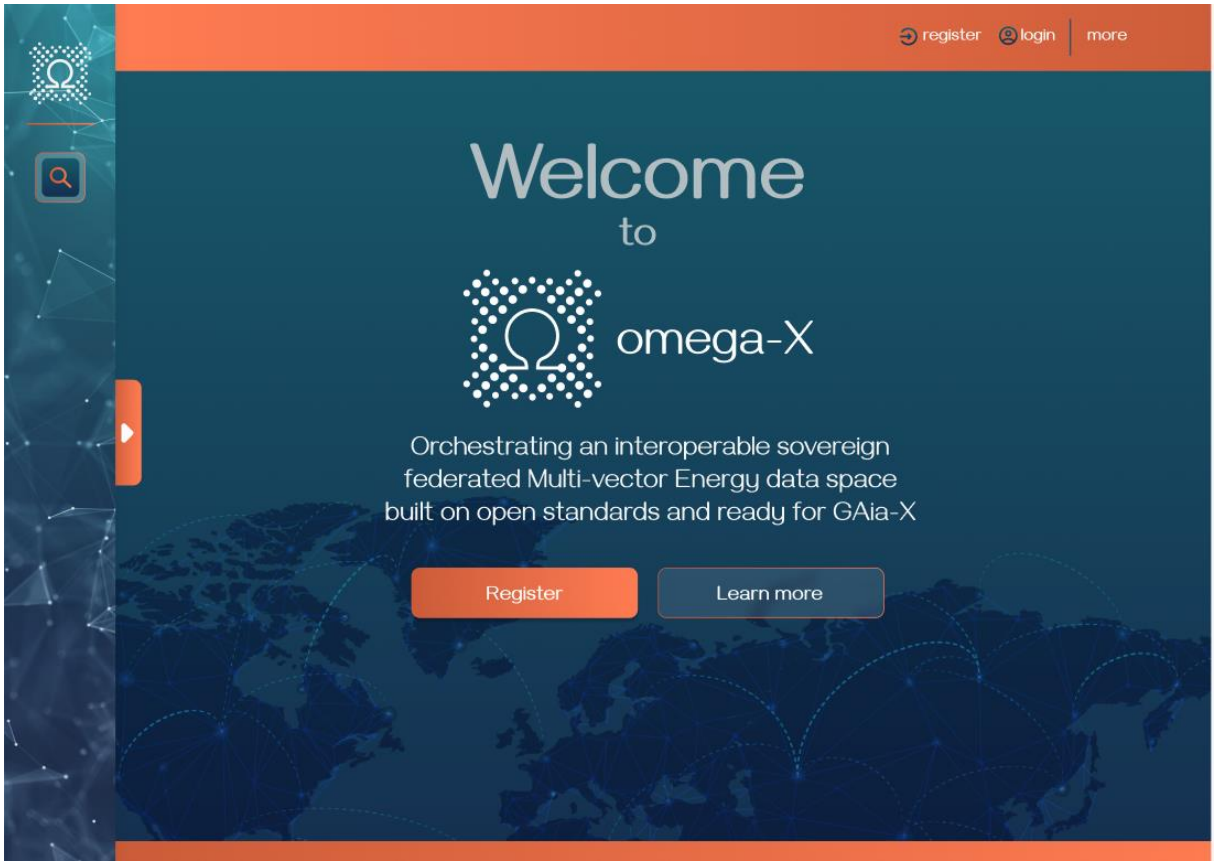

Figure 8 Welcome page of OMEGA-X Marketplace

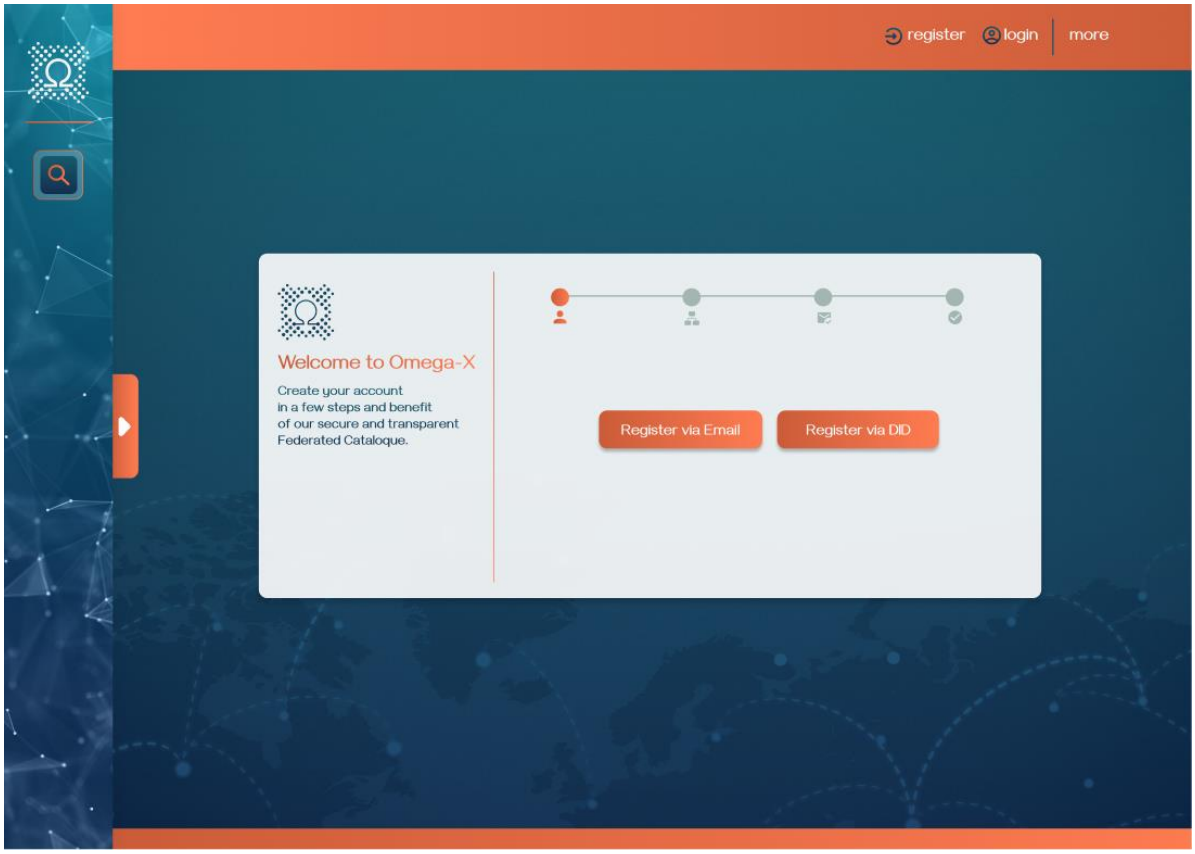

Figure 9 Register: Step 1

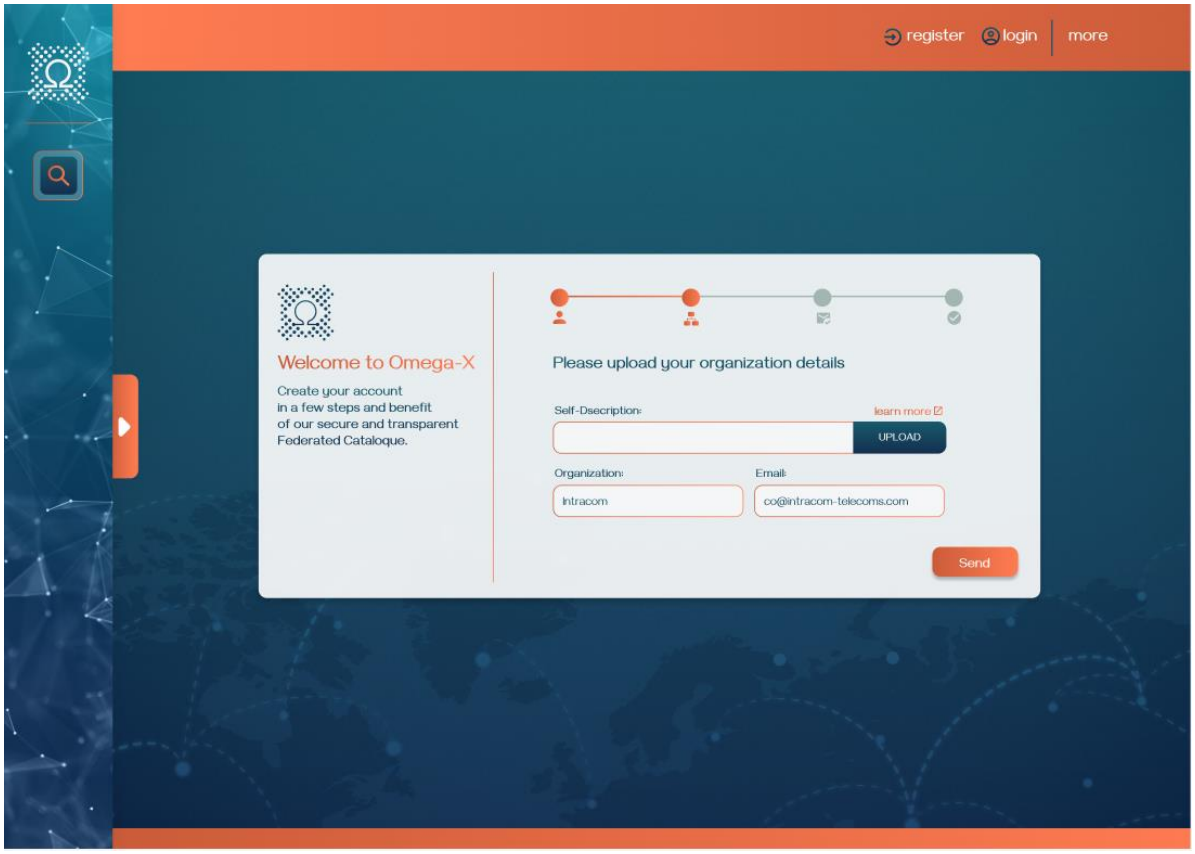

Figure 10 Register via e-mail

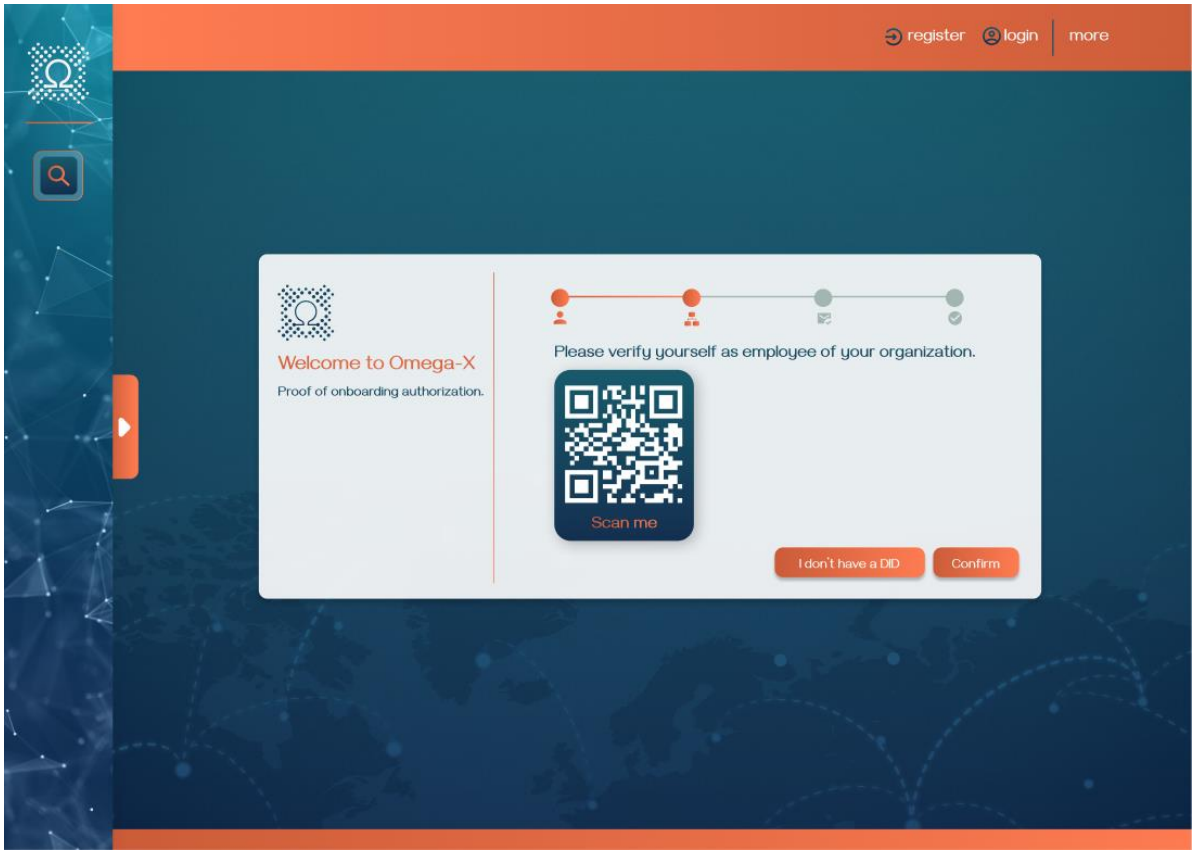

Figure 11 Register via DID

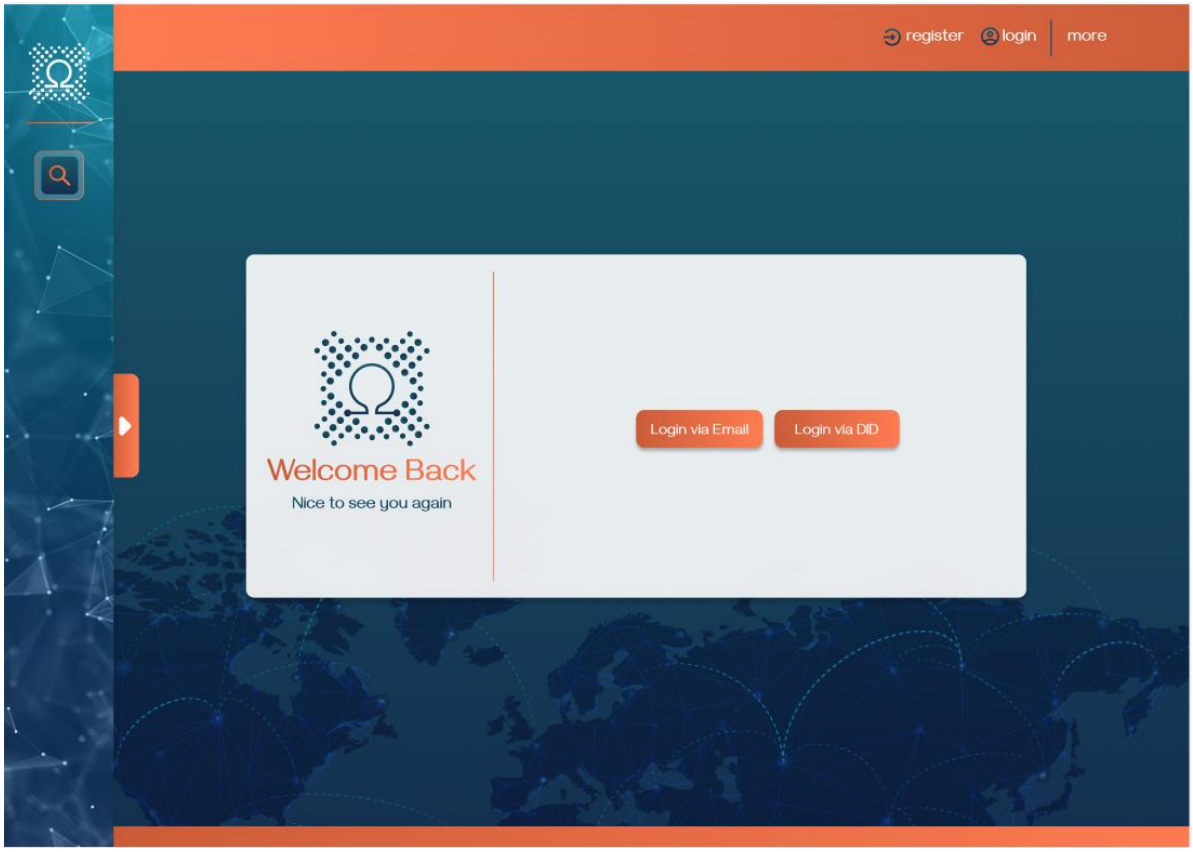

Figure 12 Login: Step 1

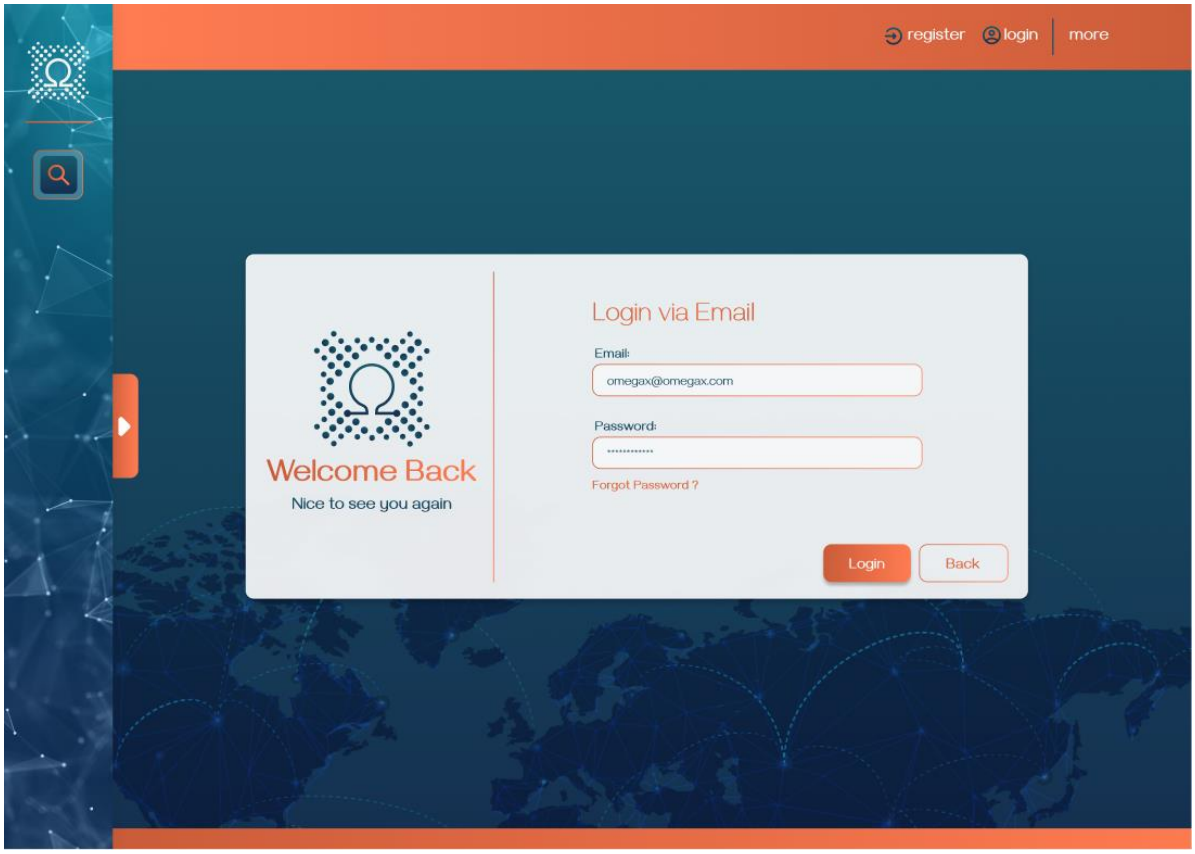

Figure 13 Login via e-mail

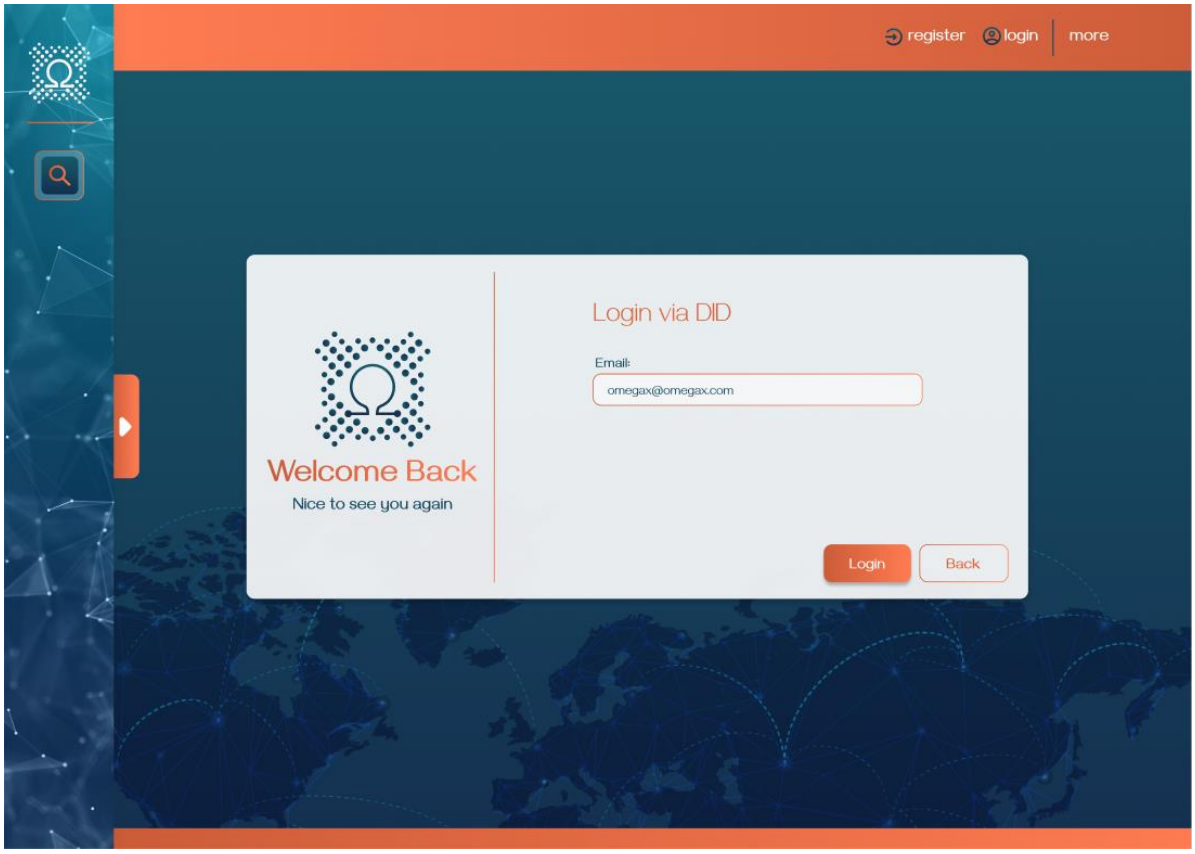

Figure 14 Login via DID

A.2 Search and Contract

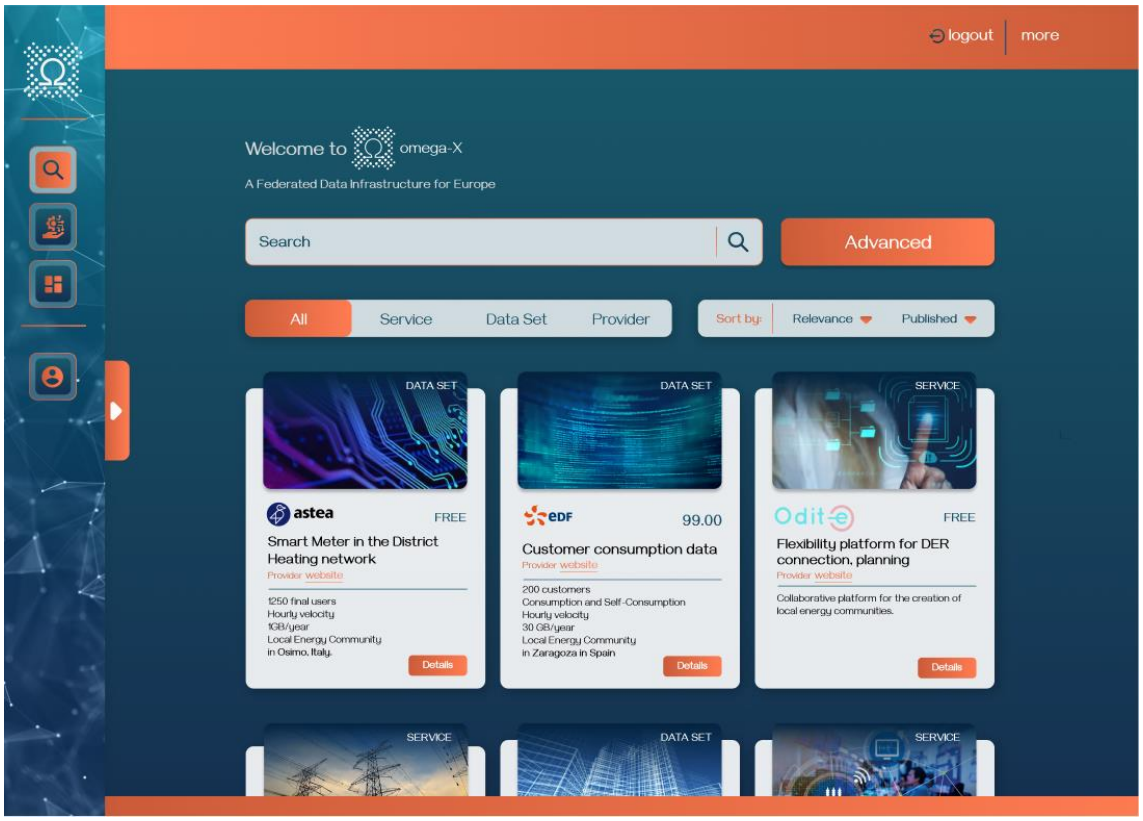

Figure 15 Search page

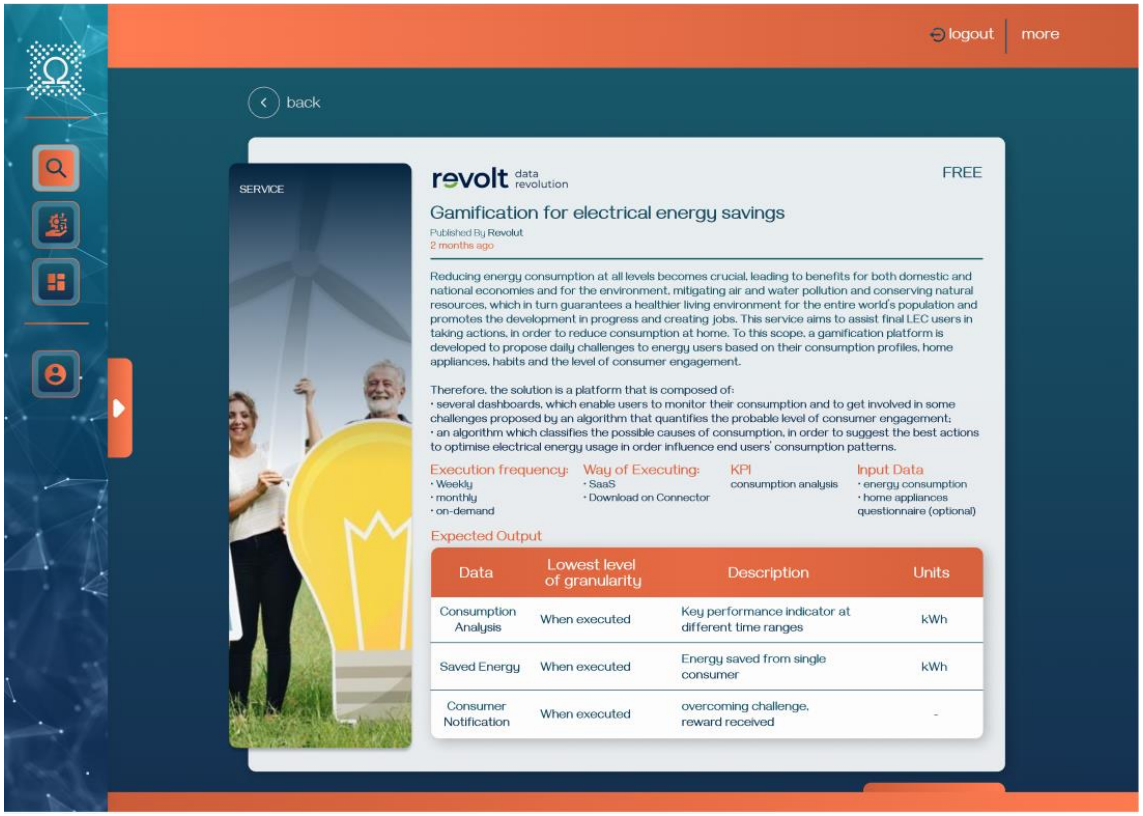

Figure 16 Service Offering example

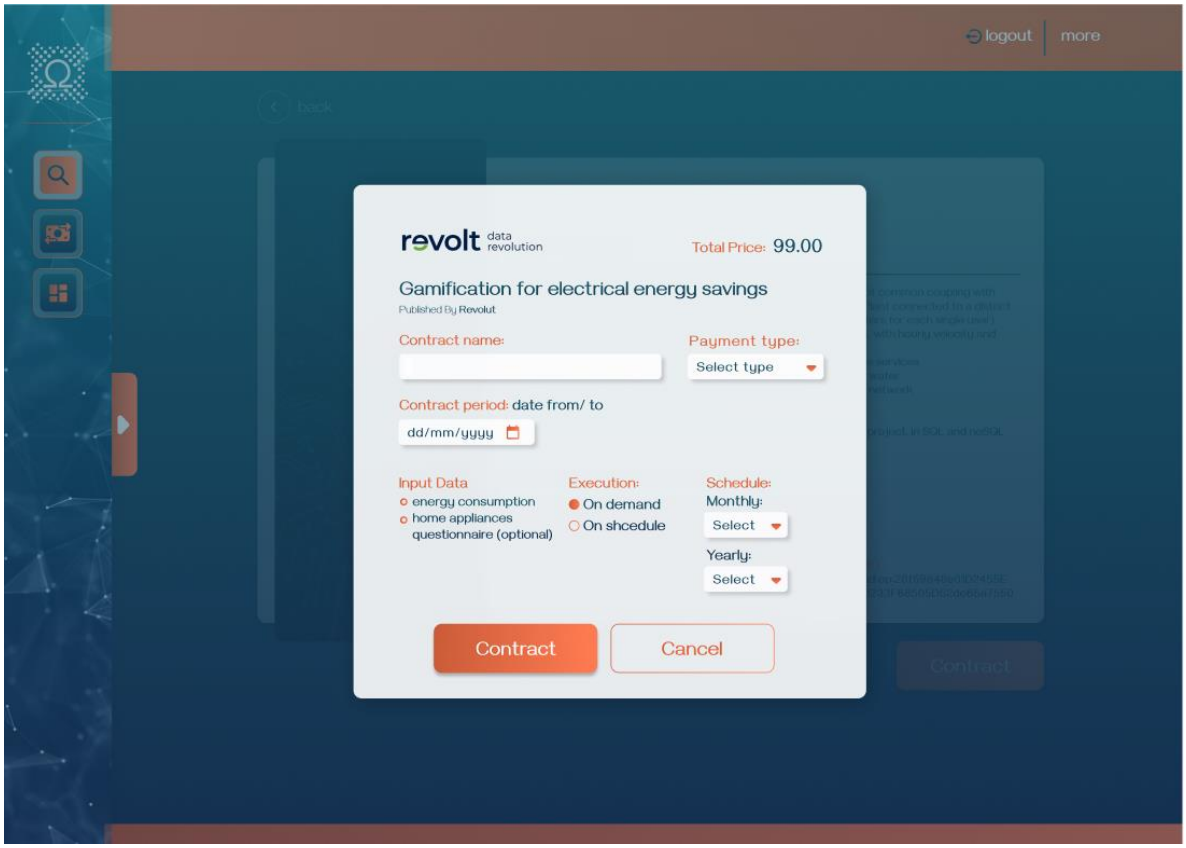

Figure 17 Service Offering example: Contract page

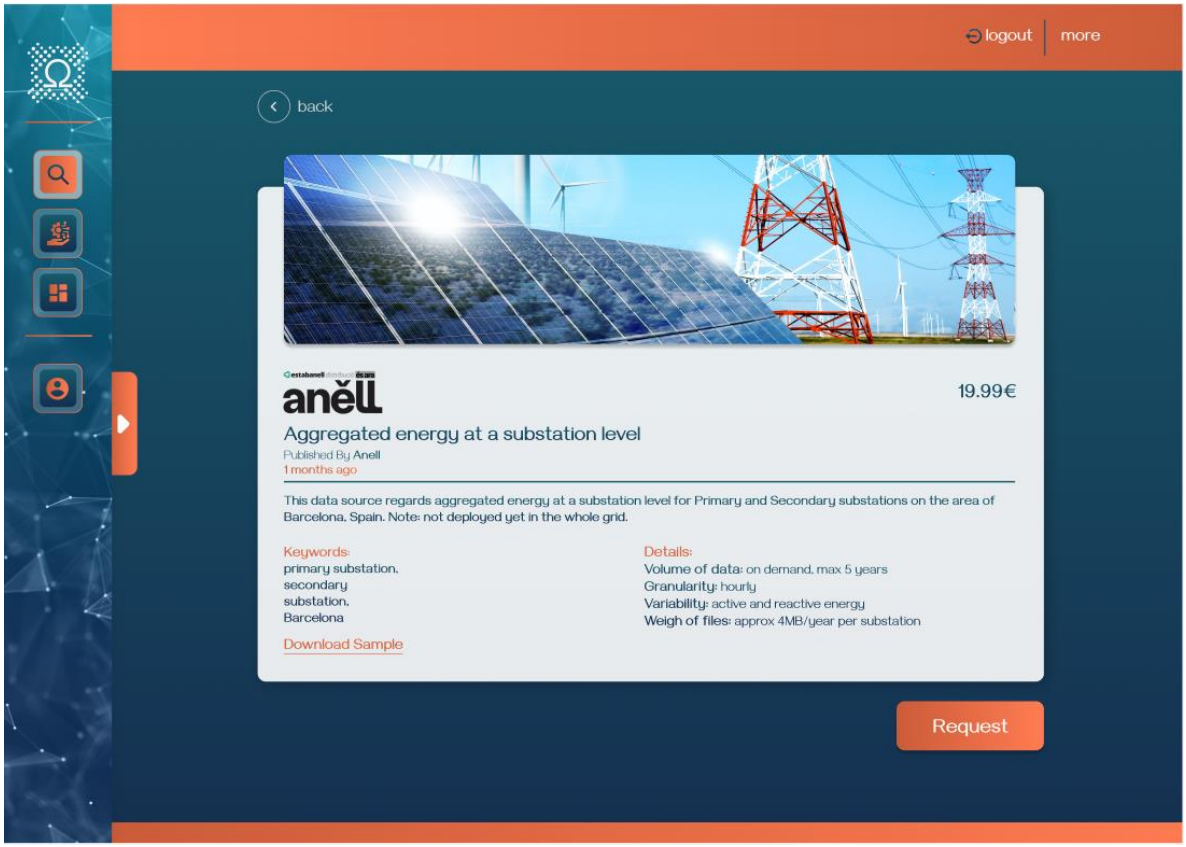

Figure 18 Data Offering example

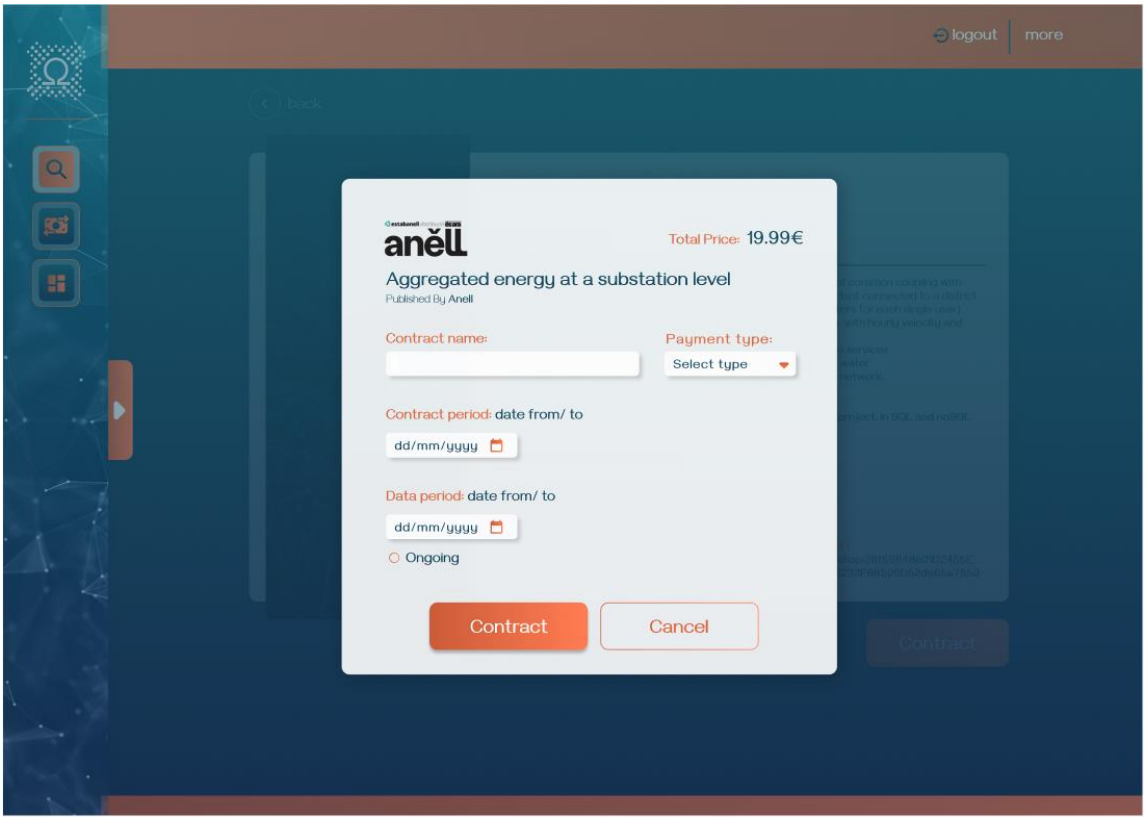

Figure 19 Data offering example: Contract page

A.3 Provide

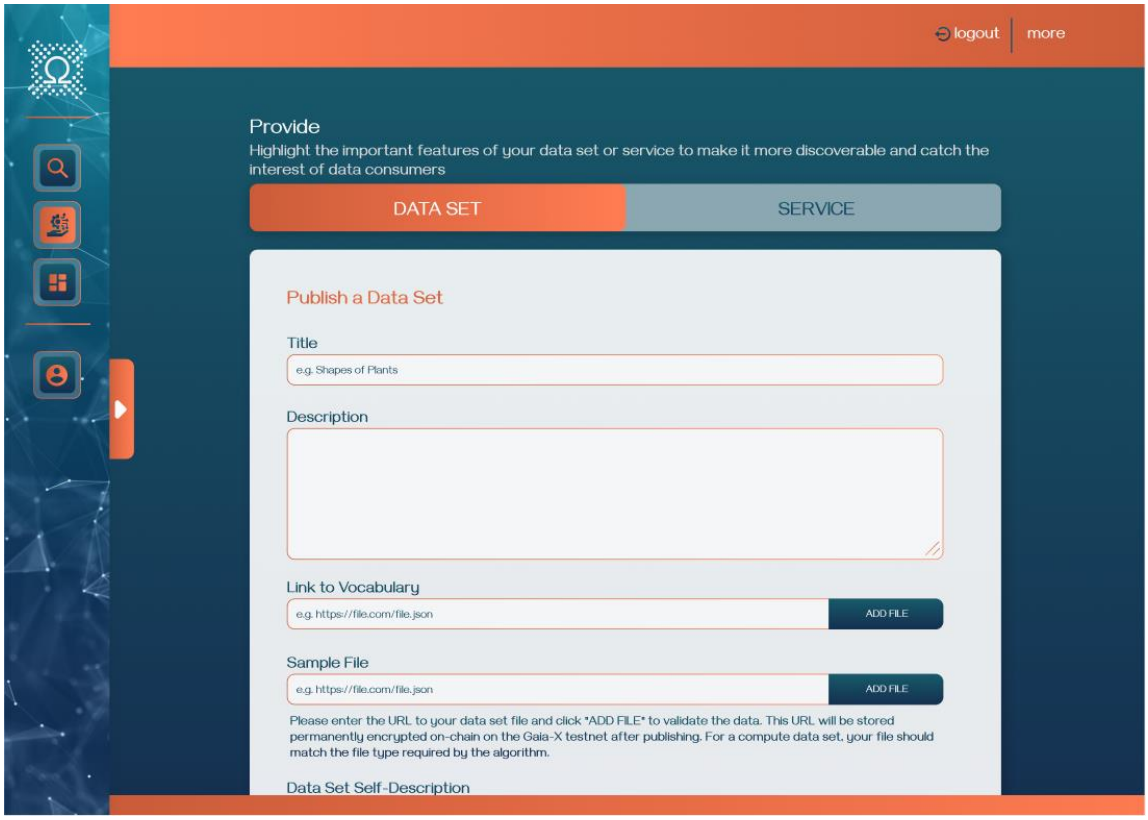

Figure 20 Provide Data Offering: top of page

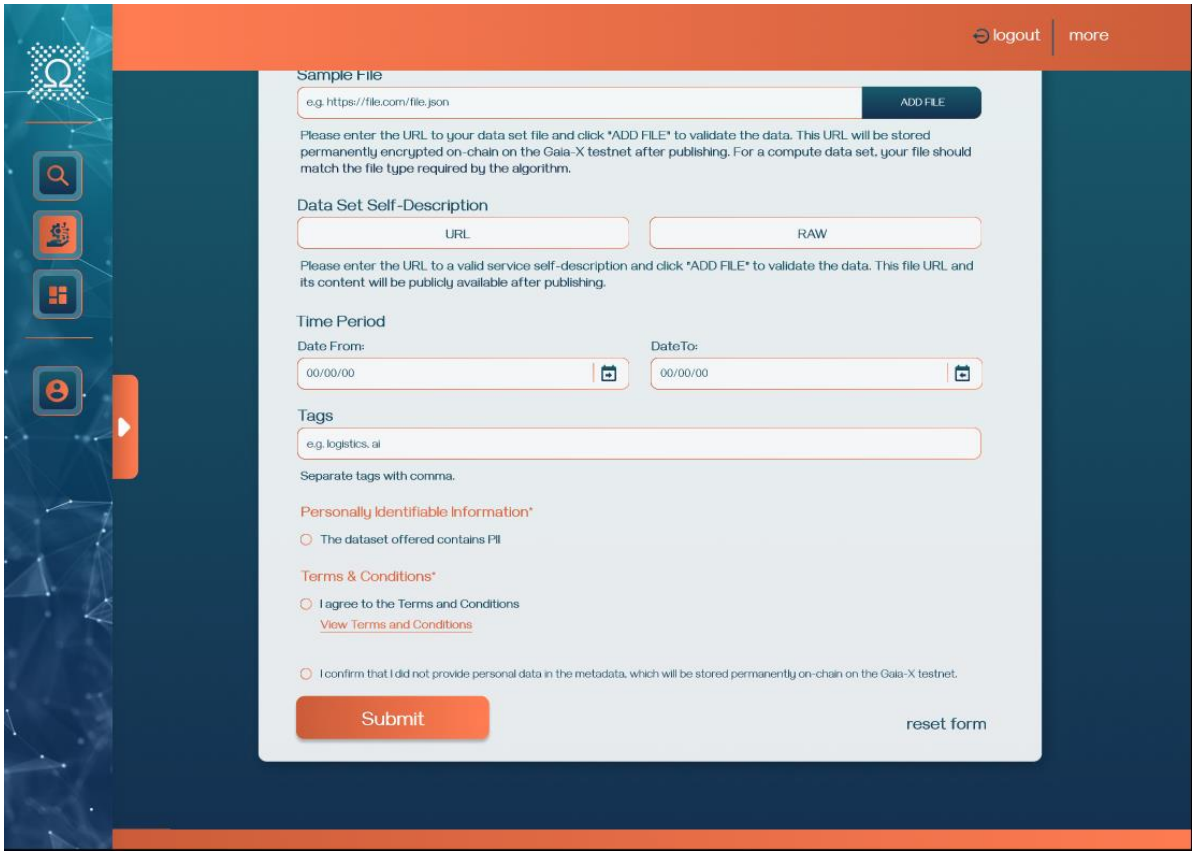

Figure 21 Provide Data Offering: bottom of page

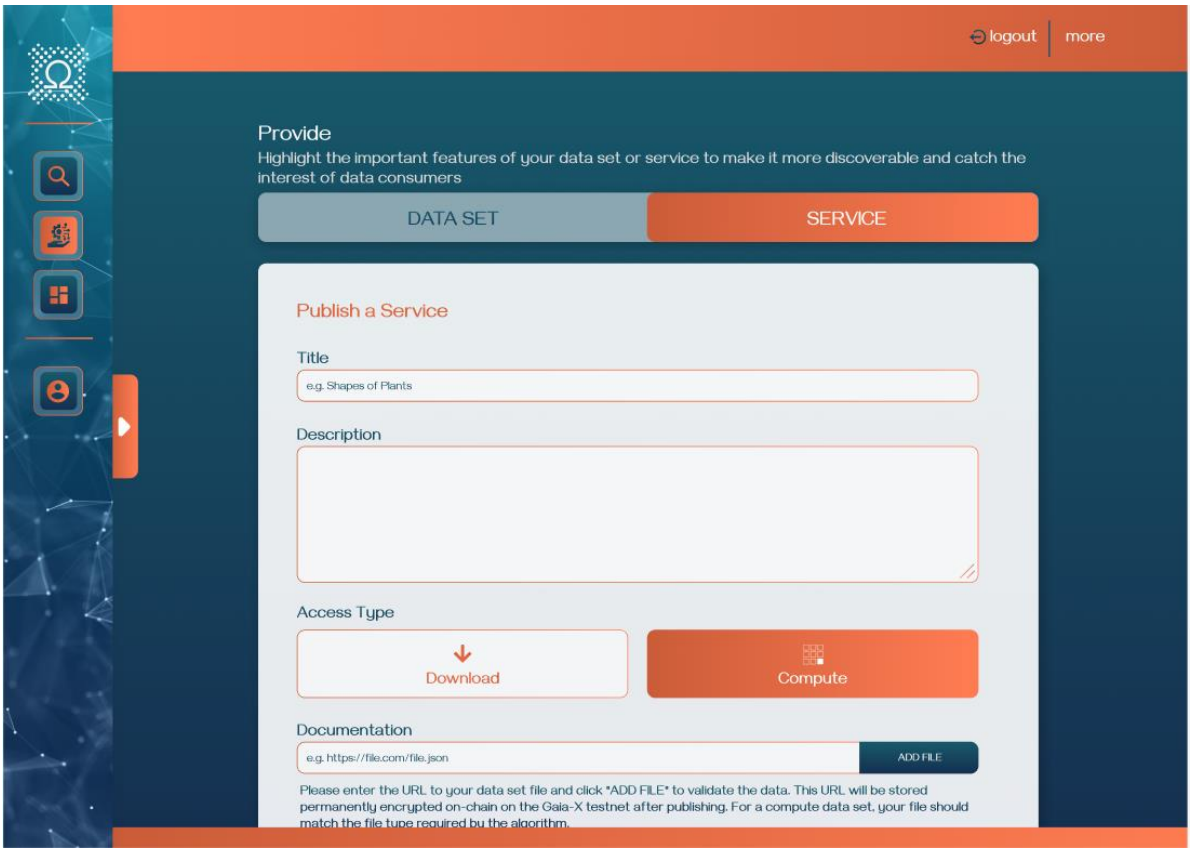

Figure 22 Provide Service Offering: top of page

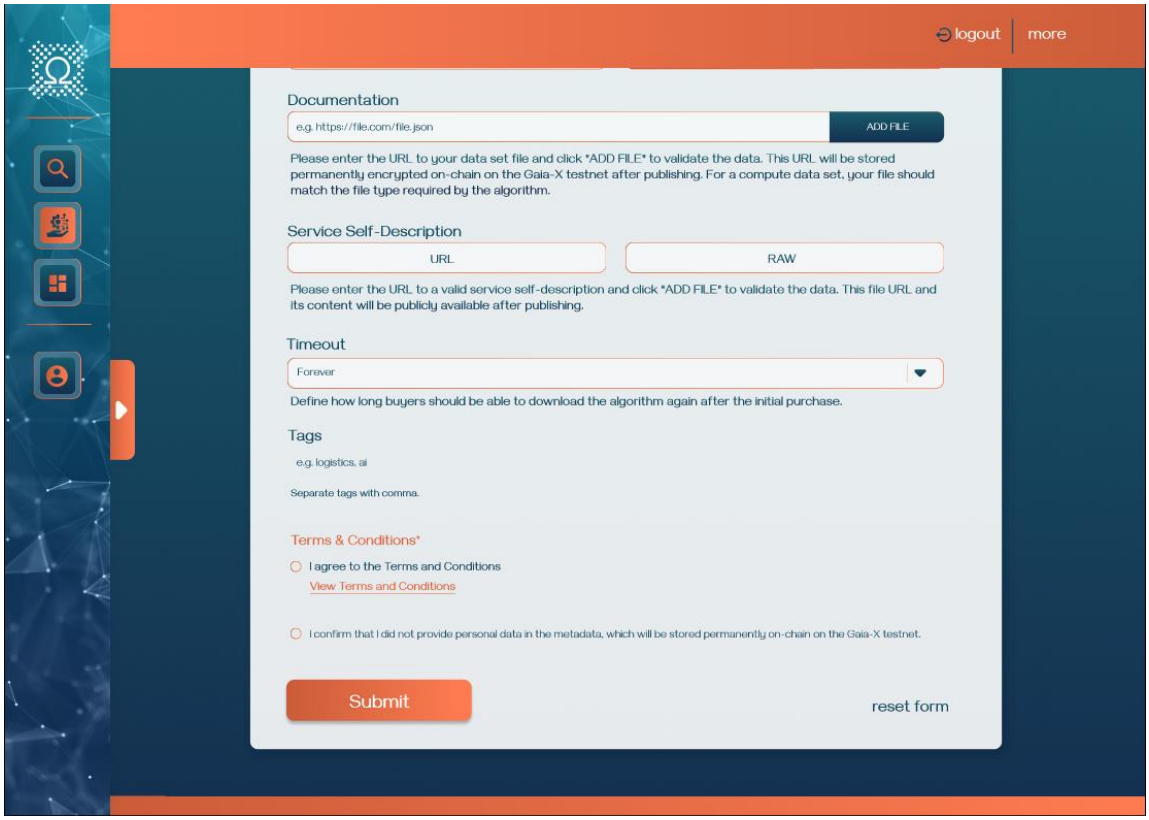

Figure 23 Provide Service Offering: bottom of page

A.4 Federator page

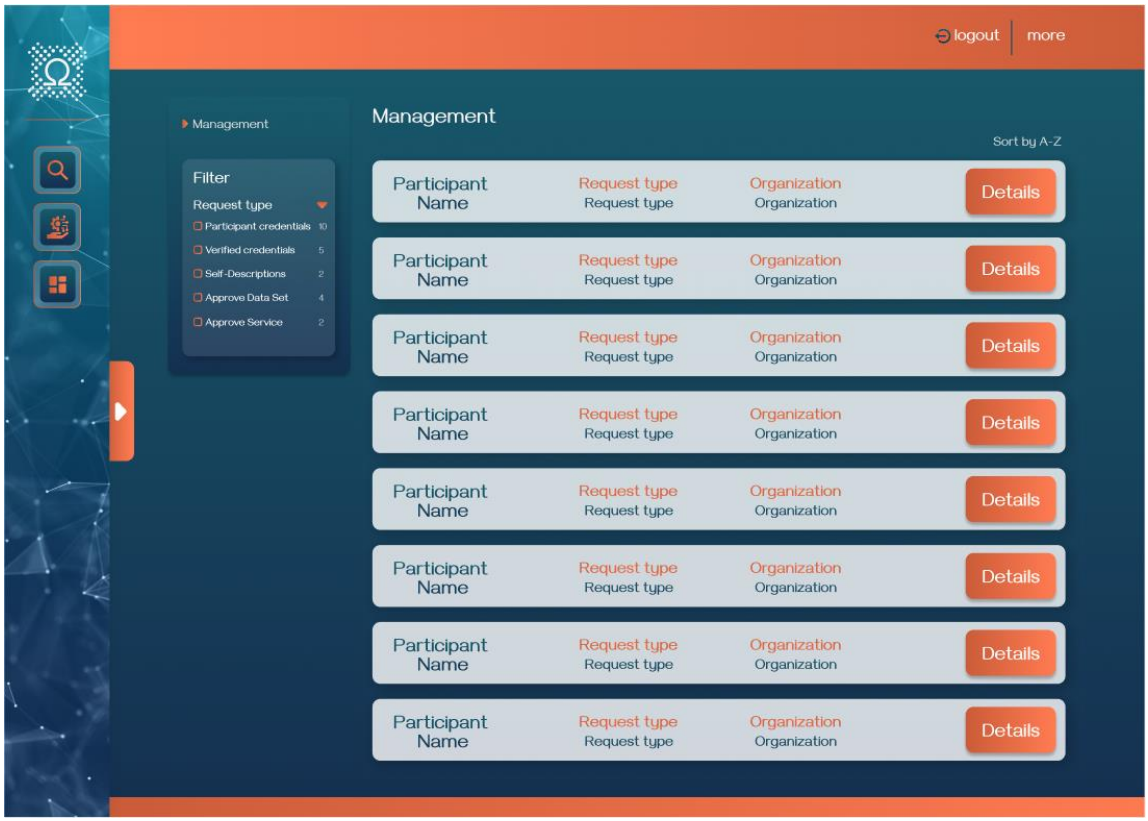

Figure 24 Federator page

A.5 Organisation Admin page

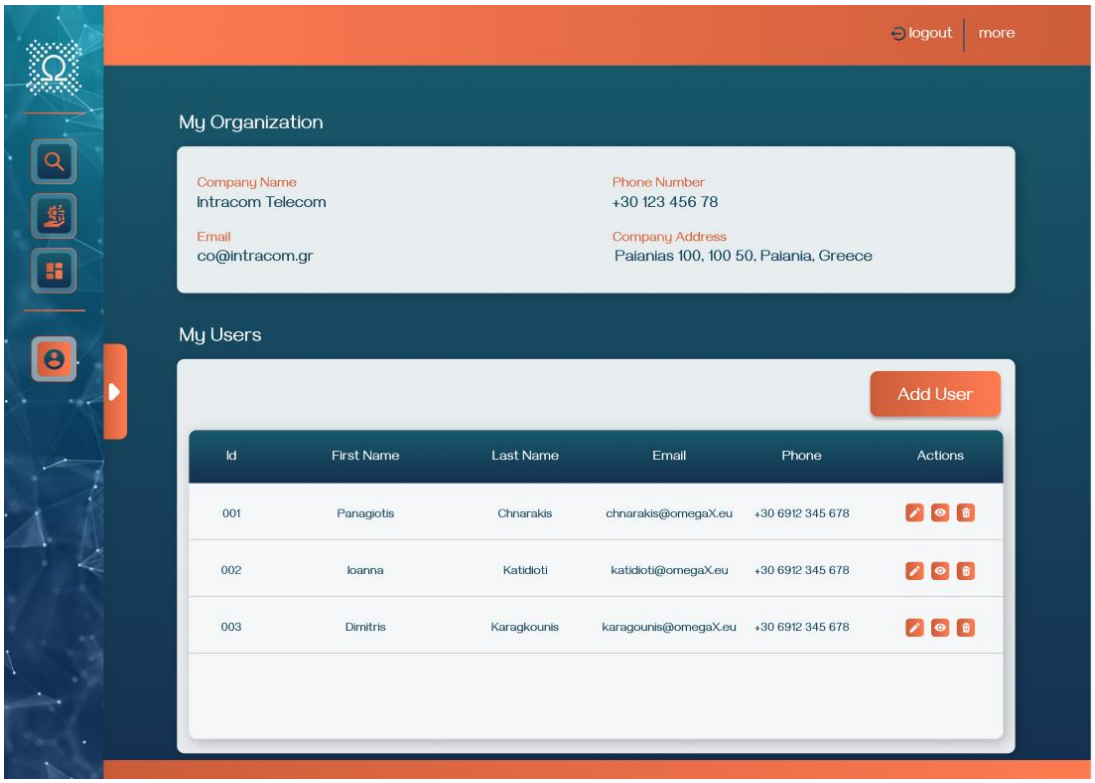

Figure 25 Organisation Admin page

A.6 Dashboard

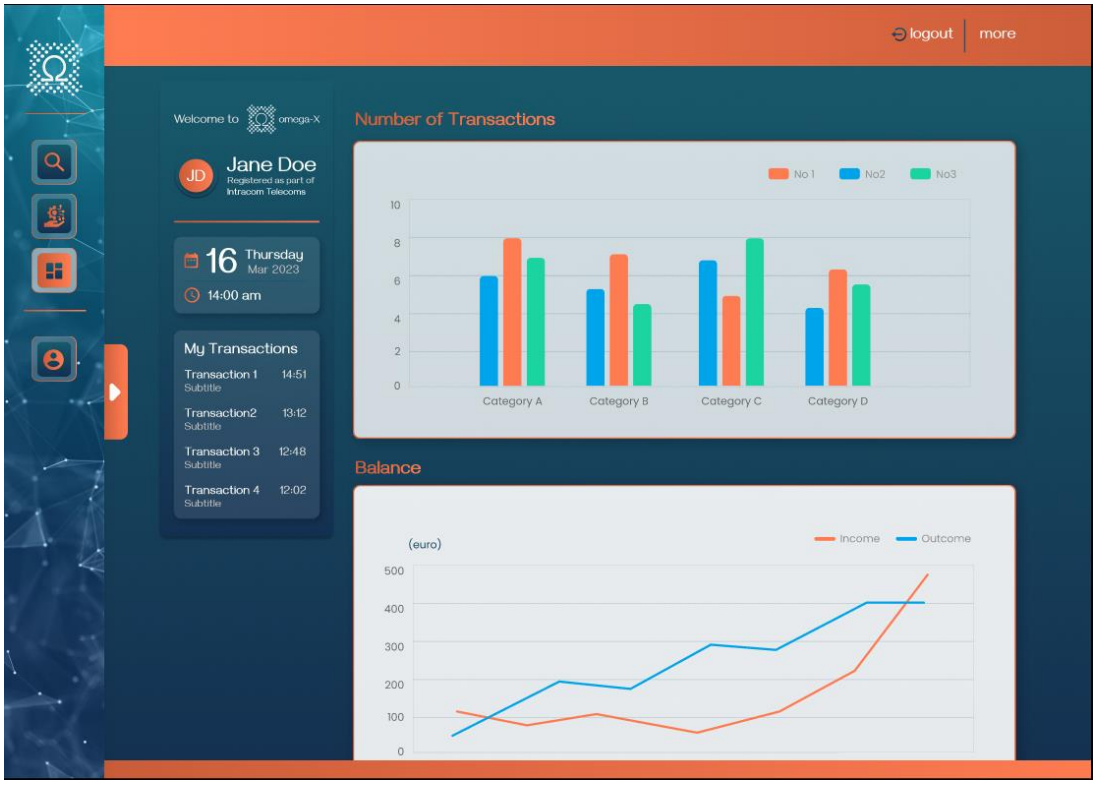

Figure 26 Dashboard: top of page

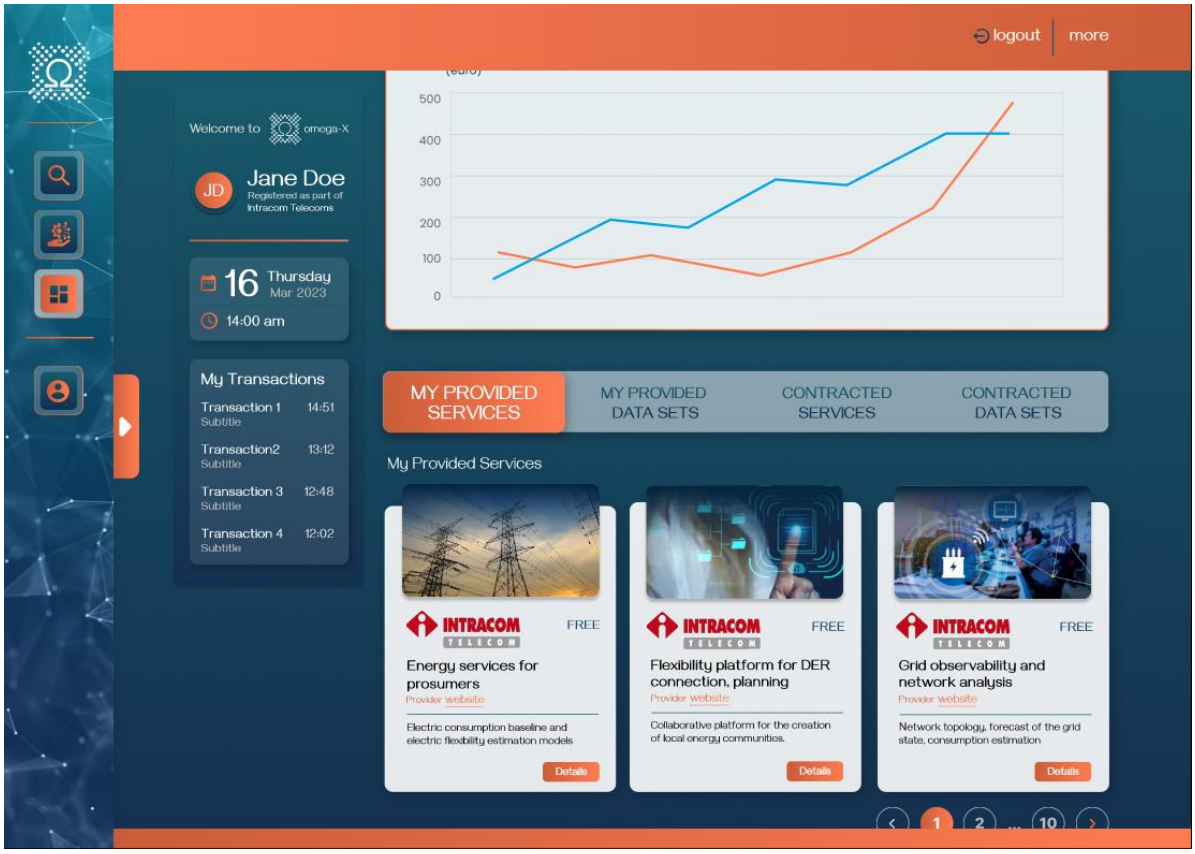

Figure 27 Dashboard: bottom of page

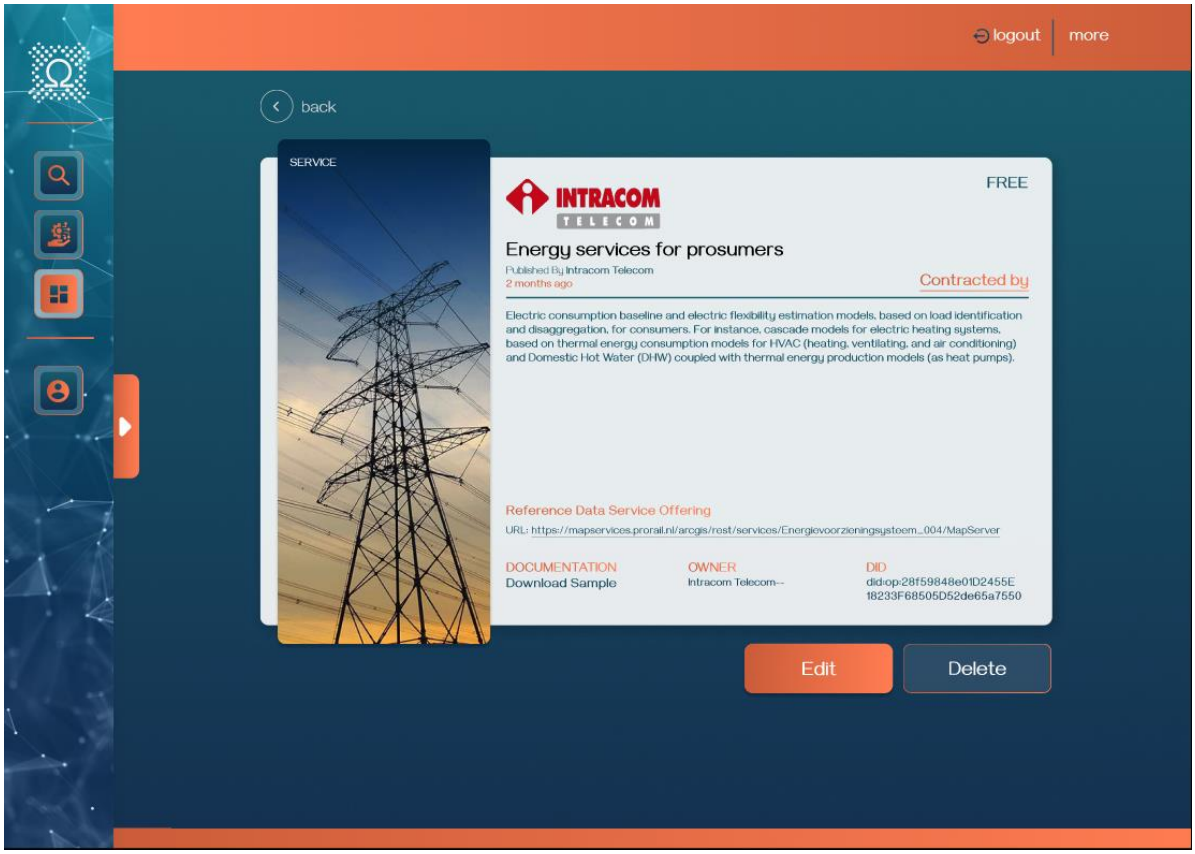

Figure 28 Example of own offering

10 ANNEX B: Data Analytics Services and Digital Twins Design Templates

B.1 Renewables UCF Services

B.1.1 Predictive Maintenance for large PV plants

Service to be offered in real-time/offline:

Preferably online but can also be run offline.

Execution frequency: Weekly, monthly or on-demand.

Input data requirements:

Table 7. Execution input data for Predictive Maintenance for large PV plants service.

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
DC and AC voltages	< 15 min	Monitoring Information from inverters and module level electronics – Raw Data. Meteorological Information– Raw Data.	V	< 1 day	EDF/MAG/EyPESA	R
DC and AC currents	< 15 min		A	< 1 day	EDF/MAG/EyPESA	R
