



D2.3: High-level requirements for the DEDALUS social, technological and business framework

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WP2, T2.5



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Technical references

Project Acronym	DEDALUS
Project Title	Data-driven Residential Energy Carrier – agnostic Demand Response Tools and Multi-value Services
Project Coordinator	Diego Arnone ENG diego.arnone@eng.it
Project Duration	May 2023 – April 2026 (36 months)
Deliverable No.	D2.3
Dissemination level*	PU
Work Package	WP2 - Socio-economic enablers for stimulating participatory, multi-value and energy carrier-agnostic residential DR
Topic	HORIZON-CL5-2022-D4-01-01
Funding Scheme	HORIZON Innovation Actions
Lead beneficiary	ENG
Contributing beneficiary/ies	ENG, NTUA, CARTIF, UNIPVM, ARC, COMS, TUC, DOM-X, HERON, OurPower
Due date of deliverable	31 January 2024
Actual submission date	10/07/2026
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Reviews	Panos Skaloumpakas (NTUA), Elena Boskov Kovacs (BLUEPRINT)
Keywords	DEDALUS framework, High Level Requirements, Demand Response

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Document History

V	Date	Description	Author
0.1	04/12/2023	ToC – first version	Marilena Lazzaro (ENG)
0.2	22/12/2023	ToC- updated version	Marilena Lazzaro (ENG)
0.3	26/01/2024	ToC – Final version	Luca Vitale (ENG) and Marilena Lazzaro (ENG)
0.4	23/02/204	First partners contributions	Marzia Mammina (ENG), Vasilis Michalakopoulos, Panos Skaloumpakas (NTUA), Riccardo Naccarelli, Serena Serroni (UNIPVM), Susana Gutiérrez (CARTIF), Ionut Anghel, Tudor Cioara (TUC), Andrija Goranović (OurPower), Klemen Bregar (COMS), Silvia Palma (ENEA), Athanasios Papakonstantinou (HERON)
0.5	08/03/2024	First Draft	Luca Vitale (ENG)
0.5.1	19/03/2024	Template fix	Luca Vitale (ENG)
0.6	05/04/2024	Consolidated version	Luca Vitale, Marzia Mammina, Marilena Lazzaro, Andrea Natalini (ENG), Panos Skaloumpakas, Katerina Sianni (NTUA), Riccardo Naccarelli (UNIPVM), Athanasios Papakonstantinou, Paraschi Marion (HERON), Klemen Bregar (COMS), Henrik Lund Stærmose (NEOGRID), Giannis Kazdaridis (DOM-X)
0.7	11/04/2024	Consolidated version	Luca Vitale (ENG), Marzia Mammina (ENG), Leandro Lombardo (ENG), Andrea Sabatino (ENG)
0.7.1	16/04/2024	Minor fix	Luca Vitale (ENG)
0.7.2	30/04/2024	Reviewing after the physical meeting. Deeper view on the architecture and new information about the use cases	Luca Vitale, Marilena Lazzaro (ENG), Elissaios Sarmas, Vasilis Michalakopoulos, Panos Skaloumpakas (NTUA), Ionut Anghel, Tudor Cioara (TUC), Roberto Arnanz (CARTIF), Athanasios Papakonstantinou (HERON)
87n0.8	10/05/2024	Peer reviewed	Panos Skaloumpakas (NTUA)
0.8.1	12/05/2024	Peer reviewed	Elena Boskov Kovacs (BLUEPRINT)
0.9	16/05/2024	Release candidate	Luca Vitale (ENG)
0.99	20/05/2024	Quality checked	Diego Arnone (ENG)
1.0	20/05/2024	Final version	Diego Arnone (ENG)
1.0.1	26/02/2026	Added contributions on Pilot 6	Jonas Van Gompel (CENTRICA)

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1.0.2	26/02/2026	Peer reviewed	Panos Skaloumpakas (NTUA)
1.0.3	27/02/2026	Peer reviewed	Christine.Gritsch (BLUEPRINT)
1.0.4	27/02/2026	Release candidate	Marzia Mammina (ENG)
1.1	03/03/2026	Quality checked	Andrea Sabatino (ENG)
2.0	17/03/2026	Final version	Diego Arnone (ENG)
2.1	10/07/2026	Final version (disclaimer updated and replaced by EnEA)	Diego Arnone (ENG)

