H2020-LC-SC3-EE-2019

EUROPEAN COMMISSION

European Climate, Infrastructure and Environment Executive Agency

Grant agreement no. 893857

frESCO

New business models for innovative energy services bundles for residential consumers

Project acronym	**frESCO**
Full title	New business models for innovative energy service bundles for residential consumers
Grant agreement number	893857
Programme	H2020-EU.3.3.1. - Reducing energy consumption and carbon footprint by smart and sustainable use
Topic identifier	LC-SC3-EE-13-2018-2019-2020 - Enabling next-generation of smart energy services valorising energy efficiency and flexibility at demand-side as energy resource
Call	H2020-LC-SC3-EE-2019
Funding scheme	IA – Innovation Action
Project duration	42 months (1 June 2020 – 30 November 2023)
Project adviser	Rebecca Kanellea- CIENA
Coordinator	CIRCE – Fundacion Circe Centro de Investigacion de Recursos y Consumos Energeticos
Consortium partners	CIRCE, S5, EI-JKU, CARTIF, UBITECH, UBE, KONCAR KET, KRK, COSMA, LCTE, VOLT, VERD, IOSA, RINA-C
Website	http://fresco-project.eu
Cordis	https://cordis.europa.eu/project/id/893857

DISCLAIMER OF WARRANTIES

This document has been prepared by frESCO project partners as an account of work carried out within the framework of the EC-GA contract no. 893857.

Neither Project Coordinator, nor any signatory party of frESCO Project Consortium Agreement, nor any person acting on behalf of any of them:

(a) makes any warranty or representation whatsoever, expressed or implied,

(i). with respect to the use of any information, apparatus, method, process, or similar item disclosed in this document, including merchantability and fitness for a particular purpose, or

(ii). that such use does not infringe on or interfere with privately owned rights, including any party's intellectual property, or

(iii). that this document is suitable to any particular user's circumstance; or

(b) assumes responsibility for any damages or other liability whatsoever (including any consequential damages, even if the Project Coordinator or any representative of a signatory party of the frESCO Project Consortium Agreement has been informed of the possibility of such damages) resulting from your selection or use of this document or any information, apparatus, method, process, or similar item disclosed in this document.

ACKNOWLEDGMENT

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n. 893857

Disclaimer: *The European Commission is not responsible for any use made of the information contained herein. The content does not necessarily reflect the opinion of the European Commission.*

Deliverable D2.5
Report on the frESCO conceptual architecture

Deliverable number	D2.5
Deliverable name	Report on the frESCO conceptual architecture
Lead beneficiary	Ubitech
Description	Description of the modular components of frESCO overall solution (big data platform and toolkit for services providers), their specifications, communication protocols and the interaction between each of them, including a workflow diagram
WP	WP2
Related task(s)	Task 2.5
Type	Report
Dissemination level	Public
Delivery date	25.05.2021.
Main author	Dimitra Georgakaki (Ubitech), Eleftheria Petrianou (Ubitech), Spyros Nikolakis (Ubitech)
Contributors	Giorgos Papadopoulos (S5), Alexandros Tsitsanis (S5), Juan Aranda (CIRCE), Andreas Muñoz (CIRCE), Roberto Lázaro (CIRCE), Víctor Serna (CARTIF)

Document history

Version	Date	Changes	Author
V1 – first draft	14.05.2021		Ubitech
2nd review	19.05.2021		EI-JKU
V2 – second draft	20.05.2021		Ubitech
3rd review	21.05.2021		CIRCE
Final version	24.05.2021		Ubitech
Final deliverable submission	25.05.2021		CIRCE

ABBREVIATIONS

Abbreviation	Name
EPC	Energy Performance Contracting
ESCO	Energy Service Company
ICT	Information and Communication Technology
P4P	Pay-For-Performance
IAQ	Indoor Air Quality
VPP	Virtual Power Plants
PV	Photovoltaics
DER	Distributed Energy Resource
EMS	Energy Management System
EE	Energy Efficiency
DSO	Distribution System Operator
TSO	Transport System Operator
BRP	Balance Responsible Party
CIM	Common Information Model
SRI	Smart Readiness Indicator
DR	Demand Response
MQTT	Message Queuing Telemetry Transport
M2M	Machine-To-Machine
GDM	Global Demand Manager
LDM	Local Demand Manager
EV	Electric Vehicle
UI	User Interface
UC	Use Case
HVAC	Heating, Ventilating, and Air Conditioning
LDM	Local Demand Manager
ISP	Internet Service Provider
WP	Work Package

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The frESCO project introduces the deployment of innovative business strategies, based on novel energy and integrated energy service bundles that properly combine and remunerate local flexibility in the form of energy savings and demand side management. Such new business models will extend the traditional EPC contracts to novel Pay for Performance Contracts by offering specific energy service bundles to potential consumers and/or prosumers.

The energy services to be developed can be grouped into smart sensoring and equipment, retrofitting, energy efficiency and self-consumption optimization, flexibility, and non-energy services. Each group (also represented via a use case methodology) offers one or more mandatory services and specific service combinations to form a potential energy service bundle.

To design and implement the frESCO solution a lot of parameters must been considered. First, a detailed asset and data landscaping must be conducted at all the involved demo sites in order to assess the smart readiness of the demo buildings and the potential data sources that will be ingested in the frESCO platform. The evaluation of the regulatory, market and social framework on the demo sites is also of crucial importance, to properly identify enablers and barriers that will directly affect the platform requirements. Business stakeholders and end-users' thorough inputs will lead to the requirements elicitation process, always taking into account that all the frESCO activities will ensure data protection and data security among all the involved actors.

The detailed description of the energy use cases, the business and user requirements as well as functional and non-functional requirements, will offer a clear picture to the design of the final conceptual frESCO architecture. The basic logical functionalities are split into layers and each layer into components. A software component may have one or more software modules. The interaction between these components or modules is described via specific interfaces complying to open communication standards, and the communication of the frESCO platform with external systems and/or data sources will also be fully described in the context of this work.

Through the detailed description of the platform's technology stack, the derived technical requirements and the data and energy services flow diagrams, the frESCO conceptual architecture is transformed into a functional architecture design, ready to be served as input to the real software implementation of the project's solution.

1 INTRODUCTION AND OBJECTIVES

1.1 Document objectives and scope

The scope of this document is to specify the functional and non-functional requirements, the system components, interactions between them and the technical features that will overall deliver the frESCO reference architecture.

This work will consider the use cases that best describe the energy services of the project, the requirements of the main involved actors such as ESCOs, aggregators and retailers and the requirements of prosumers/consumers to describe in a detailed way the key components and modules that consist of the frESCO platform along with their functionalities. For that reason, the following workflow will be followed:

- A detailed description of the use cases along with the main beneficiaries and system components involved.
- A complete list of functional and non-functional requirements and how each requirement is linked to a specific use case (or multiple use cases).
- A functional presentation of all the components and modules along with their interactions and whenever applicable a list of features that each module should support.
- A final graphical architecture presentation.

1.2 Relationship with other tasks

In addition to the main project objectives specified in the DoA, the definition of frESCO architecture is tightly linked with the introduction of the novel energy service bundles that are analysed in D3.1. The market and regulatory framework evaluation as described in D2.2, also serves as high-level input to the design of the final solution. The elicitation of stakeholders and end-user requirements of D2.3 is of crucial importance for their correct mapping and translation to the respective component functionalities of the frESCO platform.

On the other hand, the definition of frESCO architecture will be used as a technical guide for the development of ICT services in the big data platform of WP4 and the multi-service package toolkit for service providers of WP5.

1.3 Document structure

In the first section of this work, a general introduction to the document's scope, relevance with other documents of the project and objectives is highlighted. Section 2 gives an overview of the main actors of the project and how they can benefit from the introduction and design of the novel frESCO services. Section 3 aims to present the use cases of the project and highlight the functional and non-functional system requirements. Section 4 gives a detailed description of all the components and their respective modules, that comprise the final platform solution. Special attention is given to the interdependence of the components as well as the features that each module shall support from a technical perspective. All this work will produce the final frESCO architecture of section 5. Finally, the conclusions of this work are assembled and presented in the form of useful results that serve as a point of reference for other project tasks as well.

2 FRESCO ROLES

This project uses a user-driven innovation approach towards involving beneficiaries and energy value chain stakeholders throughout all stages of the project's life cycle. The project actors play a significant role in the definition of the energy service bundles as mentioned in detail in D3.1 and the formulation of concrete requirements (listed here in section 3). Main frESCO actors and their role in the project are stated below:

Energy efficiency service providers: This group is mainly composed of ESCOs, building owners and facility managers, that are responsible to provide (explicitly in the case of ESCOs or implicitly in the case of owners or managers interfacing with ESCOs) the novel energy service bundles and new business models through the introduction of the P4P contracts to their consumers. Their main interest is around energy efficiency and self-consumption optimization services. In particular, ESCOs are also concerned about non-energy services such as thermal, IAQ comfort as well as the smart readiness level of the building (see also D2.3 for an assessment of the SR indicators of frESCO's pilot buildings) that will eventually lead to a specified and personalised informative billing scheme service.

Demand flexibility service providers: The demand-side flexibility and automated VPP control services as well as the smart contracts based on blockchain technology, are of significant importance to the demand response aggregators, as they will give them a chance to improve the management and the quality of their services without carrying out heavy investments.

Building occupants as consumers and prosumers: The frESCO platform will be responsible for the definition of personalized demand response strategies for each consumer, providing targeted guidance on manual and automated control actions, in order to shift the operation of energy-intensive loads without compromising the occupant's comfort. frESCO energy packages and business models will make distributed generation (e.g., PV) more attractive for residential consumers, as they will maximize the self-consumption rate of these kind of systems while lowering the upfront costs of their installations (partially or totally covered by the ESCO/aggregator).

Installers/Manufacturers: These actors are mainly involved in the sensoring and smart equipment retrofitting services as well as in the non-energy services, as they are the main providers of the smart equipment and devices to be installed in the building premises. The project will drive the market of sustainable energy technology towards data, smart and user-driven solutions.