Operating modes	< 15 min		N/A	< 1 day	EDF/MAG/EyPESA	O
Alarms	< 15 min		N/A	< 1 day	EDF/MAG/EyPESA	O
Global Irradiance on PoA (Plane of Array)	< 15 min		W/m^2	< 1 day	EDF/MAG/EyPESA	R
Direct Irradiance (dni), diffuse irradiance above the horizontal (dhi), global irradiance above the horizontal (ghi)	<15 min	Meteorological Information– Raw Data. Monitoring Information from inverters and module level electronics – Raw Data.	W/m^2	< 1 day	EDF/MAG/EyPESA	O
Ambient and Module temperature	< 15 min		ºC	< 1 day	EDF/MAG/EyPESA	R
Rainfall events	< 15 min		mm/m^2	< 1 day	EDF/MAG/EyPESA	O
Wind speed and direction	< 15 min		m/s	< 1 day	EDF/MAG/EyPESA	O

Table 8. Training data for Predictive Maintenance for large PV plants service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
DC and AC voltages	< 15 min	Monitoring Information from inverters and module level electronics – Raw Data. Meteorological Information– Raw Data.	V	≥ 1month	EDF/MAG/EyPESA	R
DC and AC currents	< 15 min		A	≥ 1month	EDF/MAG/EyPESA	R
Operating modes	< 15 min		N/A	≥ 1month	EDF/MAG/EyPESA	O
Alarms	< 15 min		N/A	≥ 1month	EDF/MAG/EyPESA	O
Global Irradiance on PoA (Plane of Array)	< 15 min		W/m^2	≥ 1month	EDF/MAG/EyPESA	R
Direct Irradiance (dni), diffuse irradiance above the horizontal (dhi), global irradiance above the horizontal (ghi)	< 15 min	Meteorological Information– Raw Data. Maintenance Logbook with conducted maintenance actions	W/m^2	≥ 1month	EDF/MAG/EyPESA	O
Ambient and Module temperature	< 15 min		ºC	≥ 1month	EDF/MAG/EyPESA	R
Rainfall events	< 15 min		mm/m^2	≥ 1month	EDF/MAG/EyPESA	O
Wind speed and direction	<15 min		m/s	≥ 1month	EDF/MAG/EyPESA	O
Maintenance Logbook	< 15 min		N/A	≥ 1 month	EDF/MAG/EyPESA	O
Latitude and longitude	Static	Coordinates of the PV installation		Static	EDF/MAG/EyPESA	R

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Number of modules per string and strings per array	Static	Number of modules per string and strings per array connected to each inverter input (in series and in parallel).		Static	EDF/MAG/EyPESA	R
Characteristic parameters of the PV modules	Static	Characteristic parameters available in the module manufacturer's technical sheet: Voc, Isc, Vmp Imp, temperature coefficients, the number of cells in series for the calculation of the ideality factor and the type of module and assembly for the thermal model of the temperature of operation		Static	EDF/MAG/EyPESA	R