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List of Acronyms

AGPL	Affero General Public License
API	Application Programming Interface
BM	Building Manager
CoReDEX	Compliant Regulatory Data Exchange
DHN	District Heating Network
DLT	Distributed Ledger Technologies
DR	Demand Response
DT	Digital Twin
EC	European Commission
EFIs	Energy Flexibility Indicators
FC	Facility Manager
GDPR	General Data Protection Regulation
GUI	Graphic User Interface
HLUC	High Level Use Case
IAQ	Indoor Air Quality
IoT	Internet of Things
LD	Linked Data
MQTT	Message Queuing Telemetry Transport
NGSI	Next Generation Service Interface
PO	Platform Operator
PPE	Privacy Protection Enforcement
PRESS	Privacy, data protection, Ethics, Security and Societal
PRIMULA	Privacy, Reputation Mechanisms and Mutual Auditability toolbox
RES	Renewable Energy Sources
REST	REpresentational State Transfer
SAML	Security Assertion Markup Language
SSO	Single Sign-On
TE	Technology Enablers

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TRL	Technology Readiness Level
UC	Use Case
USG	Universal Secure Gateway
WP	Work Package

Executive summary

The document focuses on defining the functional specifications for the DEDALUS business, privacy, and cyber-security framework, incorporating inputs from requirements analysis. The document serves as a comprehensive roadmap, guiding stakeholders towards the successful realization of the DEDALUS vision. The document is derived from D2.1 and aims to delve deeper into the information already collected within its pages.

The primary goal of Demand Response (DR) is to enhance grid reliability, avoid blackouts, and efficiently use available energy resources. The DR refers to a strategy employed by energy providers to manage energy consumption during periods of high demand or supply constraints. It involves modifying the energy consumption patterns of consumers/users in response to signals such as price incentives or grid reliability concerns. The objective is to implement a comprehensive framework encompassing social, technological, and business aspects, with the following aims: (i) to enhance and expand the involvement of residential energy consumers in DR initiatives on a large scale; (ii) to accommodate a spectrum of diverse mono-carrier (such as electricity, heat) or multi-carrier synergistic contexts (e.g., interactions between electricity and heat, or between electricity and natural gas), ensuring thorough consideration of synergies and interactions among the involved energy commodities. The DEDALUS framework will be applied, implemented, and validated in 7 real-life pilots (5 Front Runners and 2 Multipliers), across 7 countries. The large geographical coverage of the pilot sites, encompassing nations from Northern Europe (Denmark and Ireland), Central Europe (Austria and Romania), and Southern Europe (Greece, Spain, and Italy) aims to support the large-scale EU-wide replicability and market take-up of solutions in different socio-economical contexts to maximize the impact of DEDALUS services across Europe.

In the document, information about each Technology Enablers (TE) is systematically gathered and presented. Subsequently, this collated data is organized within a structured table, standardizing the information for enhanced clarity and accessibility. Additionally, 23 distinct use cases are identified, each delineated alongside its corresponding set of pertinent functional and non-functional requirements. A high-level software architecture is presented, aiming to clarify the interconnection among the components of the DEDALUS project. It is important to note that one of the goals of the DEDALUS project was to leverage existing solutions that have previously been developed.

An important aspect addressed in the document pertains to security and privacy, with different strategies being discussed. As DEDALUS involved in the social aspects, it includes different data about personal data. Through the exploration of various strategies and approaches, the initiative endeavours to safeguard user data and uphold ethical standards in its operations.

By following the methodology proposed, it is possible to systematically analyse, synthesize, and prioritize the various components, insights, and stakeholder inputs relevant to the development and deployment of DEDALUS technology and data-driven services.

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1. Introduction

1.1 Purpose and audience of the document

This deliverable presents the high-level functional specifications pertaining to the DEDALUS business, privacy, and cyber-security framework. These specifications serve as a comprehensive guide outlining the core functionalities for the effective implementation and management of the DEDALUS framework. By detailing the business processes, privacy protocols, and cyber-security measures, this document lays the foundation for the successful integration and operation of DEDALUS within project objectives. The methodology proposed has 3 main steps:

- Analysis of the requirements gathered in D2.1.
- Analysis of each component of the DEDALUS Technology Enablers (TE) and data-driven services.
- Analysis of the pilots' and consumers' needs through the use cases.