3 REQUIREMENTS ANALYSIS

3.1 Methodology

A use case is a definition of a specific business objective that the system needs to accomplish. A use case will define the process by describing the various external actors that exist outside of the system, together with the specific interactions they have with it, in the accomplishment of the business objective. The use cases after being well defined and described can serve as the basis for the functional requirements formulation which represent the intended behaviour of the system, the desired functionality, the possible constraints imposed and the objectives that need to be satisfied (from the system point of view). So let us try to approach the use cases considering the four business objectives of the frESCO platform: assess, monitor and potentially upgrade the smart readiness of a building using smart equipment; provide and optimize energy efficiency; provide flexibility services and ensure the comfort and wellbeing of the building occupants (users comfort profiles taken into account in the whole process, see D2.1 for a description of the users of frESCO's pilot buildings). After the use cases formulation, a list of functional requirements is compiled and the relevance to each use case is documented.

3.2 Use Cases Analysis

As we mentioned, each use case described below is trying to represent an objective that will be delivered through the frESCO solution. Each use case is directly linked with one or more of the main frESCO components, which will be further presented and analysed in section 4: Energy Management System (EMS), Distributed Energy Resources System (DER), Big Data Management Platform, Global Demand Manager and Local Demand Manager.

The detailed description of each use case is provided below:

Table 1

Title	UC.01: Secure data asset ingestion, handling, and storage
Description	An imperative factor when it comes to the collection and analysis of data produced by building assets refers to the availability of flexible and sophisticated mechanisms that can enable the collection of such data assets (either them being real-time or data in rest/ batch data), while respecting their needs for transparency and security in the overall data collection, handling and storage process. In this context, frESCO shall provide such mechanisms that will enable the collection and ingestion of different modalities of data (through direct uploading of data, leveraging APIs exposed by the building stakeholders or even utilizing streaming data management mechanisms for real-time data flows), while leveraging trusted and secure data containers for data storage to ensure a high degree of trust and security on the building stakeholders' side. Secure and trustworthy data storage shall come together with the establishment of robust data access control mechanisms to safeguard data sovereignty and protect the data assets from any potential abuse, or misuse. Such mechanisms will be responsible for safeguarding and securing any data asset that becomes available or passes through the platform, allowing the building stakeholders that produce the data to define the exact terms for the availability and accessibility of their data assets by other business actors and service providers.
Actors involved	Residents, facility managers and owners acting as data owners and producers
Linked components	Big Data Management Platform

Table 2

Title	UC.02: Smart equipment and building smart readiness assessment
Description	The basis of the frESCO project will be smart devices and equipment that will play an important role for deploying the services offered. In order for premises' assets to be exploitable in the project and monitor the performance of different loads of the buildings involved, an installation of a series of sensor devices, clamps, meters, and features will take place. In addition to smart equipment, an assessment of the readiness of a building in terms of smartness will be offered so that service providers have a better understanding of the potential of the building to get involved in different types of services (for energy efficiency and/or flexibility provision). It is essential to gain insight as to what extent the frESCO solution can be deployed in premises based i.e. on the level of control, automation or connectivity of available DERs, in order for service providers to offer the respective retrofitting and related services. Also, based on the Smart Readiness Indicator of a building, an opportunity for possible upgrades of the equipment will be revealed, so as to improve the smart readiness of a dwelling, that could lead to savings and new service possibilities.
Actors involved	ESCOs, retailers, installers, aggregators, residents, facility managers and owners, energy communities
Linked components	EMS, DER, Big Data Management Platform

Table 3

Title	UC.03: Personalized informative billing
Description	With the installation of smart equipment (meters, devices etc) a need for monitoring the measured values arises but even more their actual cost and possible savings for the consumer. In this context, with the provision of applications and interfaces made available to consumers, they will be allowed to better understand their consumption patterns, their energy wastes, and their flexibility to shift their consumption towards avoiding

	increased energy charges. This kind of energy consumption awareness can enable an easy identification of the main cost drivers, meaning how much their consumption decision impacts on the bills, and as an extension, delivery of information about flexibility remuneration, and self-generation surplus compensation.
Actors involved	Aggregators, residents, facility managers and owners
Linked components	Global Demand Manager, Local Demand Manager, Big Data Management Platform

Table 4

Title	UC.04: Personalised energy analytics and recommendations for energy behaviour optimization
Description	The valuable information gathered from smart equipment can be used for provision of personalized analytics and therefore to smart recommendations for energy management in terms of efficiency based on users' energy behaviour optimization. In the context of frESCO project, users will be given enough insights about the way the energy is used at the dwelling level and receive recommendations from the platform to support decision making towards a more efficient use of the energy, balancing economic savings with a well-established user comfort environment. Recommendations may be explicit, by properly analysing the energy behaviours of building occupants and defining possible actions that can generate energy savings, or implicit, by leveraging on well-established behavioural change techniques that employ peer comparisons to motivate changes in energy behaviour towards more sustainable lifestyles.
Actors involved	Residents, facility managers and owners
Linked components	Local Demand Manager, Big Data Management Platform

Table 5

Title	UC.05: Holistic self-consumption optimisation

Description	As the usage of distributed energy resources is one of the basic concepts of the project, new opportunities for self-consumption arise. During high self-generation periods there is a need for reducing the energy surplus, thus maximising self-consumption. On the other hand, during times that billing tariffs are higher, stored self-generated energy could be exploited. The abovementioned can be provided by designing efficient energy management strategies. Energy savings for prosumers occur by shifting the energy consumption to periods of higher i.e. PV generation, or by consuming energy previously stored, without the need for energy consumption directly from the grid, that would be otherwise charged to the consumer.
Actors involved	ESCOs, facility managers and owners, prosumers, energy communities
Linked components	Global Demand Manager, Big Data Management Platform

Table 6

Title	UC.06: Automated device control for energy efficiency optimization
Description	Exploitation of the price elasticity of the demand along with users' identified energy behaviour patterns, comfort preferences and indoor quality constraints can lead to strategic control actions for shifting the operation of major loads from peak price periods to valley price periods and for avoiding excess electricity consumption. As a result, monitoring the comfort parameters in real-time, along with information related to the energy consumption behaviour, and acting occasionally in an automatic way on the controllable DERs, will allow consumers to reduce energy charges and optimize their energy consumption.
Actors involved	ESCOs, facility managers and owners, residents, energy communities
Linked component	EMS, Local Demand Manager, Big Data Management Platform

Table 7

Title	UC.07: Explicit and tradable demand-side flexibility
Description	The evolving decentralization of the energy system, comes together with the decentralization of energy markets, thus creating significant opportunities for buildings and small prosumers to become active market players and gain significant benefits by getting involved in flexibility transactions. Since the concept of flexibility is something new for such small prosumers, it is really critical that they get equipped with appropriate tools that will allow them to understand their flexibility and the potential benefits they can gain by offering it to balancing or ancillary services markets. By increasing awareness on their flexibility potential (through accurate forecasts) and understanding the benefits they can receive (in monetary terms), building stakeholders (managers and occupants) will be able to get engaged in such flexibility transactions that will, subsequently, enable the deployment of explicit demand response programmes (in collaboration with aggregators). The success of such programmes, though, is tightly linked to the respect of key occupants' comfort preferences and schedules, so as to avoid these direct (and automated) load control strategies being rejected by the occupants themselves. In this context, frESCO shall prioritize the definition of context-aware flexibility profiles (capacity and forecasts) which can be further analyzed and utilized by aggregators for the formulation of highly effective Virtual Power Plants (VPPs) towards supporting network operators ineffectively managing their grids, by utilizing such flexibility in cases of grid congestions, frequency deviations or anticipated imbalances. As a result, building owners and occupants will have the opportunity to enjoy increased revenues in the form of compensation for flexibility activation (or even more for flexibility availability) as per the terms of the relevant contract signed with the aggregator.
Actors involved	Aggregators, facility managers and owners, residents, energy communities

Linked components	Global Demand Manager, Local Demand Manager, Big Data Management Platform

Table 8

Title	UC.08: Dynamic VPP formulation and on-the-fly re-configuration
Description	The ability to configure clusters of consumers as effective and cost-efficient Virtual Power Plants and schedule their flexibility in a close future is a powerful optimization mechanism, acting to the benefit of both the network operators (in operational terms, through the provision of the required flexibility) and the aggregators (in monetary terms, through the cost-effective management of their portfolio and the avoidance of potential penalties in case of VPP underperformance). This continuous optimization process, involving real-time monitoring of flexibility events, identification of control strategy overrides, continuous assessment of the VPP performance and on-the-fly re-configuration to achieve the delivery of the required flexibility to network operators needs to be addressed through powerful optimization tools residing on the aggregator side and enabling the introduction of domestic buildings as highly competitive and reliable flexibility sources in the respective markets.
Actors involved	Aggregators, DSOs, TSOs and BRPs
Linked components	Global Demand Manager, Big Data Management Platform

Table 9

Title	UC.09: Smart contract monitoring, handling and remuneration
Description	Aggregators are expected to play a key role in unleashing the flexibility potential of the building sector and transforming it into a tradeable commodity in energy markets. In this context, aggregators need access to fine-grained information streams from buildings, towards being able to assess the flexibility they can offer at different temporal granularity. On the other hand, prosumers need to better understand their flexibility and get involved in transparent and trusted flexibility transactions and respective contracts. This requires the establishment

	of innovative Smart Contracting Mechanisms that will enable both aggregators and prosumers to be continuously aware of the parameters involved in their contractual agreements, while transparently monitoring the satisfaction of the contractual terms and the effectiveness of their bilateral contracts, thus having a clear understanding of the settlement and remuneration processes in relation to flexibility events (activation) or flexibility availability.
Actors involved	Aggregators, facility managers and owners, residents, energy communities
Linked components	Global Demand Manager (Smart Contract Monitoring and Management Module), Big Data Management Platform