Characteristic parameters of the PV inverters	Static	The maximum power point voltage operating range for each input section of the MPPT. Maximum current and power values for each input section of the MPPT.		Static	EDF/MAG/EyPESA	R
Position of the irradiance sensor	Static	The location of the irradiance sensor in the PV plant		Static	EDF/MAG/EyPESA	O

Expected outputs:

Table 9. Output data for Predictive Maintenance for large PV plants service

Data	Lowest level of granularity	Description	Units
Alarms	< 15 min	List of triggered alarms in the case these performance parameters present a significant deviation. For each case, the affected component or subsystem will be identified.	NA
Diagnosis	<15 min	Specific failure modes related to reported alarms will be identified and the potential causes will be exposed	NA

Applied Techniques:

The AI techniques applied in this service are:

- Data Mining and Feature Engineering.
- Clustering algorithms to identify different operating conditions.
- Regression algorithms.

Open-source/Proprietary software: Proprietary offered as a service.

B.1.2 Benchmarking Service

Service to be offered in real-time/offline:

Preferably online but can also be run offline.

Execution frequency: Weekly, monthly or on-demand.

Input data requirements:

Table 10. Execution input data for Benchmarking Service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
DC and AC voltages	< 15 min	Monitoring Information from inverters and module level electronics – Raw Data. Meteorological Information– Raw Data.	V	< 1 day	EDF/MAG/EyPESA	R
DC and AC currents	< 15 min		A	< 1 day	EDF/MAG/EyPESA	R
Operating modes	< 15 min		N/A	< 1 day	EDF/MAG/EyPESA	O
Alarms	< 15 min		N/A	< 1 day	EDF/MAG/EyPESA	O
Global Irradiance on PoA (Plane of Array)	< 15 min		W/m^2	< 1 day	EDF/MAG/EyPESA	R
Direct Irradiance (dni), diffuse irradiance above the horizontal (dhi), global irradiance above the horizontal (ghi)	<15 min	Meteorogical Information– Raw Data. Monitoring Information from inverters and module level electronics – Raw Data.	W/m^2	< 1 day	EDF/MAG/EyPESA	O
Ambient and Module temperature	< 15 min		ºC	< 1 day	EDF/MAG/EyPESA	R
Rainfall events	< 15 min		mm/m^2	< 1 day	EDF/MAG/EyPESA	O
Wind speed and direction	< 15 min		m/s	< 1 day	EDF/MAG/EyPESA	O

Table 11. Training data for Benchmarking Service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