3.3 Functional and Non-Functional Requirements

A list of functional and non-functional requirements is compiled below, presented in the form of "The system should do something", in case of a desired/recommended feature or "The system shall do something", when the feature to be supported is mandatory:

Table 11

Req_id	Description	WP	UC
Req_001	The system shall have access to DER management system data.	WP4, WP6	UC.01, UC.02
Req_002	The system shall have access to EMS data.	WP4, WP6	UC.01, UC.02
Req_003	The system shall provide the possibility for the ingestion of real-time data assets.	WP4, WP6	UC.01, UC.02
Req_004	The system should have access to weather data.	WP4	UC.01
Req_005	The system should have access to wholesale market data.	WP4	UC.01
Req_006	The system shall allow the harmonization and storage of all available data assets under a common information model (CIM).	WP4	UC.01
Req_007	The system should provide the possibility to a user to upload data files (i.e. csv, json, xml, etc.) or schedule future data asset uploads.	WP4	UC.01
Req_008	The system shall allow the storage of encrypted and unencrypted data assets in a secure data storage environment.	WP4	UC.01
Req_009	The system shall allow the mapping of all data assets to the CIM.	WP4	UC.01
Req_010	The system shall provide the definition of metadata of available data assets under a CIM.	WP4	UC.01
Req_011	The system should allow the user to define data anonymization rules.	WP4	UC.01
Req_012	The system should allow the user to define data curation rules on the data that the user owns.	WP4	UC.01

Req_013	The system shall provide near real time monitoring of energy demand, generation, and consumption at dwelling level.	WP5	UC.01, UC.02, UC.03, UC.04, UC.05
Req_014	The system shall provide calculation of the SRI performance of the building.	WP2, WP5	UC.02, UC.04
Req_015	The system shall provide monitoring of the SRI performance of the building	WP2, WP4, WP5	UC.02, UC.04
Req_016	The system shall allow user flexibility monitoring.	WP4, WP5	UC.04, UC.07
Req_017	The system shall allow short-term forecasts on the available flexibility on the prosumer side.	WP4, WP5	UC.04, UC.07
Req_018	The system shall allow the energy service providers to perform consumers portfolio segmentation /clustering according to different parameters.	WP4, WP5	UC.03, UC.05, UC.08
Req_019	The system shall allow the aggregators to optimize their DR strategies considering DR attributes and dynamic electricity prices.	WP5	UC.07, UC.08
Req_020	The system shall allow automated device control in respect to the received DR signal at dwelling level.	WP5	UC.06, UC.07
Req_021	The system shall allow the identification and categorization of asset control properties (interrupted, shiftable and uncontrolled).	WP5	UC.06
Req_022	The system shall allow the schedule of future flexibility activations.	WP5	UC.08
Req_023	The system shall allow the update and optimization of consumer flexibility clusters (dynamic VPPs) to balance user comfort and flexibility remuneration.	WP5	UC.08
Req_024	The system shall provide forecasts of energy consumption trends.	WP4, WP5	UC.03, UC.04
Req_025	The system shall provide forecasts of energy demands and generations (mid-term and long-term) at dwelling level.	WP5	UC.05
Req_026	The system shall provide the possibility for short-term (day-ahead) energy demand forecast.	WP4	UC.05
Req_027	The system shall provide short-term weather forecast.	WP4	UC.04
Req_028	The system should maximize the self-consumption considering all dynamic and static parameters involved and without compromising optimum overall energy usage .	WP5	UC.05
Req_029	The system should allow configuration of flexibility assets into virtual power plants based on assets flexibility availability.	WP5	UC.08
Req_030	The system should allow aggregators to introduce the Smart contract information, established with prosumers, in a blockchain infrastructure, by utilising a user interface.	WP5	UC.09

Req_031	The system should allow aggregators to search for flexible assets through a user interface.	WP5	UC.09
Req_032	The system should allow aggregators to get access to the results of the remuneration process (i.e., their contracts) through a user interface.	WP5	UC.09
Req_033	The system should allow calculation of prosumer revenue for flexibility capacity.	WP5	UC.09
Req_034	The system should allow calculation of prosumer revenue for flexibility provision.	WP5	UC.09
Req_035	The system should allow calculation of prosumer penalty for non-delivery of flexibility.	WP5	UC.09
Req_036	The system should allow flexibility settlement based on flexibility ordered by the aggregator.	WP5	UC.09
Req_037	The system should provide remuneration mechanisms to settle flexibility contracts.	WP5	UC.09
Req_038	The system should allow flexibility remuneration based on the contractual agreement economical terms.	WP5	UC.09
Req_039	The system shall provide the option to the user to set their preferences (thermal, IAQ etc. comfort profiles) on a user interface.	WP5	UC.04
Req_040	The system shall allow the dynamic update of user's comfort profiles.	WP4, WP5	UC.04
Req_041	The system shall allow the dynamic update of user's flexibility profiles.	WP4, WP5	UC.04, UC.07
Req_042	The system should be able to automatize energy management based on the users' comfort profiles.	WP5	UC.04, UC.06
Req_043	The system shall provide notifications and recommendations to the user on their energy behaviour profile through a user interface.	WP5	UC.04
Req_044	The system shall allow prosumers and consumers to setup rules for the control of devices through a user interface.	WP5	UC.04, UC.06
Req_045	The system shall show the price signals and the expected energy savings through a user interface.	WP5	UC.04
Req_046	The system shall provide visualization of information at different levels: individual, clusters, portfolio through a user interface for the aggregators.	WP5	UC.04, UC.05, UC.07
Req_047	The system shall provide visualization of EE/flexibility information at consumer level through a user interface.	WP5	UC.04, UC.05, UC.07
Req_048	The system shall increase the user awareness regarding EE and flexibility patterns through an informative user interface.	WP5	UC.04
Req_049	The system shall provide information to the aggregator on ongoing/completed DR campaigns through a user interface.	WP5	UC.08
Req_050	The system shall formulate and enforce a data access control decision based on the associated data access policies.	WP4	UC.01

Req_051	The system shall execute data anonymization operations on a user's data.	WP4	UC.01
Req_052	The system should support data encryption.	WP4	UC.01
Req_053	The system should enable the periodic data retrieval from Open Data APIs.	WP4	UC.01
Req_054	The system shall allow users to configure the notifications they wish to receive.	WP4	UC.01
Req_055	The system shall push notifications to the users.	WP4	UC.01
Req_056	The system shall provide informative notifications to the user if the import of data fails.	WP4	UC.01
Req_057	The system shall allow a user to monitor the progress and status of their ongoing data import jobs.	WP4	UC.01
Req_058	The system shall enable the execution of flexibility analytics.	WP4	UC.01
	Non-functional requirements The system should consider the market framework at each demo site. The system should ensure the provision of interactive tools with the minimum latency on data visualization. The system should ensure an intuitive, easy-to-use user interface.		

3.4 End User Requirements

Besides the use case methodology presented in the previous section, a common method that is also used for the requirements definition is conducting interviews with the main stakeholders (ESCOs/Aggregators in this case). These energy authorities require specific functionalities to be addressed in the scope of this project and represent the requirements from their customer portfolio, as they themselves are in charge to circulate customer surveys and collect their feedback (deliverables 2.3 and 3.1). A list of the main requirements that are in line with the functional requirements presented earlier is shown in the following table:

Table 12

Req_id	Description	WP	UC
Req_001	The system shall allow automatic operation of DERs.	WP5	UC.06
Req_002	The system shall allow near-real-time monitoring of the energy consumption and performance and their visualisation for ESCOs and consumers/prosumers.	WP4, WP5	UC.03, UC.04

Req_003	The system shall allow communication, monitor and control of legacy systems through open communication gateways.	WP2, WP6	UC.02
Req_004	The system shall allow energy savings maximization for prosumers without compromising their indoor comfort.	WP5	UC.03, UC.04
Req_005	The system shall allow recommendations for energy usage to promote user participation through a reward process.	WP5	UC.04
Req_006	The system shall provide forecasting tools for energy efficiency assessment and verification.	WP3, WP5	UC.04
Req_007	The system shall support the traditional EPC services and the compatibility with the new P4P services.	WP3	UC.04
Req_008	The system shall support a fair and transparent measurement and verification methodology for pay for performance in flexibility and energy efficiency events.	WP3	UC.04, UC.07, UC.08, UC.09
Req_009	The system shall support demand side aggregation with about 5 seconds' delay.	WP5	UC.07
Req_010	The system shall allow demand forecast, generation forecast, incoming market flexibility requests, market bid prices monitoring, DER management and VPP configuration, information about connection status, localization, clustering of DERs under smart contracts, energy dispatch, final flexibility delivery, remuneration parameters.	WP4, WP5	UC.07, UC.08, UC.09
Req_011	The system shall allow the identification of available and appropriate flexibility assets.	WP5	UC.07, UC.09
Req_012	The system shall support different clustering criteria (type of DERs, historic participation etc.).	WP5	UC.06, UC.07
Req_013	The system shall support a secure environment for the introduction, visualization, and signature of flexibility contracts.	WP5	UC.09
Req_014	The system shall support the provision of monthly billing reports.	WP5	UC.03

4 COMPONENTS AND MODULES

After properly defining the requirements in section 3, we now proceed to the detailed description of the system components and modules and an attempt will be made to describe their interactions, their communications, and their features.

The complete frESCO architecture, followed by the detailed description of the system's components and modules, is presented in figure 1:

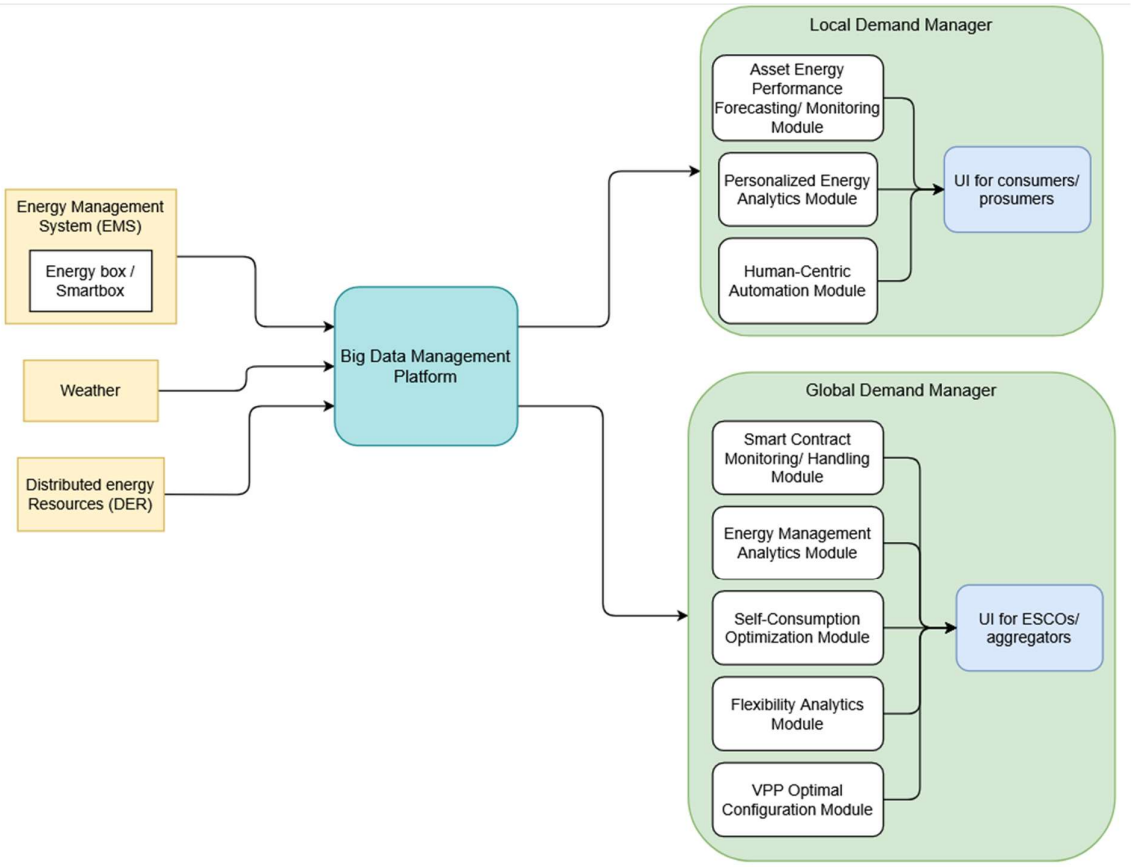

Figure 1: The complete frESCO architecture

The framework presented above supports the two main pillars of the frESCO project: the introduction/monitoring/configuration of EE and flexibility smart contracts from ESCOs and Aggregators respectively, with the aim to promote energy savings and revenue streams to their customers.

4.1 EMS System

Overview

The Energy Management System provides programmable interfaces and acts as the controller and monitoring module of all the available energy assets in a residence.

Component Functional Elements

Energy Box. It has the role of a local data management system. It helps to reduce the number of equipment communicating with the high layers of control and integrates them into one single device that holds several communication technologies, improving the efficiency control of the system. It is based on a multicore architecture with a non-blocking exchange structure that provides state-of-the-art capacities, offering not only domestic level benefits, but also other complex system requirements for most demanding environments and closer to a real time management. Therefore, the Energy Box is presented as an embedded and compact solution to monitor and manage intelligent devices in different kinds of real scenarios.

Figure 2: Example of Energy Box in a real scenario

Due to the powerful microprocessor included, based on a Raspberry Pi 3 Compute Module, and the plethora of open communication interfaces included, it is possible to execute remotely high-level services and monitoring, meanwhile the local operation of the scenario remains entirely in the Energy Box itself, improving the quality, efficiency, and security of the service. The hardware has been built *ad hoc* to adapt to these environments, and the software could be divided between management and communications.

As shown in **Error! Reference source not found.**, communication software handles several standard protocols, highly used in domestic and industrial environments. ZigBee and WiFi were selected as wireless protocols to provide this service with a quite big number of possible devices to select, and Modbus was selected as the main standard industrial protocol for wired communications. Nevertheless, it is possible to add new protocols that make use of Ethernet communications. Being the EMS Gateway for the system, the communication with EMS platforms or any other cloud platform is performed using MQTT protocol, an M2M communication protocol highly used in IoT scenarios.

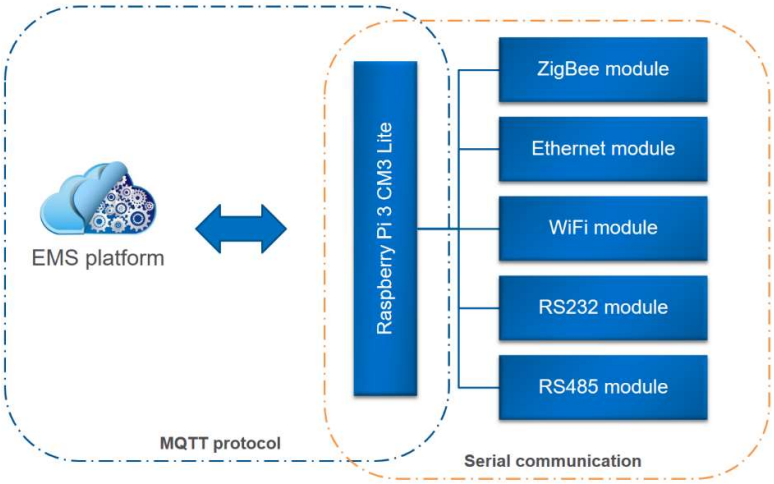

Figure 3: **EMS Communication architecture**

Finally, the management software handles the gathering of information and its upload to the frESCO cloud platform, besides the real time management of the local platform. For this reason, local algorithms and functionalities were developed to generate the real time commands for the devices, from the operation objectives shared by the cloud.

Inside frESCO platform, appropriate intelligent devices that will be prepared to use one of the protocols supported by the Energy Box have to be selected, and the data exchange between frESCO and EMS platforms, will have to be supported via a common information data model.

Dependencies/Communication with other components

Big Data Management Platform: Data exchange always under a common information model. The parameters of this communication (frequency, data types, granularity…) should be configurable.

4.2 DER System

The Distributed Energy Resources (DER) System is comprised by smart devices or equipment that have their own control and monitoring capabilities, as well as communication protocols, and are part of the legacy system in premises. They include a large variety of equipment such as smart heat pumps, EV charging systems, PV inverters, battery storage regulators, etc. The DER management system in frESCO will be a software module interrelated with the other modules of the cloud platform. This module will be responsible for sending and receiving information from the DER, for example, using OCPP to communicate with EV chargers.

The data from each of these legacy devices can be either captured by the Energy Box or handled by the DER manager to be properly sent to the FRESCO data platform. The interaction with the other cloud modules will be described and included in the common information data model and the communication protocols will be defined based on the standards supported by those legacy systems. Common IoT protocols, as MQTT or REST API will be used. In the link with the DER devices, the DER manager must be adapted to implement the communications that these devices allow. This work will be carried out during demonstration definition phase, covered by task 6.1 of the project.

Dependencies/Communication with other components

Big Data Management Platform: Data exchange always under a common information model. The parameters of this communication (frequency, data types, granularity…) should be configurable.

4.3 Big Data Management Platform

Overview

As part of the backbone for all integration activities in the frESCO project, the Big Data Management Platform poses an essential ICT framework to allow interoperable and secure data acquisition, processing, and analytics, to enable the deployment of novel energy services. The platform will contribute both to the granular communication and data exchange between numerous sources, such as buildings, DER management systems, weather data sources and wholesale energy prices, as well as to the optimal mass ingestion and storage of big volumes of the corresponding data sets. Suitable techniques and methods for data importing, curation,

and semantic mapping will be utilized, to ensure high performance and ability to adapt to the requirements and needs of the value chain stakeholders. In addition, the Big Data Platform will also offer a big data analytics module, that essentially allows the preparation and execution of analytics algorithms, along with reporting of the respective results, utilizing a catalogue of pre-trained analytics models, to generate new insights and knowledge for all frESCO stakeholders.

Component Functional Elements

The Big data platform consists of the following main modules, that are visualized in Figure 4 below, namely:

- Data Collection Module
- Data Analytics Module
- Data Security and Storage Module
- Data Search Module
- Platform Orchestration Module

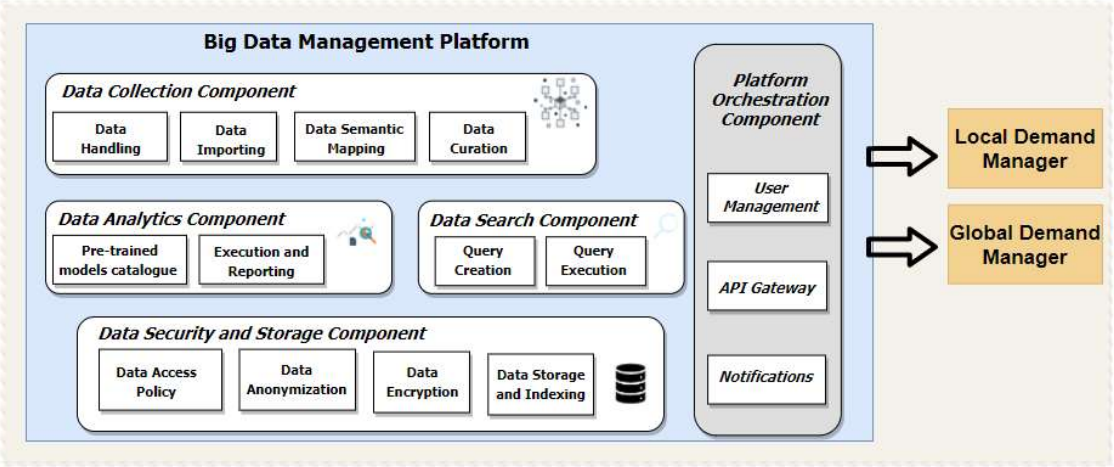

Figure 4: The Big Data Management Platform Architecture

Each one of these modules is analysed below:

4.3.1 Data Collection Module

The Data Collection Module, responsible for the data ingestion process in the frESCO Big Data Management Platform, is considered as a fundamental part in the overall Big Data

Management Platform configuration since it will provide a variety of functions and features, spanning data importing from various sources and in different formats, handling and semantic mapping of the data imported in the platform, together with data quality assurance for ensuring the completeness and integrity of the data to be later processed within the platform or provided to the overlay components of the architecture (consisting of the components and applications that will be responsible for the end-user services of the frESCO project). The key features involved in the Data Collection Module are discussed in the following paragraphs.