DC and AC voltages	< 15 min	Monitoring Information from inverters and module level electronics – Raw Data. Meteorological Information– Raw Data.	V	≥ 1month	EDF/MAG/EyPESA	R
DC and AC currents	< 15 min		A	≥ 1month	EDF/MAG/EyPESA	R
Operating modes	< 15 min		N/A	≥ 1month	EDF/MAG/EyPESA	O
Alarms	< 15 min		N/A	≥ 1month	EDF/MAG/EyPESA	O
Global Irradiance on PoA (Plane of Array)	< 15 min		W/m^2	≥ 1month	EDF/MAG/EyPESA	R
Direct Irradiance (dni), diffuse irradiance above the horizontal (dhi), global irradiance above the horizontal (ghi)	< 15 min	Meteorogical Information– Raw Data. Maintenance Logbook with conducted maintenance actions	W/m^2	≥ 1month	EDF/MAG/EyPESA	O
Ambient and Module temperature	< 15 min		ºC	≥ 1month	EDF/MAG/EyPESA	R
Rainfall events	< 15 min		mm/m^2	≥ 1month	EDF/MAG/EyPESA	O
Wind speed and direction	<15 min		m/s	≥ 1month	EDF/MAG/EyPESA	O
Maintenance Logbook	< 15 min		N/A	≥ 1 month	EDF/MAG/EyPESA	O
Latitude and longitude	Static	Coordinates of the PV installation		Static	EDF/MAG/EyPESA	R

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Number of modules per string and strings per array	Static	Number of modules per string and strings per array connected to each inverter input (in series and in parallel).		Static	EDF/MAG/EyPESA	R
Characteristic parameters of the PV modules	Static	Characteristic parameters available in the module manufacturer's technical sheet: Voc, Isc, Vmp Imp, temperature coefficients, the number of cells in series for the calculation of the ideality factor and the type of module and assembly for the thermal model of the temperature of operation		Static	EDF/MAG/EyPESA	R
Characteristic parameters of the PV inverters	Static	The maximum power point voltage operating range for each input section of the MPPT. Maximum current and power values for each input section of the MPPT.		Static	EDF/MAG/EyPESA	R
Position of the irradiance sensor	Static	The location of the irradiance sensor in the PV plant		Static	EDF/MAG/EyPESA	O

Expected outputs:

Table 12. Output data for Benchmarking Service

Data	Lowest level of granularity	Description	Units
PV Characterisation	< 1 month	Characterisation of PV generator performance parameters between different PV plants.	NA

Applied Techniques:

The AI techniques applied in this service are:

- Data Mining and Feature Engineering.
- Clustering algorithms to identify different operating conditions.
- Regression Algorithms.
- Hybrid Digital Twins for KPI generation.
- Visual Analytics.