Effective Handling of Data Management Processes:

It consists of one of the cornerstone features of the Data Collection Module and allows for the effective management of data processes to insert the data originating from various sources, into the frESCO Big Data Management Platform. The data owners, by specifying how, when and what data they own and are ready to share, shall utilize the platform to configure, through a guided and intuitive user interface, all settings, under which the timely and successful retrieval of data shall be performed. In more detail this feature will allow for:

- *Definition of steps for the data import*: All parameters of the data ingestion process, according to their preferences and needs are configurable, such as the insertion method via file(s) uploading, APIs and Streaming Data Ingestion, in combination with the sample data that should be stored, as well as the retrieval schedule for each import.
- *Definition of steps for data semantic mapping configuration*: Through an intuitive user interface, the data owners' users will be able to easily navigate through the mapping predictions, providing the necessary guidance for mapping and transformation actions. In that way, all data attributes can be correctly mapped with the frESCO Common Information Model (CIM) concepts.
- *Definition of steps for data curation*: Data Owners uploading data to the platform will be able to improve the overall quality and value of their data, by identifying incomplete, incorrect, inaccurate, or irrelevant parts of the data and providing the necessary options to handle them.
- *Definition of steps for data anonymisation configuration*: Data Owners uploading data to the platform will be allowed to: (a) semi-automatically check for any

"privacy-risky" columns within their data taking into account the frESCO Common Information Model (CIM), and (b) define appropriate anonymisation rules for any potentially "identifying", and "personal" columns/fields in their data.

- *Definition of steps for data encryption configuration*: The different Data Owners that intend to upload their data to the frESCO Platform are able to set their encryption parameters, selecting whether the whole data will be encrypted, or part of the data (in terms of selected columns/fields) will be encrypted, or no encryption is applicable for the specific data.
- *Secure handling of advanced authentication aspects and protection of personal data*: API-based or streaming data import jobs are initiated in the Data Collection Module and the authentication aspects should be defined in such a way, that establish a reliable connection with the frESCO Data Management platform. It is the responsibility of the data owner, to define the applicable type of authentication and provide the necessary parameters (e.g. tokens, username and password for custom login) during the insertion configuration.

Lifecycle management of data import configurations: The user-defined configuration details, are stored in a configuration file for each import job. Under certain conditions, configuration details can be altered by the data owners, that allow (a) the update of already imported data, (b) the update of the periodic data retrieval schedule (c) the deletion of already imported data.

Flexible Data Import Mechanisms and Methods:

It provides the means for flexible data importing into the frESCO Data Management Platform, based on the configuration performed by the user. The feature can handle various data import methods to support stakeholders needs, making it possible to consume data as files, through APIs and using streaming (PubSub) mechanisms. Each one of these methods has different configuration options, like scheduling when data import should be performed through APIs, authentication aspects, the applicable connection error handling strategy and pagination aspects. With the API and the PubSub data import involving sensitive parameters, like API keys, tokens and PubSub connection details, it is of great importance to store them carefully, in an encrypted form in the Security and Data Storage Module.

This feature is triggered for execution on demand, based on the actions performed by the user. The imported data are stored in a temporary object storage for increased reliability and roll-back options in case of failure in any other subsequent feature and process performed in the module.

In more detail this feature will allow for:

- *Data insertion from files*: allowing for data retrieval from files in formats that can be processed (e.g. csv, tsv, json, xml) or that should be stored as-is (e.g., other types).
- *Data collection from APIs:* supporting data retrieval from 3rd-party APIs, that are exposed by the pilots' systems and from Open Data APIs (e.g weather data, other local sources).
- *Data insertion of streaming data:* supporting streaming data import through PubSub mechanisms hosted in the frESCO Data Management Platform (providing the connection details and the topic the stakeholders should use to push data to the platform).
- *Secure and reliable data transfer:* enabling secure and reliable transfer of the data an organisation owns to the Big Data Management Platform infrastructure.

Enabling Data Interoperability through Semantic Mapping into the Common Information Model (CIM):

This feature allows for performing the necessary transformations to the imported data, to match with the concepts foreseen in the frESCO CIM. Considering that the CIM foresees specific types, formats, and measurement units (where applicable) for its concepts, the defined configuration may apply, apart from field renaming, actions such as casting data types, adapting data to foreseen measurement units, specifying date formats to allow the appropriate conversions to be performed.

Data semantic mapping is an important part of the data handling process and acts as an enabler for functionalities offered by other Data Management Platform components. The transformed data are stored in a temporary object storage for increased reliability and backup/ roll-back purposes. In more detail this feature will allow for:

- *Mapping imported data to the frESCO CIM*: offering a mapping service that executes the defined mapping configuration, including steps such as the renaming of the data

fields (e.g. column names of tabular data, field names of json data etc.) to match the mapped CIM concept names.

- *Transformation of imported data to comply with the frESCO CIM*: Depending on the data type and the accompanying CIM provisions, the module performs calculations to bring the data values to the CIM measurement units, reformats data (e.g. transforming datetime fields to the CIM foreseen format and to the UTC time zone if time zone info is not included in the data), casts data types and applies any other transformation required to execute the defined mapping configuration.
- *Clear results of the transformation rules performed over the imported data*: enabling the collection and storage of the results of the changes and transformations that were performed on the imported data. The data owner can view the mapping and transformation reports both for failed and for successful executions.

Effective Data Curation for Data Quality Assurance Enhancement:

The Data Collection module is, also, responsible for ensuring that data imported into the frESCO Data Management Platform is accurate and complete, based on rules defined by the data owner. Removing or correcting of incomplete, inconsistent, improperly formatted or otherwise incorrect data, improves data quality and reusability, making the insights extraction more reliable. In this sense, the Data Collection module will employ the required mechanisms for data curation, by utilizing methods such as simple value substitutions, reformatting and duplicate removals and more advanced tasks such as outlier detection and substitution. Furthermore, through monitoring the curation rules execution, it provides valuable insights to the data owner.

In more detail this feature will allow for:

- *Data curation rules execution*: During the curation configuration process, the user defines the constraints and limitations that the data ingested to the module must adhere to and associates them to specific actions that need to be performed over the data if any of these constraints is violated. This configuration translates to a set of curation rules which are executed by invoking the corresponding data curation methods. Numerous data validation options depending on the data type of each column/field is offered, that allows verification of value ranges, uniqueness constraints,

mandatory constraints (for handling missing data values), regular expression patterns, and outliers identification. It also offers two main types of corrective measures: dropping entries and replacing values, the latter offering more options as to how the new value is generated, either provided by the user (i.e., a fixed value) or dynamically calculated based on the data (i.e., mean, min, max, previous values). The combination of a validation option and a corrective action for a certain field forms a curation rule, and all curation rules are executed on the transformed data (resulting from the data semantic mapping) resulting in clean data.

- *Feedback from the executed curation rules*: When executed, the defined curation rules will affect some of the imported data entries, resulting either in dropping entries or in altering the values in certain fields. Information, concerning the number of times a curating rule was executed (i.e., its corrective action was applied) are collected and these numbers are made available to the data owners, indicating unforeseen issues with the imported data or a misconfigured curation rule – both cases would require the data owner's attention.

4.3.2 Data Security and Storage Module

The Data Security and Storage Module's role is twofold. Firstly, it assumes the responsibility to address data security and privacy concerns of the Data Owners, concerning the data that will be imported and handled in the frESCO Data Management Platform. For that reason, it offers several functions and features, that can be intuitively configured in the platform, and cover Data Access policy definitions, Anonymization and Encryption capabilities. Secondly, this module covers the need for reliable storage and indexing of the data, by providing resilience strategies and various indexing methods.

Easy Data Access Policy configuration:

The Data Security and Storage module offers the data access policy feature that increase the trust of the data owners in the overall frESCO Data Management Platform, by providing a mechanism that allows data owners to define, in a flexible and easy way, the access rules that permit or deny access requests on their data within the platform. Permission and denial policies can be combined, to achieve the desired behaviour, based on the characteristics of each dataset. A proper separation of concerns between policy definition and policy

enforcement is effectively ensured via the Data Access Policy feature, ensuring that the data can only be viewed and consumed by eligible platform users. In more detail this feature will allow for:

- *Definition, configuration, and update of access policies*: Via a graphical user interface, users are allowed to create complex access policy rules for their assets. These rules may be built upon properties of the data and characteristics of the requestor. Policies may define when access is granted or when it is denied, and they can be combined using Boolean logic to form complex rules. The rules are stored and can be easily changed through the provided interface by the Data Owner.
- *Enforcement of data access policies:* When a request is performed to access a data that has been imported in the frESCO Data Management Platform, the access policies specified are enforced. The allow/deny decision is taken by the Data Access Policy feature in a performant manner as it affects both the Data Search Module results as well as the data that are to be retrieved through the API Gateway feature of the Platform Orchestration Module.

Flexible Data Anonymization Methods:

A way to safeguard data against unintended disclosure of personal or corporate information is offered by the Data Security and Storage Module. Anonymisation actions that reflect into specific parts of the data (i.e. which fields) are performed prior to making the data available within the frESCO platform. Data owners are informed about potentially sensitive information within their data and provided with appropriate functionalities to anonymise this information, as well as any field of their data that they consider as containing any identifying information. The anonymised data are stored in a temporary object for increased reliability and roll-back options in case of failure in the next pre-processing steps (Encryption Service).