Open-source/Proprietary software: Proprietary offered as a service.

B.1.3 Compare actual production versus expected

Service to be offered in real-time/offline:

Offline.

Execution frequency: daily.

Input data requirements:

Table 13: Execution input data for Compare actual production versus expected service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Energy	Hourly or less Recom: 10 min	Sum of energy on the granularity period	kWh	1 day	EDF, EyPESA and MAG	R
Global Horizontal Irradiance (GHI)	Hourly or less Recom: 10 min	Global Horizontal Irradiance measured by a meteorological station on site	W/m²	1 day	EDF, EyPESA and MAG	R

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Diffuse Horizontal Irradiance (DHI)	Hourly or less Recom: 10 min	Diffuse Horizontal Irradiance measured by a meteorological station on site	W/m²	1 day	EDF, EyPESA and MAG	R
Ambient temperature	Hourly or less Recom: 10 min	Ambient temperature measured by a meteorological station on site	ºC	1 day	EDF, EyPESA and MAG	R
Wind speed	Hourly or less Recom: 10 min	Wind speed measured by a meteorological station on site	m/s	1 day	EDF, EyPESA and MAG	R
Soiling	Daily	Soiling measure	%	1 day	EDF, EyPESA and MAG	R
Availability	Daily	Plant availability considering Strings, power stations and transformers	%	1 day	EDF, EyPESA and MAG	R
Grid restrictions	Hourly or less Recom: 10 min	Grid restrictions to be considered	MW	1 day	EDF, EyPESA and MAG	R

Table 14. Training data for Compare actual production versus expected service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Plant layout UTM coordinates	As built	Coordinates of the PV fixed structure/tracker	m	N/A	EDF, EyPESA and MAG	R
PVsyst model	As built	Simulation model with main characteristics	N/A	N/A	EDF, EyPESA and MAG	R

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Energy	Hourly or less Recom: 10 min	Sum of energy on the granularity period	kWh	> 1 year	EDF, EyPESA and MAG	R
Power per string	Hourly or less Recom: 10 sec	Average power per string on the granularity period	kW	> 1 year	EDF, EyPESA and MAG	R
Soiling	Daily	Soiling measure	%	> 1 year	EDF, EyPESA and MAG	R
Availability	Daily	Plant availability considering Strings, power stations and transformers	%	> 1 year	EDF, EyPESA and MAG	R
Grid restrictions	Hourly or less Recom: 10 min	Grid restrictions to be considered	MW	> 1 year	EDF, EyPESA and MAG	R
Degradation	Daily	Plant cumulated degradation	%	> 1 year	EDF, EyPESA and MAG	O
Intensity and voltage per string	Hourly or less Recom: 10 sec	Intensity and voltage per string on the granularity period	A and V	> 2 months	EDF, EyPESA and MAG	O
Tracking mode	Hourly or less Recom: 10 min	Tracking or back-tracking mode specified for tracker if different	-	> 1 year	EDF, EyPESA and MAG	O
Global Horizontal Irradiance (GHI)	Hourly or less Recom: 10 min	Global Horizontal Irradiance measured by a meteorological station on site	W/m²	> 1 year	EDF, EyPESA and MAG	R

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Diffuse Horizontal Irradiance (GHI)	Hourly or less Recom: 10 min	Diffuse Horizontal Irradiance measured by a meteorological station on site	W/m²	> 1 year	EDF, EyPESA and MAG	R
Ambient temperature	Hourly or less Recom: 10 min	Ambient temperature measured by a meteorological station on site	ºC	> 1 year	EDF, EyPESA and MAG	R
Wind speed	Hourly or less Recom: 10 min	Wind speed measured by a meteorological station on site	m/s	> 1 year	EDF, EyPESA and MAG	R

Expected outputs:

Table 15. Output data for Compare actual production versus expected service

Data	Granularity	Description	Units
Expected performance of the plant	Hourly or less	Sum of energy on the granularity period	kWh
Daily cumulated production	Daily	Cumulated energy of the simulation day	kWh
Deviation	Daily	% of deviation between the simulation and the real energy generation	%

Applied Techniques:

The techniques applied in this service are:

- Performance Modelling of PV plants
  - Precise determination of Plant Performance, considering:
    - Actual shadowing, via ray-tracing methods
    - I-V curves behaviour of cells+panels+strings+inverters
- Fine tuning of PV plant model to represent real life behaviour
- Ray tracing techniques
- Data analytics
- Regression algorithms

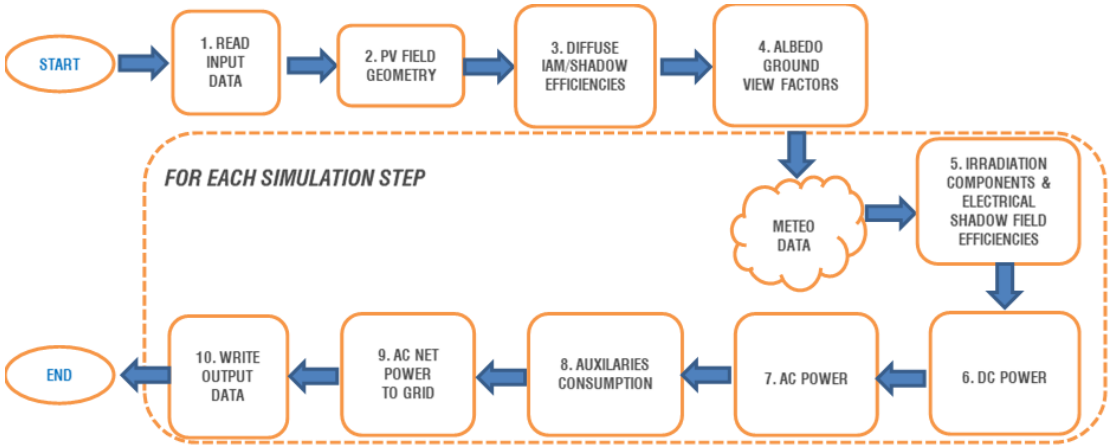

Figure 29 Service Pipeline. Source: SENER ING.

Open-source/Proprietary software: Proprietary software, whose results **only** will be delivered through an API service.

Additional Information: Only a maximum of two plants will be simulated per Client.

B.1.4 PV Cleaning Advisor

Service to be offered in real-time/offline:

Offline.

Execution frequency: daily.

Input data requirements:

Table 16. Execution input data for PV Cleaning Advisor service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Energy per string	10 min	Sum of energy on the granularity period	kWh	1 day	EDF, EyPESA and MAG	R
Clean string energy	10 min	Sum of energy on the granularity period	W/m²	1 day	EDF, EyPESA and MAG	R

Table 17. Training data for PV Cleaning Advisor service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Cleaning loss threshold	As built	Cleaning loss % below which the cleaning is recommended	%	1 day/1 year	EDF, EyPESA and MAG	R

Expected outputs:

Table 18. Output data for PV Cleaning Advisor service

Data	Granularity	Description	Units
Soiling loss per string	Hourly or less	Energy loss on the granularity period	kWh
Soiling loss per string	Daily	Cumulated energy loss due to soiling	kWh
Cleaning advise	Daily	Cleaning signal for string	-

Applied Techniques:

The techniques applied in this service are:

- Advanced data analytics.

Open-source/Proprietary software: Proprietary software, whose results only will be delivered through an API service.

B.1.5 Shading Analysis

Service to be offered in real-time/offline:

Offline.

Execution frequency: daily.

Input data requirements:

Table 19. Execution input data for Shading Analysis service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Energy per string	10 min	Sum of energy on the granularity period	kWh	1 day	EDF, EyPESA and MAG	R

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Unshaded string energy	10 min	Sum of energy on the granularity period	W/m²	1 day	EDF, EyPESA and MAG	R

Table 20. Training data for Shading Analysis service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Plant layout UTM coordinates	As built	Coordinates of the PV fix structure/tracker	M		EDF/MAG/EyPESA	R

Expected outputs:

The outputs of the service:

Table 21. Output data for Shading Analysis service

Data	Granularity	Description	Units
Unshaded string performance	Hourly or less	Sum of energy on the granularity period	kWh
Shaded string performance	Hourly or less	Sum of energy on the granularity period	kWh
Shading loss per string	Daily	% of performance loss estimate due to shading	%

Applied Techniques:

The techniques applied in this service are:

- Advanced data analytics

Open-source/Proprietary software: Proprietary software, whose results only will be delivered through an API service.

B.1.6 Tracking algorithm check

Service to be offered in real-time/offline:

Offline.

Execution frequency: daily.

Input data requirements:

Table 22. Execution input data for Tracking algorithm check service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Tracking angle of the trackers	1 min or less	Tilt angle of the tracker. Reference: (+) east, (-) west	º	1 day	EDF, EyPESA and MAG	R
Tracking angle of the trackers - setpoint	1 min or less	Tilt angle of the tracker. Reference: (+) east, (-) west	º	1 day	EDF, EyPESA and MAG	R
Tracking mode	1 min or less	Tracking or back-tracking mode	-	1 day	EDF, EyPESA and MAG	R

Expected outputs:

The outputs of the service:

Table 23. Output data for Tracking algorithm check service

Data	Granularity	Description	Units
Tracking accuracy	Hourly or less	Plant tracking compared to the setpoint considering the tracking mode on the granularity period	º
Performance loss	Hourly or less	Production loss estimate with respect to tracking error	kWh/kWp
Daily tracking deviation	Daily	Daily percentage of deviation of the trackers	º, RMS

Applied Techniques:

The techniques applied in this service are:

- Astronomic algorithm for sun positioning.
- Flat terrain backtracking for the avoidance of shadows.
- Advanced analytics.

Open-source/Proprietary software: Proprietary software, whose results only will be delivered through an API service.

B.1.7 Detect measurement errors

Service to be offered in real-time/offline:

Offline and online. Execution frequency: on-demand. When a service requires to clean its input data, this service will be requested.

Input data requirements:

The inputs depend on the Service User. They must be time series with at least one datetime column. For this project, some of the data that will be feed to this service are:

- Active and reactive power of a PV plant
- Active and reactive energy of a PV plant
- Smart meter active and reactive power readings
- Data concentrators and ekors time series

Expected outputs:

- Clean dataset with no errors nor missing values. (Excel, csv file).
- Outliers report, txt file (if requested by the Service User).
- Missing data report, txt file (if requested by the Service User).

Applied Techniques:

Missing imputation service:

The missing values should be replaced with rational records in order to offer the data-driven services a complete dataset. The approach of handling missing values is called Imputation. Several Imputation techniques are applied and offered in this service, ranging from Statistics to Artificial Intelligence.

- Statistic methods:
  - Univariate imputation: The following methods are used as the imputation value for the Statistical estimation of the missing data.
    - Mean.
    - Median.
    - Mode.
    - Zero values.
    - Most frequent value (categorical data).
  - Interpolation: Interpolation is a mathematical method that adjusts a function to the dataset and uses this function to extrapolate the missing data. The simplest type is the linear interpolation, but polynomial is also available in DME, indicating the degree.
    - Linear.
    - Polynomial (order quadratic, cubic...).
- Machine Learning methods
  - Multivariate Imputation: For this imputation technique, a distributed set of observed data is used to estimate a set of imputation values for the missing data. In this method, a Multiple Imputation by Chained Equations (MICE method) is applied.
  - Random Forest.
  - KNNeighbours.
  - Bayesian Ridge.

Outlier detection:

This service offers two methods to detect outliers.

- Statistic methods
  - IQR method: The Interquartile Range (IQR) is often used to detect outliers in data, following these steps:
    - First, calculate the interquartile range for the data.
    - Multiply the interquartile range (IQR) by a parameter set up by the service used. Usually, the value 1.5 is set to discern outliers.
    - Add 1.5 x (IQR) to the third quartile (Q3). Any number more significant than this is considered an outlier.
    - Subtract 1.5 x (IQR) from the first quartile (Q1). Any number less than this is considered an outlier.
  - Mean-std difference method: This method deletes the outliers that are above and below the mean value minus the standard deviation, multiplied by a parameter:

$$\text{Outlier} = (\text{mean} \pm \text{std}) * \text{Constant parameter}$$

Open-source/Proprietary software: Open-source.

B.1.8 Detect non-technical losses

Service to be offered in real-time/offline:

Offline. Execution frequency: Weekly, monthly or on-demand.

Input data requirements:

Table 24. Execution input data for Detect non-technical losses service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
SM Active Power	Hourly	Hourly active power recorded by the SMs under a specific CT	kW	> 1 month	EyPESA	R
SM Reactive Power	Hourly	Hourly reactive power recorded by the SMs under a specific CT	kW	> 1 month	EyPESA	O
SM event logs	Daily	Daily recording of SM event logs. These indicate errors and alarm arising from SMs	ID integer numbers	> 1 month	EyPESA	O
Transformer Active Power	Hourly	Hourly active power recorded the CT meter	kW	> 1 month	EyPESA	R

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Transformer Reactive Power	Hourly	Hourly reactive power recorded the CT meter	kvar	> 1 month	EyPESA	O
Topology	-	Grid topology including line impedances to calculate Technical Losses	-	-	EyPESA	O

Table 25. Training data for Detect non-technical losses service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Historical Detected Frauds	-	Information regarding the historical detected fraud: type of fraud, day of inspection, magnitude of fraud, etc.	-	N/A	EyPESA	O
Historical SM Active Power	Hourly	Hourly active power recorded by the SMs under a specific CT that experienced fraud	kW	N/A	EyPESA	O
Historical SM Reactive Power	Hourly	Hourly reactive power recorded by the SMs under a specific CT that experienced fraud	kvar	N/A	EyPESA	O
Historical SM event logs	Daily	Daily recording of SM event logs. These indicate errors and alarm arising from SMs.	ID integer numbers	N/A	EyPESA	O
Historical Transformer Active Power	Hourly	Hourly active power recorded the CT meter	kW	N/A	EyPESA	O

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Historical Transformer Reactive Power	Hourly	Hourly reactive power recorded the CT meter	kvar		EyPESA	O

Expected outputs:

Table 26. Output data for Detect non-technical losses service

Data	Lowest level of granularity	Description	Units
NTL detected	When executed	Sent a notification if NTL > X%	YES / NO
Fraud data: Type	When executed	Classification between Marihuana Plantation, Crypto Mining, Squatting and Unclear	Classification
Fraud data: Probability	When executed	Probability of correct prediction of type of fraud and fraudster.	%
Fraud data: Magnitude	When executed	Magnitude of fraud (95% percentile)	kW
Fraud data: Duration	When executed	Duration of fraud in days.	days
SM ID	When executed	SM ID of the consumer who is potentially committing fraud	SM ID

Applied Techniques:

The AI techniques applied in this service are

- Classification Algorithms (e.g., Random Forest Classifier, Gradient Booster Classifier and Support Vector Classifier) to find the type of fraud based on the NTL profile.
- Fuzzy c-Means as a clustering algorithm to detect SMs with suspicious shifts in their consumption patterns.
- Data Mining and Feature Engineering to extract features and information from active power curves.

Open-source/Proprietary software: Open-source.

B.1.9 Congestion detection

Service to be offered in real-time/offline:

Offline.

Execution frequency: Day-ahead.

Input data requirements:

Table 27. Execution input data for Congestion detection service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
SM Active Power	Hourly	Hourly active power recorded by the SMs under a specific CT	kW	> 1 month	EyPESA	R
SM Reactive Power	Hourly	Hourly reactive power recorded by the SMs under a specific CT	kvar	> 1 month	EyPESA	O
Transformer Active Power	Hourly	Hourly active power recorded the CT meter	kW	> 1 month	EyPESA	R
Transformer Reactive Power	Hourly	Hourly reactive power recorded the CT meter	kvar	> 1 month	EyPESA	O
Topology	-	Grid topology including line impedances	-	-	EyPESA	R

Table 28. Training data for Congestion detection service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
SM Active Power	Hourly	Hourly active power recorded by the SMs under a specific CT	kW	> 1 month	EyPESA	R
SM Reactive Power	Hourly	Hourly reactive power recorded by the SMs under a specific CT	kvar	> 1 month	EyPESA	O
Transformer Active Power	Hourly	Hourly active power recorded the CT meter	kW	> 1 month	EyPESA	R
Transformer Reactive Power	Hourly	Hourly reactive power recorded the CT meter	kvar	> 1 month	EyPESA	O

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Topology	-	Grid topology including line impedances	-	-	EyPESA	R

Expected outputs:

Table 29. Output data for Congestion detection service

Data	Lowest level of granularity	Description	Units
Probability of congestions in lines and/or bus voltages.	When executed	Probability of a line or bus voltage	kA, V p.u. or % of overload
Forecast of demand	When executed	Demand of loads for the day-ahead	kW

Applied Techniques:

The techniques applied in this service are:

- Probabilistic Power Flows, as a method to analyse the grid and scenario creation.
- Machine Learning regression methods such as: random forest, support vector machines, and neural networks.

Open-source/Proprietary software: Open-source.

B.1.10 Behind-the-meter (BTM) PV disaggregation

Service to be offered in real-time/offline:

Offline

Execution frequency: Daily or on-demand.

Input data requirements:

Table 30. Execution input data for Detection of the volatility of voltage in grids with high renewable penetration service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
SM Active Power	Hourly or less	Active power recorded by the SMs	kW	> 1 month	DSO	R
SM Reactive Power	Hourly or less	Reactive power recorded by the SMs	kvar	> 1 month	DSO	R

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
GIS Data	-	Geographic coordinates of grid assets	Latitude and Longitude	-	DSO	R
Global Horizontal Irradiance (GHI)	Hourly or less	Global Horizontal Irradiance measured by a meteorological station on site	W/m²	> 1 month	DSO	R
Diffuse Horizontal Irradiance (GHI)	Hourly or less	Diffuse Horizontal Irradiance measured by a meteorological station on site	W/m²	> 1 month	DSO	O

Expected outputs:

Table 31. Output data for Behind-the-meter PV disaggregation service

Data	Lowest level of granularity	Description	Units
BTM PV system installed	When executed	Detects whether a customer has a BTM PV system installed or not	Yes / No
BTM PV system capacity	When executed	Power capacity of every behind-the-meter distributed PV system	kWp
BTM PV generated power	When executed	Time series of hourly PV generated power	kW

Applied Techniques:

The AI techniques applied in this service are:

- Classification Algorithms to determine whether a customer has an installation of BTM PV or not.
- Regression Algorithms to estimate the BTM PV system capacity and the generated power.