In more detail this feature will allow for:

- *Identification of fields that need anonymisation:* Through Data Anonymisation (utilizing the User Interface provided in the Data Handling Manager), it provides to the data owners the ability to identify any data fields that hold information that is in any way sensitive or identifying personal/corporate.

- *Data anonymisation rules execution :* Depending on the type of the field (personal, identifying, quasi-identifying) and the data type, the Data Anonymisation feature allows the data owner to define the anonymisation method that should be applied in an easy-to-understand manner with examples. Indicative methods that are supported under the k-anonymity algorithm include: generalization methods to create arithmetic intervals or categories for numeric fields, and masking methods for string fields.

Flexible Data encryption Methods:

The Data Security and Storage Module offers data encryption functionalities to data owners, as additional mechanisms to safeguard their data and eliminate the possibility of unauthorised data access and/or data leakage of any type. Specific data are therefore encrypted in the frESCO Data Management Platform, according to the owner's needs and requirements. The Data Encryption mechanism provides flexibility in the definition of the encryption configuration to be applied, enabling modular control over the data contents that should be encrypted. Specifically, the engine allows the data provider to encrypt the full data or select the parts of a data. In more detail this feature allows for:

- *Data encryption rules execution*: The Data Encryption mechanism provides symmetric encryption mechanisms and is responsible for both the generation of the encryption key and the actual encryption of the underlying data so that the data owner will be in full control of who can access the information.
- *Computations on data prior to encryption for search purposes*: Part of the encryption process configuration is to define which data fields should be used for data discoverability purposes, even if the actual field values will be encrypted. The Data Encryption mechanism enables this functionality by calculating some predefined statistics on the fields that are marked as to-be encrypted, but searchable. The extracted information will be made available to other frESCO components, responsible for searching within data and for providing insights into asset contents.
- *Data decryption*: The Data Encryption mechanism provides the services needed to decrypt the data so that they can be used by the users that are authorised to access them. In this case, the mechanism ensures that the decryption key becomes available in order to decrypt and access the underlying information.

Applicable Data Storage and Indexing:

Storing a plethora of data, along with their associated metadata, and the jobs-related data in a secure and reliable manner is provided by the Data Security and Storage Module. All storage and indexing tools used in the context of frESCO are taken under consideration and are mainly pertaining to:

- *Storage of configuration data:* Storing the configuration of the data import and the configuration of the data analysis jobs to ensure that all steps performed over the data are traceable.
- *Storage of data:* Storing the different data (i.e. datasets, analytics models, analytics results and reports) along with their metadata, in order to be available for all the components and services in the frESCO platform.
- *Storage of encrypted data:* Secure, encrypted storage of sensitive data (e.g. sensitive parameters for the API calls, such as tokens, API keys, usernames and passwords).
- *Storage of log data:* Storing log-related information for the frESCO Data Management platform operation and usage, users' and organisations' data and all administrative information required for the smooth operations of the Platform Orchestrator Component.
- *Storage of the CIM:* Storing the frESCO Common Information Model in its different versions along with its associated concepts and fields.

Depending on the type of information that is to be stored in the frESCO Platform and the way it will be retrieved, different storage and indexing tools are foreseen to accommodate the varying needs.

4.3.3 Data Analytics Module

The Data Analytics Module allows users in the frESCO platform Infrastructure to run analytics over their own data. It provides a catalogue of pre-trained analytics models that can be selected based on the data owner needs, and by executing and visualizing their results, leverage the added value that data analytics can bring through the offerings of the frESCO models.

Propagation of pre-trained model's catalogue:

With this feature, selected data analytics algorithms, that are prioritized by the frESCO demo cases and demonstrators are pre-trained and populated in the analytics catalogue of the core frESCO platform. The pre-trained data analytics in frESCO span over 2 baseline dimensions: (i) personal data analytics (e.g. for consumer energy behaviour, comfort preferences and flexibility), (ii) enterprise/industrial data analytics (indicatively involving Building Energy analytics, Forecasting and Flexibility analytics). Nevertheless, and in the case they are needed (even though such a requirement has not been identified), fine-grained models will be made available (light-weight versions of the personal analytics models) to be executed on the edge (in the Energy Box). In more detail this feature will allow for:

- *Personal Data Analytics catalogue:* Data owners, will be offered several pre-trained personal data analytics models, covering various profiles dealing with comfort, energy behaviour and flexibility. Considering that energy management optimization at the end-user level should not affect their comfort and well-being, the pre-trained analytics methods will wisely embed the user preferences, translating them into user comfort models and providing this perspective in the flexibility profiling and energy management optimization, to guarantee that end-user comfort levels are constantly maintained.
- *Industrial Data Analytics catalogue:* Pre-trained models, that provide analytics capabilities, such as short-term Demand Forecasting, Generation Forecasting and DER Flexibility Analytics, will be offered to the frESCO platform users, allowing them to select among available models that target specific problems of the energy domain and apply them to their own data.

Intuitive Analytics Execution and Reporting:

An uncomplicated mechanism, able to execute the selected pre-trained models and verify the produced reports, is an integral part of the Data Analytics Services Module, as it gives to the data owners and consumers the ability to validate and visually gain insights from analytics results. By addressing the needs of different types of users (e.g. ESCO managers, grid operators, utility companies) in terms of data processing, from executing pre-trained models, to creating visualisations and reports to highlight insights extracted from data and from analytics processes. In more detail this feature will allow for:

- *Execution of pre-trained models:* Through the Analytics Execution and Reporting mechanism, the execution of the selected pre-trained and customizable energy analytics models is configured, in order to define when it will be planned to run and the generated outputs are exported or saved according to the configuration, or directly consumed through a connected visualization/report.
- *Built-in visualization and reporting:* The Analytics Execution and Reporting mechanism offers predefined charts per different analytics process which can be fed with data to provide meaningful visualisations.
- *Saving and exporting visualisations and reports:* All assets created using the Analytics Execution and Reporting mechanism can be saved both as static objects (i.e. as image or pdf) and as dynamic objects (in which case a configuration template is created and used to render the updated results every time it is accessed).

4.3.4 Data Search Module

The Data Search Module constitutes an essential part in the Big Data Management Platform of frESCO, enabling the users of the platform to search and discover data that can be proven useful, determine and define which of these available data are of importance and eventually, have a clear and thorough view on the provided results. The key features of the Data Search Module are described in the following paragraphs.

Dynamic Query Creation:

A key element of the Data Search Module, providing data Owners the necessary methods for data discoverability and exploration, that enables data sharing operations. The data Owners can search for data that are interesting for their needs, browse through the results and investigate the data in more detail to identify useful candidates for retrieval. In more detail this feature will allow for:

- *User-friendly data search supporting both keyword-based queries and faceted search:* To offer flexibility in the way users search for and discover data, the Query Creation feature enables query generation using both a flexible free-text search and filtering on the data assets' information. Specifically, the Query Creation enables users to search based on the assets' metadata, the assets' contents, and meta-information regarding

these contents. Faceted search is also supported across selected facets most commonly used to identify interesting assets.

- *Analytics Reports search:* The Query Creation feature enables a more straightforward process of data search, that supports other types of assets, including analytics reports. This poses additional challenges in offering a useful and seamless querying and exploration functionality.

Adjustable Query Execution processes:

Building upon the data discoverability and exploration functionalities offered by the Query Creation feature, the adjustable Query Execution provides a built-in way to execute the query created, offering a quick overview of the results that will be generated. In that way, the user can promptly identify if the results meet the expectations and proceed with adaptations and corrections as required. In more detail this feature will allow for:

- *Execution of queries and results:* The query configuration provided by the data creator is transformed by the Query Execution feature to a query that can be intuitively executed in the platform, and results that match the query are returned, processed, and provided to the user. Appropriate accompanying information for queried data is provided to facilitate the user in quickly locating the most interesting results for his needs.
- *Search history and search query update and re-execution:* Re-Execution of data queries, either unchanged or slightly altered, that the users want to evaluate in the future, is made possible through an easy interface. Using this interface users may store the search queries that they want and update them or use them as needed.

4.3.5 Platform Orchestration Module

The Platform Orchestration Module in the platform of frESCO is of crucial importance, as it establishes the means and processes for secure and reliable registration of the users to the platform. Through appropriate authentication and safeguarding processes, the users are granted access to the data they are eligible to use and are offered the capability to receive analytics results, as well. Also, the users will be informed for import or data analysis jobs occurring to the platform, according to their preferences, via platform notifications and e-mail.

The key features of the Platform Orchestration Module are described in the following paragraphs.

Secure and Reliable User Management:

Imperative element of the module, the User Management offers different aspects and layers of security, providing identity checks and allowing for reliable registration of organisations and users and authenticating the platform's users. Authenticated users are granted access only to data that they are entitled to use, based on the data access policy rules defined. Lastly, in collaboration with the API Gateway, the User Management mechanism verifies the API keys for external retrieval (either the frESCO applications or 3rd-party applications), while generating tokens for the secure data exchange between the internal platform modules. In more detail this feature will allow for:

- *Identity information for the frESCO platform's users and organisations:* The User Management acts as an identity provider and creates and manages identity information for the users belonging to organisations that are eligible to gain access to the frESCO platform.
- *Authentication and authorisation services to components and services:* The User Management provides authentication and authorisation services to underlying applications within the frESCO platform for defining appropriate policies per case and generating and managing the respective tokens.

Configuration of APIs for Data Retrieval:

Integral part of the module as it poses as a single-entry point for applications (frESCO applications and 3rd party applications) to retrieve data they are permitted to access from the frESCO Platform, as well as analytics results. The API gateway accepts all API calls, fetches and aggregates data from the various services required to respond to the call and returns the appropriate result. In more detail this feature will allow for:

- *Raw and derived data retrieval:* The API Gateway allows authorised applications to configure the retrieval of data originating from a single dataset, multiple data or analytics results, through the frESCO Open APIs. Selection of exact fields of the data needed and the usage of filters represented by API request parameters, are methods to fine-tune the retrieved results. The API Gateway creates a unique identifier,

provides instructions for the endpoints to be used and provides a test API functionality to quickly test them to check what results they retrieve.

- *Management of failures:* Depending on the service that may be unresponsive or unavailable, the API Gateway determines whether a partial response or an error is preferable to be returned to the authorised frESCO application and any authorised 3rd party application.
- *Management of API keys:* The API Gateway in collaboration with the User Management mechanism, applies authorisation and access control on all data, based on the API keys generated and stored in the platform.

Dynamic Personalized Notifications:

The different frESCO platform users will be offered the capability to be notified about certain events that occur in the platform and concern them, according to the preferences they have set. Real-time information for the progress of ongoing import jobs and/or data analysis jobs at specific milestones will be always updated. Notifications will be sent both within the frESCO platform and through email, in order to ensure that important information is not delayed in being viewed by the respective stakeholders. In more detail this feature will allow for:

- *Issue and deliver notifications for different events in the frESCO Platform:* The Notifications feature generates and delivers the relevant notifications for the progress of the execution of a data import jobs (regarding successful completion each time it is executed, or details for any failure), the progress of the execution of a data analysis job (regarding successful completion once it is executed, or details for any failure, through the frESCO platform and/or via email).
- *Notifications management:* The users may view the different notifications to act upon them as required or delete them. In addition, users may set their preferences about what notifications they wish to receive and control what mode of communication to use at every event.

<u>Dependencies/Communication with other components</u>

Energy Management System and additional data sources: A key challenge of the Big Data Management Platform is data heterogeneity, that reflects to the need to collect data from different and heterogeneous data sources, coming from diverse sources, such as the Energy

Management System, wholesale energy prices, weather data, etc. Utilizing the Data Collection Module and the respective Data Importing, Data Semantic Mapping and Data Curation features, the frESCO platform allows the collection, the cleaning, and the mapping of the data respectively. The use of a standards-based Common Information Model, that facilitates semantic interoperability between the different data during this process, serves as the "common language" that all stakeholders using the platform, either for uploading data or for finding and using data, understand and communicate upon.

Global Demand Manager: The Big Data Management Platform provides access on real-time/historical data, concerning wholesale market, energy networks, DER management systems and smart meter measurements, coming from the smart gateways, by utilizing the Data Search and the Platform Orchestration Module and more specifically the Query Search and Execution features, combined with the API Gateway function. In that way the Global Demand Manager accesses raw and derived data that are properly processed and stored in the platform through the frESCO APIs.

Local Demand Manager: Similarly, to the Global Demand Manager, also the Local Demand Manager can get access on real-time/historical data that are stored in the Big Data Management Platform, via the APIs that are made available for this purpose. In addition, the Local Demand Manager can gain access on results produced from the Analytics Execution and Reporting mechanism of the Data Analytics Component, utilizing the platform's APIs.

4.4 Global Demand Manager

Overview

The role of this component is to enable the provision of implicit and explicit demand flexibility and energy efficiency services in the form of concrete business strategies to targeted clusters of consumers. The Global Demand Manager will design and optimize strategies and analytics targeted for Aggregators (flexibility) and ESCOs (energy efficiency).

The respective User Interfaces (UI for ESCOs/Aggregators) will serve as tools to analyse, segment, classify and cluster the participating consumers to demand-based dynamic VPPs, on the one hand to acquire portfolio analytics that will enable the structuring of advanced billing

policies, and on the other hand to provide optimized consumer-centric services such as holistic self-consumption optimization (through the input received from Local Demand Manager).

Component Functional Elements

The different modules of the Global Demand Manager component are presented in the following figure:

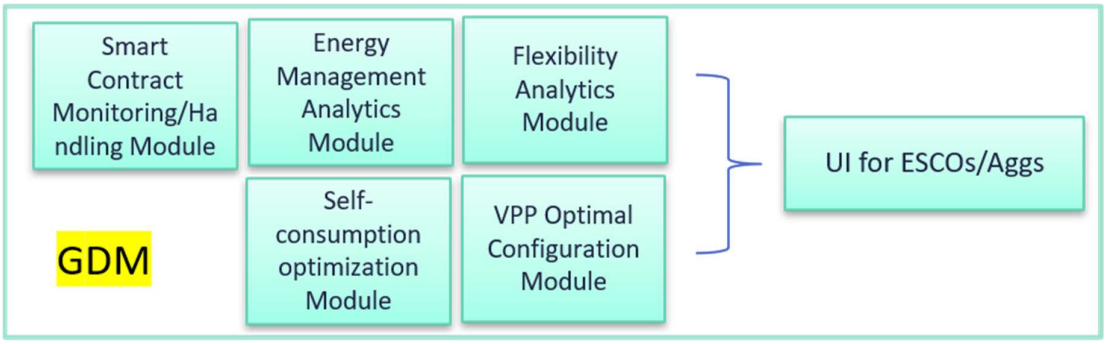

Figure 5: ***Modules of the Global Demand Manager***

Smart Contract Monitoring/Handling Module. Once a smart contract is established between an aggregator and a prosumer, the aggregator will have the possibility, through an appropriate UI linked to the module, to introduce the contract and its parameters (e.g., contract duration, amount of nominal power to be delivered, ISPs and duration etc.) in a blockchain infrastructure. The blockchain implementation will ensure transparency over the contractual process, also allowing the establishment of an advanced Settlement and Remuneration process. Through this process and based on the terms that are agreed in the Smart Contract, the activated flexibility during a DR event can be verified and eventually respective remunerations can be calculated and attributed to the prosumers.

The aforementioned module will support requirements Req_030 - Req_038 described in Table 11.

Energy Management Analytics Module. This module will serve as the calculation engine of portfolio-wide energy efficiency and self-consumption strategies that will be applied to appropriate clusters of consumers, that effectively participate in the energy efficiency remuneration programs. This module will also serve as the trigger point of the Self-Consumption Optimization Module, in case deviations are observed between actual energy

performance and the EE targets set by the energy performance baseline and/or energy performance forecasts.

Self-Consumption Optimization Module. By means of short-term generation and demand forecast, the module is able to maximise the energy consumed at high generation periods, thus maximising the self-consumption and reducing the energy surplus. For the optimization problem, dynamic PV microgeneration, battery energy storage and energy consumption data along with their corresponding static parameters such as PV capacity, battery life expectancy, EV power etc. will be fused together to give insights and predictions on prosumers' self-consumption maximization. The results of this optimization can be used to update the energy efficiency strategies defined in the Energy Management Analytics Module.

Flexibility Analytics Module will provide an AI-based forecasting engine for demand and demand flexibility, taking as input the fused context-aware flexibility profiling framework of the Big Data Platform. It will also provide the analytic mechanisms for demand portfolio forecasting and management through the dynamic segmentation, classification, and clustering of consumers' flexibility to volatile price signals.

VPP Optimal Configuration Module. All established smart contracts configuration parameters are made available to this module, as well as the flexibility clusters defined in the Flexibility Analytics Module. These inputs along with other dynamic parameters, such as energy prices, will be used for the proper update/optimization on the VPP configuration (established in the Smart Contract Monitoring/Handling Module) which is performed in relation to the needs of the respective DSO, TSO, BRP, always ensuring an optimal flexibility activation scheduling.

UI for ESCOs/Aggregators (visualization module). This module is responsible to provide the visualization framework for ESCOs (EE/self-consumption performance monitoring) and the visualization framework for aggregators (flexibility analytics and DR strategy optimization) as well as the smart contract monitoring settlement and remuneration information to aggregators.

Dependencies/Communication with other components

Big Data Management Platform: Get access on real-time/historical wholesale market, energy network constraints, DER management system data and smart measurements coming from the smart gateways, that are properly processed and stored in the platform. The communication with the platform is established through an appropriate REST API, exposed from the platform to the global demand manager.

4.5 Local Demand Manager

Overview

The role of this component is to enable the provision of local energy performance and flexibility services (now-casts and forecasts) calculated per asset level. It will help the consumers and the prosumers to gain useful insights about possible local performance optimizations through HVAC, lighting, PV output, water heaters and building thermal storage control as well as provide intelligent control strategies overall.

Component Functional Elements

The different modules of the Local Demand Manager component are presented in the following figure:

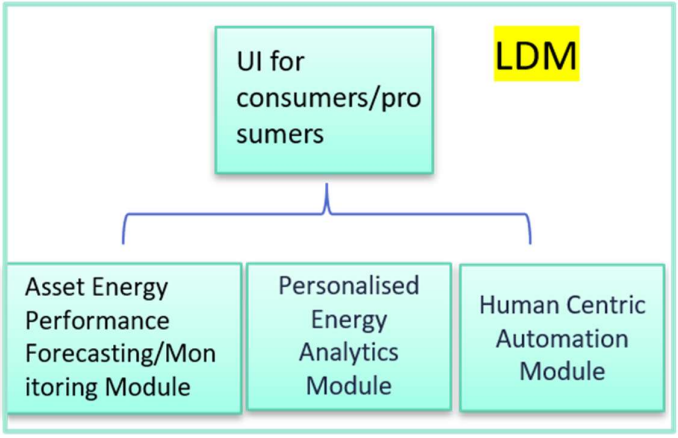

Figure 6: Modules of the Local Demand Manager

Asset Energy Performance Forecasting/Monitoring Module is in charge of monitoring energy demand and generation at dwelling level as well as providing mid-term and long-term forecasts via pre-trained algorithms. These forecasts are valuable insights for consumers and

prosumers to manage better their energy assets, comfort choices, and EE targets achievable by exploiting the thermal inertia of the building.

The module acting as a performance monitoring tool, will aim to extract previously unknown recurring patterns and anomalous working modes. As a result, consumers and prosumers will be able to monitor the system by using easy to interpret indicators for the dwelling performance in terms of demand and generation. The outcome of this module will also provide helpful insights to ESCOs regarding the overall energy generation and consumption trends and monitor the performance of EE contracts when EE services are activated (communication with GDM component).