Open-source/Proprietary software: Open-source.

B.1.11 Plan grid reinforcements for future renewable scenarios

Service to be offered in real-time/offline:

Offline.

Execution frequency: Weekly, monthly or yearly.

Input data requirements:

Table 32. Execution input data for Plan grid reinforcements for future renewable scenarios service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Transformer Active Power	Hourly	Hourly active power recorded the CT meter	kW	> 3 years	EyPESA	R
Transformer Reactive Power	Hourly	Hourly reactive power recorded the CT meter	kvar	> 3 years	EyPESA	O
Topology	-	Grid topology including line impedances, transformer parameters and bus voltages	-	-	EyPESA	R
Asset Costs	-	Investment and operational costs of line types, transformer types and Li-ion battery systems (for different capacity levels).	Euros (€)	-	EyPESA	R
GIS Data	-	Geographic coordinates of grid assets	Latitude and Longitude	-	EyPESA	O
Asset Age	-	Current life-time of line and transformers	Years	-	EyPESA	O
Expansion plans	-	Location of future load and generation expansions according to user requests.	kW	-	EyPESA	O

Expected outputs:

The service reports optimal planning actions for long term horizon scenarios, aiming to minimise asset investment costs for DSOs using traditional planning strategies (replacement/reinforcement of feeder lines and transformers) and flexible planning strategies (installation of Li-ion batteries). Once the optimal planning strategy is found, the operator can obtain, new loading percentages (%) per asset and total investment costs.

The following table summarises the different service outputs.

Table 33. Output data for Plan grid reinforcements for future renewable scenarios service

Data	Lowest level of granularity	Description	Units
CAPEX	Depends on execution frequency	Capital Investment Costs of new lines, transformers or batteries.	Euro (€)
OPEX	Depends on execution frequency	Operational Investment Costs of new lines, transformers or batteries	Euro (€)
Asset Improvements	Depends on execution frequency	Improvement of Lines Loadings, Transformer Loadings and Bus Voltages.	%

Applied Techniques:

The techniques applied in this service are:

- Optimisation model to determine best size and location of new lines, transformers or Li-ion batteries to reinforce the grid minimizing CAPEX and OPEX.
- Data driven techniques to reduce order of scenarios.
- Machine learning forecasting techniques for future renewable generation.

Open-source/Proprietary software: Open-source.

B.1.12 Energy Generation Forecast

Service to be offered in real-time/offline**:**

Real-time.

Execution frequency: Hourly, daily or on-demand.

Input data requirements:

Table 34. Execution input data for Energy Generation Forecast service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Power	Hourly or less Recom: 5 min	Average power on the granularity period	kW	> 1 year	EyPESA	R
Energy	Hourly or less	Sum of energy on the granularity period	kWh	> 1 year	EyPESA	O
Global Horizontal Irradiance (GHI)	Hourly or less	Global Horizontal Irradiance measured by a meteorological station on site	W/m²	> 1 year	EyPESA	O

Table 35. Training data for Energy Generation Forecast service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Power	Hourly or less Recom: 5 min	Average power on the granularity period	kW	> 1 year	EyPESA	R
Energy	Hourly or less	Sum of energy on the granularity period	kWh	> 1 year	EyPESA	O
Global Horizontal Irradiance (GHI)	Hourly or less	Global Horizontal Irradiance measured by a meteorological station on site	W/m²	> 1 year	EyPESA	O

Expected outputs:

The outputs of the service:

- **Power:** Power generation by the site for the following 144 hours (6 days).
- **Uncertainty:** Percentiles 10, 25, 75 and 90 to define the uncertainty respect to the most probable power generation.

The following table summarises the different service outputs.

Table 36. Output data for Energy Generation Forecast service

Data	Lowest level of granularity	Description	Units
Power	5, 10, 15, 30 or 60 minutes	Most probable accurate forecast for each data point of the 144 hours forecast	kWh [float]
Uncertainty	5, 10, 15, 30 or 60 minutes	Uncertainty percentiles 10%, 25%, 75% and 90% to define the trust of the forecast for each data point.	kWh [float]

Applied Techniques:

The AI techniques applied in this service are:

- Feature Engineering to create added value for each site to improve the forecast accuracy (e.g. Aperture Normal Irradiance feature for horizontal 1 axis tracking solar fields).
- Genetic algorithms to train the predictive models and define the most accurate Machine Learning predictive model for each site.
- Machine learning to generate the most probable forecast and an ensemble to define the uncertainty of the forecast for each data point predicted.

Open-source/Proprietary software: Proprietary software delivered as a service.

B.1.13 Digital Twin BIPV Self Consumption Systems in Buildings

Service to be offered in real-time/offline:

Preferably online but can also be run offline.

Execution frequency: Weekly, monthly or on-demand.

Input data requirements:

Table 37. Execution input data for Digital Twin BIPV Self Consumption Systems in Buildings service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
DC and AC voltages	< 15 min	Monitoring Information from inverters and module level electronics – Raw Data.	V	< 1 day	EyPESA	Required
DC and AC currents	< 15 min		A	< 1 day	EyPESA	Required
Internal temperature	< 15 min		ºC	< 1 day	EyPESA	Required
Operating modes	< 15 min		N/A	< 1 day	EyPESA	Optional
Alarms	< 15 min		N/A	< 1 day	EyPESA	Optional
Global Irradiance on PoA (Plane of Array)	< 15 min	Meteorogical Information– Raw Data.	W/m^2	< 1 day	EyPESA	Required
Direct Irradiance (dni), diffuse irradiance above the horizontal (dhi), global irradiance above the horizontal (ghi)	< 15 min		W/m^2	< 1 day	EyPESA	Optional
Ambient and Module temperature	< 15 min		ºC	< 1 day	EyPESA	Required
Rainfall events	< 15 min		mm/m^2	< 1 day	EyPESA	Optional
Wind speed and direction	< 15 min		m/s	< 1 day	EyPESA	Optional

Table 38. Training data for Digital Twin BIPV Self Consumption Systems in Buildings service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
DC and AC voltages	< 15 min	Monitoring Information from inverters and module level electronics – Raw Data.	V	≥ 1 month	EyPESA	Required
DC and AC currents	< 15 min		A	≥ 1 month	EyPESA	Required
Internal temperature	< 15 min		ºC	≥ 1 month	EyPESA	Required
Operating modes	< 15 min		N/A	≥ 1 month	EyPESA	Optional
Alarms	< 15 min		N/A	≥ 1 month	EyPESA	Optional
Global Irradiance on PoA (Plane of Array)	< 15 min	Meteorogical Information– Raw Data.	W/m^2	≥ 1 month	EyPESA	Required
Direct Irradiance (dni), diffuse irradiance above the horizontal (dhi), global irradiance above the horizontal (ghi)	< 15 min		W/m^2	≥ 1 month	EyPESA	Optional
Ambient and Module temperature	< 15 min		ºC	≥ 1 month	EyPESA	Required
Rainfall events	< 15 min		mm/m^2	≥ 1 month	EyPESA	Optional
Wind speed and direction	< 15 min		m/s	≥ 1 month	EyPESA	Optional
Maintenance Loogbok	< 15 min	Maintenance Logbook with conducted maintenance actions	N/A	≥ 1 month	EyPESA	Optional

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
PV Plant design	Static	BIM model or information required for building and PV Plant design		Static	EyPESA	Required
Latitude and longitude	Static	Coordinates of the PV installation		Static	EyPESA	Required
Number of modules per string and strings per array	Static	Number of modules per string and strings per array connected to each inverter input (in series and in parallel).		Static	EyPESA	Required
Characteristic parameters of the PV modules	Static	Characteristic parameters available in the module manufacturer's technical sheet: Voc, Isc, Vmp Imp, temperature coefficients, the number of cells in series for the calculation of the ideality factor and the type of module and assembly for the thermal model of the temperature of operation		Static	EyPESA	Required
Characteristic parameters of the PV inverters:	Static	The maximum power point voltage operating range for each input section of the MPPT. Maximum current and power values for each input section of the MPPT.		Static	EyPESA	Required

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Position of the irradiance sensor	Static	The location of the sensor in the PV system		Static	EyPESA	Required

Expected outputs:

Table 39. Output data for Digital Twin BIPV Self Consumption Systems in Buildings service

Data	Lowest level of granularity	Description	Units
Improved BIPV model with adjusted parameters providing more reliable and accurate output AC power	N/A	Characterisation of PV modules, PV arrays and inverters performance parameters between different PV plants.	N/A
Energy Prediction	< 15 min	Forecast of produced energy by the BIPV panels.	kW
Alarms	< 15 min	list of triggered alarms in the case these adjusted parameters present a significant deviation. For each case, the affected component or subsystem will be identified, the specific failure modes related to this underperformance will be reported and the potential causes will be exposed.	N/A

Applied Techniques:

The AI techniques applied in this service are:

- Data Mining and Feature Engineering.
- Clustering algorithms to identify different operating conditions.
- Hybrid Digital Twins.
- Regression.
- Bayesian optimisation using Gaussian Processes.
- Sequential optimisation using decision trees.

Open-source/Proprietary software: Proprietary offered as a service.

B.2 Local Energy Communities UC Services

B.2.1 Local Energy Communities Designer

Service to be offered in real-time/offline:

Offline.

Execution frequency: On-demand.

Input data requirements:

Table 40. Algorithm input data for Local Energy Communities Designer service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
energy_kWh	Hourly	Energy consumed in kilo-Watt-hours (kWh)	kWh	> 1 month	DSO	R
date	Daily	Date of the recording in YYYY-MM-DD	date	> 1 month	DSO	R
day	Daily	Day of the week	string	> 1 month	DSO	O
participantID	N/A	ID code identifying which is the specific building/consumer	ID integer numbers	> 1 month	DSO	R
hour	Hourly	Hour of the recording from 01 to 24.	integer (01-24)	> 1 month	DSO	R

Table 41. Consumer description data for Local Energy Communities Designer service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
participantID	N/A	ID code identifying which is the specific building/consumer/participant	ID integer numbers	N/A	DSO	R
Coverage	N/A	The percent of non-missing readings. A value of 1.000 is 100%	integer numbers (0-1000)	N/A	DSO	O
BuildingType	N/A	Type of the building related to the consumer	string	N/A	DSO	R

Expected outputs:

The outputs of the service indicate which is the best possible configuration among the consumers provided as inputs. Moreover, it contains information about another possible configuration even if not optimum. The following table summarises the service outputs.

Table 42. Output data for Local Energy Communities Designer service.

Data	Lowest level of granularity	Description	Units
optimal_configuration	When executed	Lists all the participants needed to optimise auto consumption in relation to power plant size	list of participantID
suboptimal_configuration	When executed	Several suboptimal configurations of LEC participants	array of list of participantID

Applied Techniques:

The AI techniques applied in this service are:

- Optimisation technique (heuristic model).

Open-source/Proprietary software: Proprietary software.

B.2.2 Gamification for electrical energy savings

Service to be offered in real-time/offline:

Real-time.

Execution frequency: on-demand.

Input data requirements:

Input data are summarised in the following tables. The second table represents optional questionnaire data, which consumers can compile to assist classification algorithms on recognising how mainly the energy is used.

Table 43. Input data for Gamification for electrical energy savings service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
energy_kWh	Hourly	Energy consumed in kilo-Watt-hours (kWh)	kWh	> 1 month	DSO	R
date	Daily	Date of the recording in YYYY-MM-DD	date	> 1 month	DSO	R
day	Daily	Day of the week	string	> 1 month	DSO	O
consumerID	-	ID code identifying which is the specific consumer	ID integer numbers	> 1 month	DSO	R
hour	Hourly	Hour of the recording from 01 to 24.	integer (01-24)	> 1 month	DSO	R

Table 44. Home appliances data for Gamification for electrical energy savings service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
consumerID	N/A	ID code identifying which is the specific consumer	ID integer numbers	N/A	LEC Participant	R
refrigerator	N/A	Appliances present	integer numbers	N/A	LEC Participant	O
freezer	N/A	Appliances present	integer numbers	N/A	LEC Participant	O
dishwasher	N/A	Appliances present	integer numbers	N/A	LEC Participant	O
oven	N/A	Appliances present	integer numbers	N/A	LEC Participant	O
microwave oven	N/A	Appliances present	integer numbers	N/A	LEC Participant	O
washing machine	N/A	Appliances present	integer numbers	N/A	LEC Participant	O
clothes dryer	N/A	Appliances present	integer numbers	N/A	LEC Participant	O
air conditioner	N/A	Appliances present	integer numbers	N/A	LEC Participant	O

Expected outputs:

The possible outputs of the service can be classified as follows:

- **consumer notification:** The service notifies whether or not a specific challenge is overcome and when the consumer receives rewards from the system due to his actions;
- **consumption analysis**: energy usage is analysed and visualised in graphical dashboards with optional quantitative information (KPI) relative to consumption and transferred to the User;
- **saved energy:** the amount of saved energy and reduced costs are returned to consumer

The following table summarises the different service outputs.

Table 45. Output data for Gamification for electrical energy savings service

Data	Lowest level of granularity	Description	Units
KPI	When executed	Key performance indicator at different time ranges	kWh
saved_energy	When executed	Energy saved from single consumer	kWh

Applied Techniques:

The AI techniques applied in this service are

- Classification Algorithms (e.g., Random Forest Classifier, Gradient Booster Classifier and Support Vector Classifier) to recognise appliances consumption profile.
- Data Mining and Feature Engineering to extract features and information from active consumption curves.

Open-source/Proprietary software: Proprietary software.

B.2.3 Thermal Losses Detection and Benchmarking at LEC level

Service to be offered in real-time/offline:

Real-Time.

Execution frequency: Daily/Weekly/Monthly.

Input data requirements:

Table 46. Execution input data for Thermal Losses Detection and Benchmarking at LEC level service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Ec,h	Hourly/Daily	Hourly/Daily thermal energy consumed by end-users	kWh	> 1 year	ESCO	R
Es,h	Hourly/Daily	Hourly/Daily thermal energy supplied to all end-users	kWh	> 1 year	ESCO	R
Topology	N/A	Grid topology of District Heating Network for thermal losses isolation	string	N/A	ESCO	O

Table 47. Training data for Thermal Losses Detection and Benchmarking at LEC level service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Ec,h	Hourly/Daily	Hourly/Daily thermal energy consumed by end-users	kWh	> 1 year	ESCO	R
Es,h	Hourly/Daily	Hourly/Daily thermal energy supplied to all end-users	kWh	> 1 year	ESCO	R

Expected outputs:

The outputs of the service are

- **Elosses**: Daily estimated thermal losses.
- Statistics related to thermal losses (e.g., number of detected thermal losses in different periods, % of smart meters offline, etc.).

- Benchmarking.

The following table summarises the different service outputs.

Table 48. Output data for Thermal Losses Detection and Benchmarking at LEC level service

Data	Lowest level of granularity	Description	Units
Elosses	Daily	Daily estimated thermal losses	m^3/h

Applied Techniques:

The AI techniques applied in this service are:

- Clustering algorithms to discriminate different consumption patterns.
- Data Mining and Feature Engineering to extract information from thermal consumption curves.

Open-source/Proprietary software: Proprietary software.

B.2.4 Water Losses detection and benchmarking at LEC level

Service to be offered in real-time/offline:

Real-Time.

Execution frequency: Daily.

Input data requirements:

Table 49. Execution input data for Water Losses Detection and Benchmarking at LEC level service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Qc,h	Hourly	Hourly flow rate consumed by end-users	m^3	> 1 year	ESCO	R
Qs,h	Hourly	Hourly flow rate supplied to all end-users	m^3	> 1 year	ESCO	R
Topology	N/A	Grid topology of Water Distribution Network for water losses isolation	string	N/A	ESCO	O

Table 50. Training data for Water Losses Detection and Benchmarking at LEC level service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Qc,h	Hourly	Hourly flow rate consumed by end-users	m^3	> 1 year	ESCO	R
Qs,h	Hourly	Hourly flow rate supplied to all end-users	m^3	> 1 year	ESCO	R

Expected outputs:

The outputs of the service are:

- **Qlosses**: Daily estimated water losses.
- Statistics related to water losses (e.g., number of detected water losses in different periods, % of smart meters offline, etc.).
- Benchmarking.

The following table summarises the different service outputs.

Table 51. Output data for Water Losses Detection and Benchmarking at LEC level service

Data	Lowest level of granularity	Description	Units
Qlosses	Daily	Daily estimated water losses	m^3/h

Applied Techniques:

The AI techniques applied in this service are:

- Clustering algorithms to cluster different consumption pattern.
- Data Mining and Feature Engineering to extract information from water consumption curves.

Open-source/Proprietary software: Proprietary software.

B.2.6 Electrical losses detection and benchmarking at LEC level

Service to be offered in real-time/offline:

Offline.

Execution frequency: Weekly, monthly or on-demand.

Input data requirements:

Table 52. Execution input data for Electrical losses detection and benchmarking at LEC level service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
SM Active Power	Hourly	Hourly active power recorded by the SMs under a specific CT	kW	> 1 month	DSO or LEC operator	R
SM Reactive Power	Hourly	Hourly reactive power recorded by the SMs under a specific CT	kvar	> 1 month	DSO or LEC operator	O
SM event logs	Daily	Daily recording of SM event logs. These indicate errors and alarm arising from SMs	ID integer numbers	> 1 month	DSO or LEC operator	O

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Transformer Active Power	Hourly	Hourly active power recorded the CT meter	kW	> 1 month	DSO or LEC operator	R
Transformer Reactive Power	Hourly	Hourly reactive power recorded the CT meter	kvar	> 1 month	DSO or LEC operator	O
Topology	N/A	Grid topology including line impedances to calculate Technical Losses	N/A	N/A	DSO or LEC operator	O

Table 53. Training data for Electrical losses detection and benchmarking at LEC level service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Historical Detected Frauds	N/A	Information regarding the historical detected fraud: type of fraud, day of inspection, magnitude of fraud, etc.	string	N/A	DSO or LEC operator	O
Historical SM Active Power	Hourly	Hourly active power recorded by the SMs under a specific CT that experienced fraud	kW	N/A	DSO or LEC operator	O
Historical SM Reactive Power	Hourly	Hourly reactive power recorded by the SMs under a specific CT that experienced fraud	kvar	N/A	DSO or LEC operator	O
Historical SM event logs	Daily	Daily recording of SM event logs. These indicate errors and alarm arising from SMs.	ID integer numbers	N/A	DSO or LEC operator	O
Historical Transformer Active Power	Hourly	Hourly active power recorded the CT meter	kW	N/A	DSO or LEC operator	O

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Historical Transformer Reactive Power	Hourly	Hourly reactive power recorded the CT meter	kvar	N/A	DSO or LEC operator	O

Expected outputs:

The possible outputs of the service, depending on whether or not there is fraud and the type of fraud, can be classified as follows:

- **Abnormal losses:** The service notifies whether or not there are abnormal losses in the analysed grid.
- **Losses data:** If there are abnormal losses in the grid, these are analysed, and some descriptive information is obtained and transferred to the User (type of losses, magnitude, duration and probability).
- **Culprit:** If there are SMs with anomalous behaviour, they are detected and assigned a probability of committing fraud.

The following table summarises the different service outputs.

Table 54. Output data for Electrical losses detection and benchmarking at LEC level service

Data	Lowest level of granularity	Description	Units
Abnormal losses detected	When executed	Sent a notification if NTL > X%	YES / NO
Losses data: Type	When executed	Classification between high technical losses or fraud (Marihuana Plantation, Crypto Mining, Squatting and Unclear)	Classification
Losses data: Probability	When executed	Probability of correct prediction of type of losses and fraudster.	%
Losses data: Magnitude	When executed	Magnitude of fraud (95% percentile)	kW
Losses data: Duration	When executed	Duration of abnormal losses in days.	days
SM ID	When executed	SM ID of the consumer who is potentially committing fraud	SM ID

Applied Techniques:

The AI techniques applied in this service are:

- Classification Algorithms (e.g., Random Forest Classifier, Gradient Booster Classifier and Support Vector Classifier) to find the type of losses based on their load profile.

- Fuzzy c-Means as a clustering algorithm to detect SMs with suspicious shifts in their consumption patterns.
- Data Mining and Feature Engineering to extract features and information from active power curves.

Open-source/Proprietary software: Open-source.

B.2.7 Reinforcement Plan of Local Energy Communities for Future Renewable Integration

Service to be offered in real-time/offline:

Offline.

Execution frequency: Weekly, monthly or yearly.

Input data requirements:

Table 55. Execution input data for Reinforcement Plan of LEC for Future Renewable Integration service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Transformer Active Power	Hourly	Hourly active power recorded the CT meter	kW	> 3 years	DSO or LEC operator or ESCO	R
Transformer Reactive Power	Hourly	Hourly reactive power recorded the CT meter	kW	> 3 years	DSO or LEC operator or ESCO	O
Topology	N/A	Grid topology of LEC including line impedances, transformer parameters and bus voltages	N/A	N/A	DSO or LEC operator or ESCO	R
Asset Costs	N/A	Investment and operational costs of line types, transformer types and Li-ion battery systems (for different capacity levels).	Euros (€)	N/A	DSO or LEC operator or ESCO	R

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
GIS Data	N/A	Geographic coordinates of grid assets	Latitude and Longitude	N/A	DSO or LEC operator or ESCO	O
Asset Age	N/A	Current life-time of line and transformers	Years	N/A	DSO or LEC operator or ESCO	O
Expansion plans	N/A	Location of future load and generation expansions according to User requests.	kW	N/A	DSO or LEC operator or ESCO	O

Expected outputs:

The service reports planning actions for future renewable scenarios in LEC, aiming to minimise asset investment costs for DSOs using traditional planning strategies (replacement or reinforcement of feeder lines and transformers) and flexible planning strategies (installation of Li-ion batteries). Once the optimal planning strategy is found, the operator can obtain, new loading percentages (%) per asset and total investment costs.

The following table summarises the different service outputs.

Table 56. Output data for Reinforcement Plan of LEC for Future Renewable Integration service

Data	Lowest level of granularity	Description	Units
CAPEX	When executed	Capital Investment Costs of new lines, transformers or batteries.	Euro (€)
OPEX	When executed	Operational Investment Costs of new lines, transformers or batteries	Euro (€)
Asset Improvements	When executed	Improvement of Lines Loadings, Transformer Loadings and Bus Voltages.	%

Applied Techniques:

The techniques applied in this service are

- Optimisation model to determine best size and location of new lines, transformers or Li-ion batteries to reinforce the grid minimizing CAPEX and OPEX.
- Data driven techniques to reduce order of scenarios.
- Machine learning forecasting techniques for future renewable generation.

Open-source/Proprietary software: Open-source.

B.2.8 Optimising self-consumption of renewable energy at LEC level

Service to be offered in real-time/offline:

The frequency of execution of the service will be daily, and the time of execution will depend on the renewal of PV production and consumption forecasts.

Input data requirements:

Table 57. Execution input data for Optimizing self-consumption of renewable energy at LEC level service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Predicted active energy production	15’	Predicted active energy production at the PV generator output	Wh	1 day	LEC operator	R
Predicted active energy consumption	15’	Predicted active energy consumption at the PCC of the prosumer	Wh	1 day	LEC operator	R

Expected outputs:

The output of the service is the 96 quarter-hour PV battery schedule for the following day.

The following table summarises the different service outputs.

Table 58. Output data for Optimizing self-consumption of renewable energy at LEC level service

Data	Lowest level of granularity	Description	Units
Battery charging/discharging active energy schedule	15’	Scheduled battery charging/discharging active energy at the battery inverter output	Wh

Applied Techniques:

The AI techniques applied in this service are:

- Optimisation Greedy algorithm.

Open-source/Proprietary software: Proprietary software.

B.2.9 Optimizing sharing coefficients in collective self-consumption

Service to be offered in real-time/offline:

The frequency and time of execution of the service will be under demand depending on operating and market conditions. For instance, the current Spanish regulation requires determination of these sharing coefficients for all the year, allowing changes twice a year.

Input data requirements:

Table 59. Execution input data for Optimizing sharing coefficients in collective self-consumption service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Historic active consumed energy	1 h	Historic active energy consumed by every consumer in the Energy Community	Wh	> 1 year	Energy Community Operator (EDP)	R

Expected outputs:

The output of the service is the hourly sharing coefficients schedule of a shared PV generator in a self-consumption application for a certain period.

The following table summarises the different service outputs.

Table 60. Output data for Optimizing sharing coefficients in collective self-consumption service

Data	Lowest level of granularity	Description	Units
Sharing coefficients of all the consumers in the collective self-consumption system for the determined period	1 h	Scheduled sharing coefficients of all the consumers in the collective self-consumption system	%

Applied Techniques:

The AI techniques applied in this service are:

- Optimisation Greedy algorithm.

Open-source/Proprietary software: Proprietary software.

B.2.10 Planning services

Service to be offered in real-time/offline:

The frequency of execution of the service would be yearly, and the time of execution will depend on the fuel energy markets and measures implementation revision in the demonstrator. The time of execution would also depend on the demonstration decarbonisation KPIs revision.

Input data requirements:

Table 61. Execution input data for Planning services

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Building geometry	N/A	Building geometry and geolocated (preferably in a GIS format)	N/A	N/A	Municipality (Public or Private information)	R
Property registry information	N/A	Building information included in a shape file or related to Building ID (Construction year, Use, Height)	N/A	N/A	Municipality (Public or Private information)	O
Additional building information	N/A	Energy Performance Certificates, Retrofitted buildings, Building Energy System, Ownership	N/A	N/A	Municipality (Public or Private information), LEC Operator	O
Historic energy consumption	60’	Provided by the LEC operator (by energy us, by fuel type). If not available, estimated by the planning service	kWh	1 year	LEC Operator	R/O
Socioeconomic data	N/A	Average income per household, per person, age of residents, educational level, etc..	N/A	1 year	Municipality (Public or Private information)	O

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Other additional information related to relevant building energy generation systems	N/A	Hourly profiles, equipment performance, installed power	N/A	1 year	LEC Operator	R/O
Historic local renewable production	60’	Hourly profiles	kWh	1 year	LEC Operator	R/O
Renewable equipment information	N/A	Equipment performance, installed power, CAPEX, OPEX, embedded impact	N/A	N/A	LEC Operator	R/O
Historic energy prices	60’	Prices agreed with the supplier. Includes the energy and price constraints agreed with the supplier.	€/kWh	1 year	LEC Operator	R
Decarbonisation objectives	yearly	Decarbonisation objectives will be defined ($kgCO_2$/year). Economical restrictions should be also defined (€invested/year)	N/A	N/A	LEC Operator, Municipality	R

The expected outputs provided by the Planning Service will vary considering the information available or provided by the LEC operator.

Expected outputs:

Table 62. Output data for Planning services

Data	Lowest level of granularity	Description	Units
Energy consumption information	60’	Demand per end-use, consumption by end-use, cost of energy consumed, emissions per end-use, degree of self-consumption, etc.	kWh
Local renewable generation (potential generation)	60’	Energy Produced, consumed and surplus. Cost of energy produced, consumed and surplus.	kWh
Local renewable interventions (alternative scenarios)	Yearly (2020-2050)	Type of intervention applied, configuration, cost of interventions, impact embedded on interventions	N/A

Results can be provided in different units considering the data input provided: per kWh consumed, per m^2, per person, per average income, per euro invested, for the global LEC, etc.

Alternative scenarios combining renewable interventions will be proposed by the Planning Service considering KPIs about decarbonisation objectives, energy consumption information and local renewable generation considering socioeconomic impacts (ex. avoiding energy poverty).

Applied Techniques:

The AI techniques applied in this service are:

- GIS techniques (TBD).
- Hourly energy simulation based on hourly-degree day calculation.

Open-source/Proprietary software: Proprietary software. Some developments will be deployed in QGIS (open-source software).

B.3 Electromobility UC Services

B3.1 EV charge booker platform

Service to be offered in real-time/offline:

The service is available in real-time on demand.

It relies on a set of data exchanges (technical services) that can take place at different time scales, depending on the needs:

Table 63. List of EV charge booker platform services

Service	Service developer	Data Providers (DPs)	Model Serving Type	End User
Searching charging points	AWG	EMRSP	Link to external platform REST API GET	EMSP
EMRSP_Searching timeslots of a charging station	AWG	EMRSP	Link to external platform REST API GET	EMSP
EMRSP_Booking a time slot on a charging station	AWG	EMRSP	Link to external platform REST API GET	EMSP
Triggering Cancellation of a reservation	AWG	EMRSP	Link to external platform REST API PUT	EMSP
Report Cancellation of a reservation	TBD	EMSP	Link to external platform REST API PUSH	EMRSP
Report NoShow	TBD	EMSP	Link to external platform REST API PUSH	EMRSP
Report Consumption of a reservation	TBD	EMSP	Link to external platform REST API PUSH	EMRSP
Report charging session	TBD	EMSP	Link to external platform REST API PUSH	EMRSP
report Billing of reservation	TBD	EMSP	Link to external platform REST API PUSH	EMRSP

Input data requirements:

Table 64. Input requirements for EV charge booker platform

Service	Data	Description	Optional/ Required
Searching charging points	listConnectorType charging powers time range location range	Criterias to search available charging points with user input	R
EMRSP_Searching timeslots of a charging station	listConnectorType charging powers time range Charging station	Criterias to search time slots available in a charging station	R
EMRSP_Booking a time slot on a charging station	Charging Point time slot Power	Criteria to book a time slot in a specific charging station	R
Triggering Cancellation of a reservation	Reservation Cancelation event	Reservation id which is required to cancel the booking and some additional information about cancelation could be sent.	R
Report Cancellation of a reservation	Reservation Cancelation event	Reservation id and cancelation event which is triggered by the CPO	R
Report NoShow	Reservation NoShow event	Reservation id and noshow event which is triggered by the CPO	R
Report Consumption of a reservation	Reservation Charging session	Reservation id and event triggered by the start of the charging session by the CPO	R
Report charging session	Reservation Charging session	Reservation id and list of charging session reported by the CPO	R
report Billing of reservation	Reservation Charging session	Reservation id and the event of charging session end	R

Expected outputs:

The output of the services is specific to each technical services.

The following table summarises the different service outputs.

Table 65. Expected output for EV charge booker platform

Service	Data	Description	Optional/ Required
Searching charging points	listCharging Stations	List of the charging stations found with some additional information like available connectors, power supplied and tarrifs	R
EMRSP_Searching timeslots of a charging station	Charging points Timeslots	List of time slots available for each charging point of the choosed charging station.	R
EMRSP_Booking a time slot on a charging station	Reservation	Reservation object contains time slot, power, connector type, noshow criteria, cancelation criteria	R
Triggering Cancellation of a reservation	ACK	Acknowledgment of the good reception of the request	R
Report Cancellation of a reservation	ACK	Acknowledgment of the good reception of the request	R
Report NoShow	ACK	Acknowledgment of the good reception of the request	R
Report Consumption of a reservation	ACK	Acknowledgment of the good reception of the request	R
Report charging session	ACK	Acknowledgment of the good reception of the request	R
report Billing of reservation	ACK	Reservation id and the event of charging session end	R

Applied Techniques:

- Data modelling and standardisation.

Open-source/Proprietary software:

Proprietary software.

B3.2 CPO open for booking

Service to be offered in real-time/offline:

The service is available in real-time on demand.

It relies on a set of data exchanges (technical services) that can take place at different time scales, depending on the needs:

Table 66. List of CPO open for booking services

Service	Service developer	Data Providers (DPs)	Model Serving Type	End User
listing charging points	GIREVE	CPOs (IZIVIA, etc.)	Link to external platform	EMRSP
CPO_Searching timeslots of a charging station (3)	GIREVE	CPOs (IZIVIA, etc.)	Link to external platform	EMRSP
CPO_Booking a time slot on a Charging station	GIREVE	CPO	Link to external platform	EMRSP
Report Cancellation of a reservation	GIREVE	CPO	Link to external platform	EMRSP
Triggering Cancellation of a reservation	AWG	EMRSP	Link to external platform	CPO
Triggering NoShow	AWG	EMRSP	Link to external platform	CPO
Triggering Consumption of a reservation	AWG	EMRSP	Link to external platform	CPO
Triggering report charging session	AWG	EMRSP	Link to external platform	CPO
Triggering Billing of reservation	AWG	EMRSP	Link to external platform	CPO

Input data requirements:

Table 67. Input requirements for CPO open for booking

Service	Data	Description	Optional/ Required
listing charging points	None		R

Service	Data	Description	Optional/ Required
CPO_Searching timeslots of a charging station	listConnectorType charging powers time range Charging station	Criterias to search time slots available in a charging station	R
CPO_Booking a time slot on a Charging station	Charging Point time slot Power	Criteria to book a time slot in a specific charging station	R
Report Cancellation of a reservation	Reservation Cancelation event	Reservation id which is required to cancel the booking and some additional information of cancelation could be sent	R
Triggering Cancellation of a reservation	Reservation Cancelation event	Reservation id and cancelation event which is triggered by the CPO	R
Triggering NoShow	Reservation NoShow event	Reservation id and noshow event which is triggered by the CPO	R
Triggering Consumption of a reservation	Reservation Charging session	Reservation id and event triggered by the start of the charging session by the CPO	R
Triggering report charging session	Reservation Charging session	Reservation id and list of charging session reported by the CPO	R
Triggering Billing of reservation	Reservation Charging session	Reservation id and the event of charging session end	R

Expected outputs:

The output of the services is specific to each technical services.

The following table summarises the different service outputs.

Table 68. Expected output for CPO open for booking

Service	Data	Description	Optional/ Required
Listing charging points	listCharging Stations	List of all charging points available in the CPO with additional information like connector types, power and tariffs	R

Service	Data	Description	Optional/ Required
CPO_Searching timeslots of a charging station	Charging points Timeslots	List of time slots available for each charging point of the chosen charging station.	R
CPO_Booking a time slot on a Charging station	Reservation	Reservation object contains time slot, power, connector type, NoShow criteria, cancelation criteria	R
Report Cancellation of a reservation	ACK	Acknowledgment of the good reception of the request	R
Triggering Cancellation of a reservation	ACK	Acknowledgment of the good reception of the request	R
Triggering NoShow	ACK	Acknowledgment of the good reception of the request	R
Triggering Consumption of a reservation	ACK	Acknowledgment of the good reception of the request	R
Triggering report charging session	ACK	Acknowledgment of the good reception of the request	R
Triggering Billing of reservation	ACK	Reservation id and the event of charging session end	R

Applied Techniques:

- Data modelling and standardisation.

Open-source/Proprietary software: Proprietary software.

B.4 Flexibility UC Services

B.4.1 Grid observability and network analysis

Service to be offered in real-time/offline:

Analysis offline, Observability real time.

Execution frequency: On demand.

Input data requirements:

Table 69. Execution input data for Grid observability and network analysis service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Smart Meter (SM) – ID	NA	Identification number of the SMs	NA	NA	DSO	R
Secondary Substation (SS) – ID	NA	Identification number of the SSs	NA	NA	DSO	R
SM – Type	NA	{“Single phase”; “Three-phase"}	NA	NA	DSO	R
Single phase SM Active Power load curve	10 min timestep, daily batch	10 minutes time step active power load curve recorded by the SMs under a specific SS	kW	> 1 month	DSO	R
Three phase SM Active Power load curve – Phase 1						
Three phase SM Active Power load curve – Phase 2						
Three phase SM Active Power load curve – Phase 3						
Single phase SM Reactive Power load curve	10 min timestep, daily batch	10 minutes time step reactive power load	kvar	> 1 month	DSO	O

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Three phase SM Reactive Power load curve – Phase 1		curve recorded by the SMs under a specific SS				
Three phase SM Reactive Power load curve – Phase 2						
Three phase SM Reactive Power load curve – Phase 3						
Single phase SM Voltage Profile	10 min timestep, daily batch	10 minutes time step voltage profile recorded by the SMs under a specific SS	V	> 1 month	DSO	R
Three phase SM Voltage Profile – Phase 1						
Three phase SM Voltage Profile – Phase 2						
Three phase SM Voltage Profile – Phase 3						
SM – Location	NA	GPS coordinate of each SM	NA	NA	DSO	O
SS – Location	NA	GPS coordinate of each SS	NA	NA	DSO	O

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Primary Substation (PS) - Location	NA	GPS coordinate of each SM	NA	NA	DSO	R
Nominal voltage limits	NA	Regulatory voltage limit for electricity supply	V	NA	DSO	R
SM – SS connection	NA	A priori SM – SS connection as recorded in legacy systems	NA	NA	DSO	R
SM – LV feeder connection	NA	A priori SM – LV feeder connection as recorded in legacy systems	NA	NA	DSO	R
SS – LV fuse rating	NA	Rating of each fuse of a specific SS	A	NA	DSO	R
SS – PS connection	NA	SS – PS connection as recorded in legacy systems	NA	NA	DSO	R
SS – PS feeder connection	NA	SS – PS feeder connection as recorded in legacy systems	NA	NA	DSO	R
PS – Active power	10 min timestep provided in real time	10 minutes averaged active power recorded at PS level	kW	Every 10 minutes	DSO	R

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
PS – Voltage profile	10 min timestep provided in real time	10 minutes averaged voltage recorded at PS level	V	Every 10 minutes	DSO	R
Meteorological data	10 min timestep provided in real time	Real-time meteorological data (temperature, sunshine)	NA	Every 10 minutes	Meteorological data provider	R

The required training data is similar to the Execution input data but with two months of historical value, which will grow longer with the execution.