Personalised Energy Analytics Module:

This module will provide energy analytics and recommendations as an implicit energy service. Information about energy performance, DER and the user's behaviour and preferences will be read from the Big Data Platform in order to estimate which options are the best in each case. All the analytics and recommendations will be based on securing user's comfort and energy efficiency.

The aforementioned module will support the following features:

- Get energy performance forecasting, DER and user's information from the Big Data Platform, both monitored and post-processed data.
- Provide analytics and recommendations to the users through the appropriate UI.

Human-Centric Automation module:

This module will generate regulation signals in order to manage user's electrical devices, working as an explicit energy service. The objective is to ensure energy efficiency and economic savings taking into account the DER generation, energy performance forecasting information and user's behaviour and comfort. Communication between the Big Data Platform and this module will be continuous.

The aforementioned module will support the following features:

- Read energy performance forecasting, DER and user's information from the Big Data Platform, both monitored and post-processed data.
- Automatizing electrical devices management based on user's comfort preferences.

UI for consumers/prosumers (visualization module): This user interface (UI) will act as a web-based visualization toolkit for the personalized informative billing service, the asset performance monitoring, receiving recommendations and notifications and the scheduling and automation of assets based always on the user's comfort preferences. Visualization on smart contract parameters (e.g., asset availability) and information on the consumer's remuneration must also be made available through this UI.

Dependencies with other components

Big Data Management Platform: Get access on real-time/historical wholesale market, energy network constraints, DER management system data and smart measurements coming from the smart gateways, that are properly processed and stored in the platform. The communication with the platform is established through an appropriate REST API, exposed from the platform to the local demand manager.

5 FINAL ARCHITECTURE

Finally, this section is responsible to provide the detailed fresco architecture. Figure 7 demonstrates the ingestion of all the data sources inside the Big Data Management Platform.

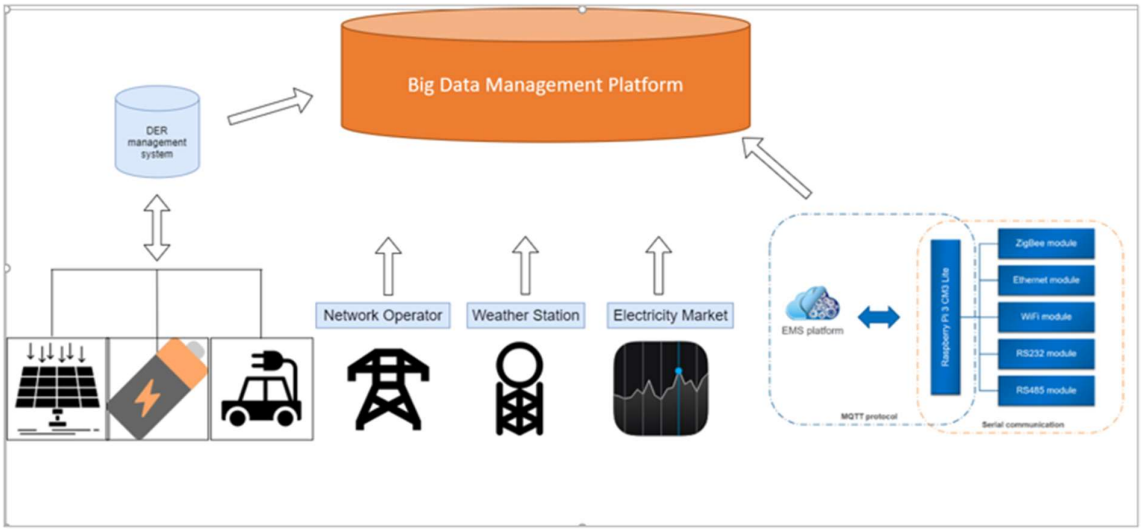

Figure7: Data ingestion in the Big Data Management Platform

Regarding the flexibility business scenario from the aggregators point of view, figure 8 demonstrates the flow:

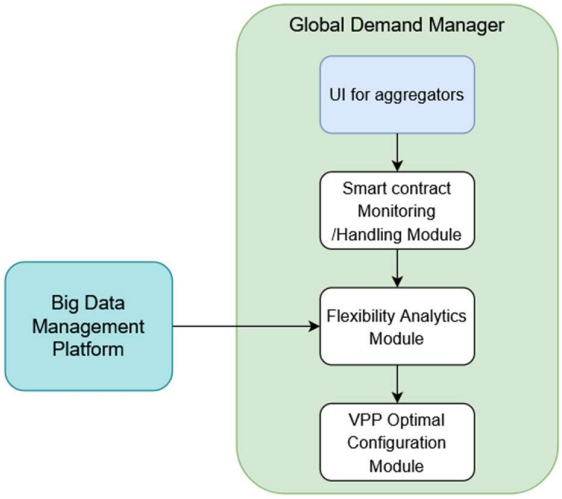

Figure 8. Flexibility calculation, optimization and visualization for aggregators

Energy management analytics and self-consumption optimization mechanisms for the ESCOs are presented in figure 9:

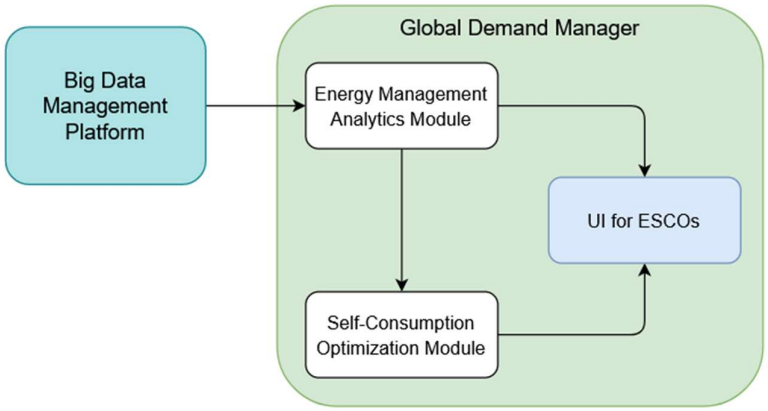

Figure 9. Energy efficiency, optimization, and visualization for ESCOs

Finally, the corresponding services for the consumers and prosumers are depicted in figure 10:

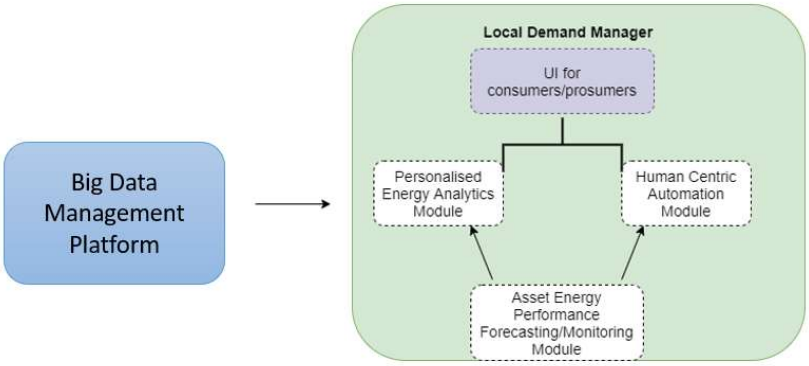

Figure 10. Energy efficiency, device control, personalised analytics and visualization for consumers and prosumers

6 CONCLUSIONS

Deliverable (D2.5) presents the definition of the frESCO architecture, documents the frESCO roles, analyzes the requirements and the use cases that describe the functionality of the platform and analyses the different features that each component and module of the platform serves.

The given document is essentially a representation of the frESCO project conceptual architecture, containing all the high-level details necessary for the implementation of the frESCO platform and the interactions between all the different components with a focus on the end-users needs. The architecture is represented both schematically with all the components and how they all fit together and verbally with the usage of functional and non-functional requirements of the platform.

This report on the conceptual architecture of the frESCO platform will help all the different stakeholders of the energy landscape to visualize how the platform should function, understand how their requirements are met, and which services will bring value to their customers. From a technical point of view the report will act as reference for WP4 and WP5 for any ongoing software development activity.

7 REFERENCES

European Commission (2016) Impact assessment study on downstream flexibility, price flexibility, demand response & smart metering. ENER/B3/2015-641 [https://bit.ly/3o3Ri4F, access: 06/05/2021].

European Commission (2014) Communication from the Commission to the European Parliament and the Council, European Energy Security Strategy.

Eurostat (2021) Renewable Energy Statistics [https://bit.ly/3xQEnY9, access: 06/05/2021].

Guelpa, E., Marincioni, L., Deputato, S., Capone, M., Amelio, S., Pochettino, E., & Verda, V. (2019) Demand side management in district heating networks: A real application. Energy, 182, 433-442.

HOLISDER (2020) *Integrating Real-Intelligence in Energy Management Systems enabling Holistic Demand Response Optimization in Buildings and Districts* [https://bit.ly/3f1p5qX, access: 06/05/2021].

Hwang, Y. H. (2015). IoT Security & Privacy. Proceedings of the 1st ACM Workshop on IoT Privacy, Trust, and Security - IoTPTS '15. doi:10.1145/2732209.2732216.

Johra, H., Weiss, T., et al. (2019) *Examples of Energy Flexibility in Buildings*, International Energy Agency.

Morton, A., Reeves, A., Bull, R., & Preston, S. (2020). Empowering and Engaging European building users for energy efficiency. Energy Research & Social Science, 70, 101772.

Stavrakas, V., & Flamos, A. (2020). A modular high-resolution demand-side management model to quantify benefits of demand-flexibility in the residential sector. Energy Conversion and Management,205, 112339.

Yokotani, T., & Sasaki, Y. (2016). Comparison with HTTP and MQTT on required network resources for IoT. 2016 International Conference on Control, Electronics, Renewable Energy and Communications (ICCEREC). doi:10.1109/iccerec.2016.7814989.

Use Cases and Scenarios, https://www.inflectra.com/ideas/topic/use-cases.aspx