Expected outputs:

The output of the service is a deep analysis of the network's operating conditions and a model which provides a state estimation:

- Reliable low voltage network topology from a priori connections.
- Set of KPIs depicting low voltage assets health level.
- User interface to navigate in the analysis.
- Real-time and forecasted state estimation.

The following table summarises the different service outputs.

Table 70. Output data for Grid observability and network analysis service

Data	Lowest level of granularity	Description	Units
LV topology	When executed	SM – SS's feeder – SS connection	NA
LV KPIs	When executed	Set of KPIs (load level, unbalancing level, …)	NA
SM – RT voltage	Every 10 minutes	Voltage estimation at SM level	V
SM – Forecasted Voltage	Every 2 hours for the time horizon	Voltage profile estimation at SM level during the time horizon	V
Asset – RT load	Every 10 minutes	Load estimation at Asset level	V
Asset – Forecasted load	Every 2 hours for the time horizon	Voltage profile estimation at SM level during the time horizon	V

Applied Techniques:

- Optimisation algorithms.
- Classification and clustering algorithms.
- Regression algorithms.
- Neural networks models.

Open-source/Proprietary software: Proprietary software.

B.4.2 Grid validation platform, real-time

Service to be offered in real-time/offline:

Real-time with execution frequency of 10 minutes.

Input data requirements:

Table 71. Execution input data for Grid validation platform, real-time service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Smart Meter (SM) – ID	NA	Identification number of the SMs	NA	NA	DSO	R
Secondary Substation (SS) – ID	NA	Identification number of the SSs	NA	NA	DSO	R
SM – Type	NA	{“Single phase”; “Three-phase"}	NA	NA	DSO	R
Single phase SM Active Power load curve	10 min timestep, daily batch	10 minutes time step active power load curve recorded by the SMs under a specific SS	kW	> 1 month	DSO	R
Three phase SM Active Power load curve – Phase 1						
Three phase SM Active Power load curve – Phase 2						
Three phase SM Active Power load curve – Phase 3						
Single phase SM Reactive Power load curve	10 min timestep, daily batch	10 minutes time step reactive power load curve recorded by the SMs under a specific SS	kvar	> 1 month	DSO	O
Three phase SM Reactive Power load curve – Phase 1						
Three phase SM Reactive Power load curve – Phase 2						

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Three phase SM Reactive Power load curve – Phase 3						
Single phase SM Voltage Profile	10 min timestep, daily batch	10 minutes time step voltage profile recorded by the SMs under a specific SS	V	> 1 month	DSO	R
Three phase SM Voltage Profile – Phase 1						
Three phase SM Voltage Profile – Phase 2						
Three phase SM Voltage Profile – Phase 3						
SM – Location	NA	GPS coordinate of each SM	NA	NA	DSO	O
SS – Location	NA	GPS coordinate of each SS	NA	NA	DSO	O
Primary Substation (PS) - Location	NA	GPS coordinate of each SM	NA	NA	DSO	R
Nominal voltage limits	NA	Regulatory voltage limit for electricity supply	V	NA	DSO	R
SM – SS connection	NA	A priori SM – SS connection as recorded in legacy systems	NA	NA	DSO	R
SM – LV feeder connection	NA	A priori SM – LV feeder connection as recorded in legacy systems	NA	NA	DSO	R

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
SS – LV fuse rating	NA	Rating of each fuse of a specific SS	A	NA	DSO	R
SS – PS connection	NA	SS – PS connection as recorded in legacy systems	NA	NA	DSO	R
SS – PS feeder connection	NA	SS – PS feeder connection as recorded in legacy systems	NA	NA	DSO	R
PS – Active power	10 min timestep provided in real time	10 minutes averaged active power recorded at PS level	kW	Every 10 minutes	DSO	R
PS – Voltage profile	10 min timestep provided in real time	10 minutes averaged voltage recorded at PS level	V	Every 10 minutes	DSO	R
Meteorological data	10 min timestep provided in real time	Real-time meteorological data (temperature, sunshine)	NA	Every 10 minutes	Meteorological data provider	R

Open-source/Proprietary software: Proprietary software.

B.4.3 Flexibility platform for DER connection, planning

Service to be offered in real-time/offline:

Offline and On-demand.

Input data requirements:

Table 72. Execution input data for Flexibility platform for DER connection, planning service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Smart Meter (SM) – ID	NA	Identification number of the SMs	NA	NA	DSO	R
Secondary Substation (SS) – ID	NA	Identification number of the SSs	NA	NA	DSO	R
SM – Type	NA	{“Single phase”; “Three-phase"}	NA	NA	DSO	R
Single phase SM Active Power load curve	10 min timestep, daily batch	10 minutes time step active power load curve recorded by the SMs under a specific SS	kW	> 1 month	DSO	R
Three phase SM Active Power load curve – Phase 1						
Three phase SM Active Power load curve – Phase 2						
Three phase SM Active Power load curve – Phase 3						
Single phase SM Reactive Power load curve	10 min timestep, daily batch	10 minutes time step reactive power load curve recorded by the SMs under a specific SS	kvar	> 1 month	DSO	O
Three phase SM Reactive Power load curve – Phase 1						
Three phase SM Reactive Power load curve – Phase 2						

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Three phase SM Reactive Power load curve – Phase 3						
Single phase SM Voltage Profile	10 min timestep, daily batch	10 minutes time step voltage profile recorded by the SMs under a specific SS	V	> 1 month	DSO	R
Three phase SM Voltage Profile – Phase 1						
Three phase SM Voltage Profile – Phase 2						
Three phase SM Voltage Profile – Phase 3						
SM – Location	NA	GPS coordinate of each SM	NA	NA	DSO	O
SS – Location	NA	GPS coordinate of each SS	NA	NA	DSO	O
Nominal voltage limits	NA	Regulatory voltage limit for electricity supply	V	NA	DSO	R
SM – SS connection	NA	A priori SM – SS connection as recorded in legacy systems	NA	NA	DSO	R
SM – LV feeder connection	NA	A priori SM – LV feeder connection as recorded in legacy systems	NA	NA	DSO	R
SS – LV fuse rating	NA	Rating of each fuse of a specific SS	A	NA	DSO	R

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Targets	NA	Specification of expected outcome from the call	NA	NA	Public Institutions	R
Area	NA	Specification of eligible area for the call	NA	NA	Public Institutions	R
Asset – ID	NA	Identification number of the asset	NA	NA	RES & flexibility investors	R
Asset – type	NA	Per asset, the type such as “Battery”, “PV panels”, “controllable load” …	NA	NA	RES & flexibility investors	R
Asset – locations	NA	List of SM – ID under which the asset is expected could be connected	NA	NA	RES & flexibility investors	R
Asset – size	NA	Sizing of the asset, (MIN / EXPECTED / MAX), unit according to its type (kWp for PV panels, (kW, kWh) for batteries…)	NA	NA	RES & flexibility investors	R

Expected outputs:

The output of the service is an optimised implementation plan of the asset proposed by the RES & flexibility investors. The optimisation weights:

- The targets from the public institution.
- The expectations from the RES & flexibility investors.
- The constraints of the DSO.

The following table summarises the different service outputs.

Table 73. Output data for Flexibility platform for DER connection, planning service

Data	Lowest level of granularity	Description	Units
Asset – Optimal size	When executed		Same as "Asset – Size"
Asset – Optimal location	When executed	Selected SM – ID to connect the asset	NA
Asset – Operating Constraints	When executed	List of rules the asset must follow	

Applied Techniques:

- Optimisation algorithms.
- Classification and clustering algorithms.
- Regression algorithms.

Open-source/Proprietary software: Proprietary software.

B.4.4 Passive consumption baseline prediction service

Service to be offered in real-time/offline:

The frequency of execution of the service will be daily, and the time of execution will depend on the market's organisation in the country where it will be demonstrated.

Input data requirements:

Table 74. Execution input data for Passive consumption baseline prediction service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Predicted ambient temperature	15'	Predicted ambient temperature at the location of the resource	ºC	1 day	Portfolio Manager	O

Table 75. Training data for Passive consumption baseline prediction service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Historic average active power consumption	15’	Historic average active power consumed by the passive resource	W	> 1 year	Portfolio Manager	R
Historic ambient temperature	15’	Historic ambient temperature at the location of the resource	ºC	> 1 year	Portfolio Manager	O

Expected outputs:

The output of the service is the 96-quarter-hour consumption forecast for the following day.

Table 76. Output data for Passive consumption baseline prediction service

Data	Lowest level of granularity	Description	Units
Predicted average active power consumption	15’	Predicted average active power consumption	W

Applied Techniques:

The AI techniques applied in this service are:

- Preprocessing techniques to remove outliers, scale the dataset and clear faulty data.
- Regressive Algorithms such as Random Forest.

Open-source/Proprietary software: Proprietary software.

B.4.5 Intermittent DER generation resource baseline prediction service

Service to be offered in real-time/offline:

The frequency of execution of the service will be daily, and the time of execution will depend on the market’s organisation in the country where it will be demonstrated.

Input data requirements:

Table 77. Execution input data for Intermittent DER generation resource baseline prediction service.

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Predicted Irradiance	15'	Predicted global Irradiance on PoA (Plane of Array) at the location of the PV generator	Wh/m^2	1 day	Portfolio Manager	R
Predicted ambient temperature	15'	Predicted ambient temperature at the location of the PV generator	°C	1 day	Portfolio Manager	R

Table 78. Training data for Intermittent DER generation resource baseline prediction service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Historic Irradiance	15'	Historic global Irradiance on PoA (Plane of Array) at the location of the PV generator	Wh/m^2	> 1 month	Portfolio Manager	R
Historic ambient temperature	15'	Historic ambient temperature at the location of the PV generator	°C	> 1 month	Portfolio Manager	R
Historic average active power	15'	Historic average active power produced by the PV generator	W	> 1 month	Portfolio Manager	R

Expected outputs:

The output of the service is the 96 quarter-hour PV production forecast for the following day. The following table summarises the different service outputs.

Table 79. Output data for Intermittent DER generation resource baseline prediction service

Data	Lowest level of granularity	Description	Units
Predicted average active power production	15’	Predicted average active power production at the PV generator output	W

Applied Techniques:

The AI techniques applied in this service are:

- Preprocessing techniques to remove outliers, scale the dataset and clear faulty data.
- Regressive Algorithms such as Random Forest.

Open-source/Proprietary software: Proprietary software.

B.4.6 Prosumer EMS internal optimisation service

Service to be offered in real-time/offline:

The frequency of execution of the service will be daily, and the time of execution will depend on the market’s organisation in the country where it will be demonstrated.

Input data requirements:

Table 80. Training input data for Prosumer EMS internal optimisation service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
List of identifiers of contracted controllable resources	N/A	List of identifiers of contracted controllable resources included in the contracted service, which schedule has to be optimised	N/A	N/A	Portfolio Manager	R
Average active power consumption	15’	Average active power consumption of each controllable resource included in the contracted service	W	1 day	Portfolio Manager	R

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Ambient temperature	15’	Ambient temperature at the location of each controllable resource included in the contracted service	C	1 day	Portfolio Manager	O
HVAC status	15’	For each HVAC resource included in the service contract, status of the HVAC	ON/OFF	1 day	Portfolio Manager	O
HVAC zone internal temperature	15’	For each of the thermal zones of an HVAC resource included in the service contract, internal temperature of that room	C	1 day	Portfolio Manager	O
HVAC zone setpoint temperature	15’	For each of the thermal zones of an HVAC resource included in the service contract, internal temperature of that room	C	1 day	Portfolio Manager	O
Pump status	15’	For each irrigation pump resource included in the service contract, status of the pump	ON/OFF	1 day	Portfolio Manager	O

Table 81. Execution input data for Prosumer EMS internal optimisation service.

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Aggregated predicted average power of passive resources	15’	For each accounting point included in the service contract, aggregated predicted renewable generators active power production and passive loads average active power consumption	W	1 day	Portfolio Manager	R
Ambient temperature	15’	For each HVAC controllable resource included in the service contract, ambient temperature forecast for the following day	C	1 day	Portfolio Manager	O
Minimum internal (comfort range) temperature	15’	For each zone of each HVAC controllable resource included in the service contract, minimum internal temperature allowed for that zone	C	1 day	Portfolio Manager	O
Maximum internal (comfort range) temperature	15’	For each zone of each HVAC controllable resource included in the service contract, maximum internal temperature allowed for that zone	C	1 day	Portfolio Manager	O

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Requested utilisation of the HVAC	15’	For each HVAC controllable resource included in the service contract, requested utilisation. ON means that all the building zones are requested to be in the comfort range during that 15-minute period	ON/OFF	1 day	Portfolio Manager	O
Allowed utilisation of the pump	15’	For each irrigation pump controllable resource included in the service contract, requested utilisation. ON means that all the building zones are requested to be in the comfort range during that 15-minute period	ON/OFF	1 day	Portfolio Manager	O
Requested daily utilisation periods of the pump	15’	For each irrigation pump controllable resource included in the service contract, number of 15-minute intervals for which the pump has to be ON during that day	N/A	1 day	Portfolio Manager	O
Power term prices	15’	For each accounting point included in the service contract, power term prices agreed with the DSO for the power term	c€/kW	1 day	Portfolio Manager	R

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Power term minimum limitation	15’	For each accounting point included in the service contract, power term minimum limitation agreed with the DSO, positive means consumption, negative means production	W	1 day	Portfolio Manager	R
Power term maximum limitation	15’	For each accounting point included in the service contract, power term maximum limitation agreed with the DSO, positive means consumption, negative means production	W	1 day	Portfolio Manager	R
Energy term prices	15’	For each aggregated retail contract (which includes the collection of accounting points of the prosumer included in the same retail contract with a supplier, energy prices agreed with the supplier for the energy term	c€/kWh	1 day	Portfolio Manager	R

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Energy term minimum limitation	15’	For each aggregated retail contract (which includes the collection of accounting points of the prosumer included in the same retail contract with a supplier, for each energy range included in the contract with the retailer, energy term (Average active power) minimum limitation	W	1 day	Portfolio Manager	R
Energy term maximum limitation	15’	For each aggregated retail contract (which includes the collection of accounting points of the prosumer included in the same retail contract with a supplier, for each energy range included in the contract with the retailer, energy term (Average active power) maximum limitation	W	1 day	Portfolio Manager	R

Expected outputs:

The output of the service is the 96 quarter-hour resource operation parameters schedule for the following day (one schedule for each flexible resource) and the predicted active energy consumption profile associated to that set of operation parameters.

Table 82. Output data for Prosumer EMS internal optimisation service

Data	Lowest level of granularity	Description	Units
Status of the resource	15’	For each controllable resource included in the service contract, decided status of the resource.	ON/OFF
Predicted average active power consumption	15’	For each controllable resource included in the service contract, predicted average active power consumption	W
Internal setpoint temperature	15’	For each zone of each HVAC controllable resource included in the service contract, decided internal setpoint temperature	C
Internal temperature	15’	For each zone of each HVAC controllable resource included in the service contract, predicted internal temperature	C

Applied Techniques:

The AI techniques applied in this service are:

- Optimisation techniques (TBD).

Open-source/Proprietary software: Proprietary software.

B.4.7 Flexibility order disaggregation service

Service to be offered in real-time/offline:

The frequency of execution of the service will be when the flexibility order from the DSO is received.

Input data requirements:

Table 83. Execution input data for Flexibility order disaggregation service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Flex order type	15’	For each bidding zone included in the flex order, type of the order	Flexibility/ CapacityMargin	1 day	Portfolio Manager	R

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Flexibility ordered	15’	For each bidding zone included in the flex order, flexibility ordered positive values are either considered as a consumption increase or a production decrease relative to the previous baseline sent by the PM	Wh	1 day	Portfolio Manager	R

Expected outputs:

The output of the service are the market constraints that the Prosumer EMS internal optimisation service will take into account when deciding the optimal schedule of the controllable resources included in the service contract.

Table 84. Output data for Flexibility order disaggregation service

Data	Lowest level of granularity	Description	Units
Bidding zone composition	N/A	For each bidding zone included in the flex order, list of identifiers of controllable resources included in that zone	N/A
Market constraint type	15’	For each bidding zone included in the flex order, the type of the flex order.	Request/Constraint
Average active power maximum limit	15’	For each bidding zone included in the flex order, average active power maximum limit (positive means consumption, negative means production)	W
Average active power minimum limit	15’	For each bidding zone included in the flex order, average active power minimum limit (positive means consumption, negative means production)	W

Applied Techniques:

The AI techniques applied in this service are:

- Optimisation techniques (TBD).

Open-source/Proprietary software: Proprietary software.

B.4.8 Aggregated flexibility offer optimisation service

Service to be offered in real-time/offline:

The frequency of execution of the service will be daily, and the time of execution will depend on the market's organisation in the country where it will be demonstrated.

Input data requirements:

Table 85. Execution input data for Aggregated flexibility offer optimisation service

Data	Granularity	Description	Units	Volume	Owner	Optional/ Required
Flexibility request composition	N/A	List of identifiers of bidding zones included in the flex request	N/A	1 day	Portfolio Manager	R
Flexibility request type	N/A	Type of Flex Request	Flexibility/ CapacityMargin	1 day	Portfolio Manager	R
Flexibility requested	15'	Flexibility requested (if the type of the Flex Request is Flexibility)	Wh	1 day	Portfolio Manager	R
Capacity margin available	15'	Capacity margin available (if the type of the Flex Request is CapacityMargin)	Wh	1 day	Portfolio Manager	R

Expected outputs:

The output of the service is the flexibility offer that will be sent to the DSO in response to the Flexibility Request.

Table 86. Output data for Aggregated flexibility offer optimisation service

Data	Lowest level of granularity	Description	Units
Flexibility offer composition	N/A	List of identifiers of bidding zones included in the flex offer	N/A
Flexibility offer type	15'	Type of Flex Offer	Flexibility/CapacityMargin
Flexibility offered	15'	Flexibility offered (if the type of the Flex Offer is Flexibility)	Wh
Capacity margin used	15'	Capacity margin used (if the type of the Flex Offer is CapacityMargin)	Wh

Applied Techniques:

The AI techniques applied in this service are:

- Optimisation techniques (TBD).

Open-source/Proprietary software: Proprietary software.