1.2 Relation to other activities

This document is the result of the cooperation of the partners within the Task 2.5 of WP2. Serving as the final specification document, it is closely associated with various activities. It commences by referencing the deliverable D2.1 [1], which delineates the use cases, requirements, and essential needs for the DEDALUS platform. Additionally, it relates to WP3, tasked with providing the technology enablers for residential energy consumer data-driven 'activation'. Particularly, it delineates the necessary tools to ensure compliance with the privacy, security, and legal requirements framework for the task T3.6, titled 'Privacy, Security, and Data Protection Framework for Trusted Data Sharing and AI'. It also intersects with WP4, responsible for specifying value-added, data-driven energy and non-energy services for DR in energy-efficient residential buildings. Lastly, T2.5 is closely tied to WP5, which oversees the planning, management, and evaluation of the DEDALUS pilots.

1.3 Structure of the document

The document, after this brief introduction, follow the below structure:

- In Chapter 2. DEDALUS Software Requirements Specification, numerous information was gathered. For instance, in Section 2.2, information regarding the Technology Enablers (TE) was compiled, while Section 2.3 focused on collecting the Use Cases.
- In Chapter 3. DEDALUS Framework High-Level Architecture Specification a high-level architecture was designed and explained.
- In Chapter 4. Data Privacy, Ethics and Cyber Security various aspects concerning data privacy and security were addressed. Proposed tools for achieving security within the DEDALUS platform were discussed.
- In Chapter 5. Conclusions summary and conclusions of the deliverable were reported.

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2. DEDALUS Software Requirements Specification

2.1 Methodology

The methodology applied was focused on the engagement with the key stakeholders, including TE leaders and pilot leader to understand their needs. The methodology is based on different iterations and on the feedback received from stakeholders to ensure that the DEDALUS project is designed and implemented to effectively address their needs and to deliver real value. Here the following steps:

1. The organization of workshop with each TE leader to analyse the existing technological solutions.
2. The organization and development of the co-creation workshops for each pilot to establish a direct dialogue with the stakeholders and to extract the user requirements.
3. The analysis of the user requirements gathered and the definition of the new features to develop for the DEDALUS project.

2.2 Analysis of existing technological solutions, tools, and services

One of the DEDALUS goals is to re-use existing software whenever suitable, whilst developing software solutions that go beyond the state of the art. Indeed, partners bring into the project existing technological solutions, tools and services that will be extended in the frame of DEDALUS project to be applied into Project pilots. In the Table 1 displays the definitive mapping of TE usage across the DEDALUS pilot sites. The Table 2: Asset template is a template that is intended to collect standardized information from each TE.

In the table below, each row corresponds to a TE, and each column represents a Pilot country (AU for Austria, DK for Denmark, GR for Greece, IT for Italy, SP for Spain, IE for Ireland, and RO for Romania). A highlighted box means that the TE will be used to the respective pilot. In total are 14 TE and 7 pilots in total, consisting of 5 Front Runners (FR) and 2 Multipliers (Mult).

Table 1: Usage of TE in DEDALUS's pilots

Technology Enablers	Front Runners					Multipliers	
	AU	DK	GR	IT	SP	IE	RO
TE-1: Consumers clustering and segmentation tools							
TE-2: DR-ready connected smart appliances control and interoperability							

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Technology Enablers	Front Runners					Multipliers	
	AU	DK	GR	IT	SP	IE	RO
TE-3: Residential DR/flexibility interoperability building blocks							
TE-4: Flexibility modelling tool for residential DR							
TE-5: DLT/Blockchain/Smart contracts solution							
TE-6: Universal Secure Gateway							
TE-7: Secure and Privacy/Confidentiality Preserving Data Transactions							
TE-8: Digital Twins for consumer-aware optimal flexibility planning							
TE-9: Comfort-based flexibility model							
TE-10: Nudging Apps for near real-time closed-loop residential consumers activation and multi-vector DR							
TE-11: Multi-value DR for virtual cluster of buildings							
TE-12: P2P digital platform for trading pre-aggregated building flexibility							
TE-13: District-level DR for self-consumption and cost optimization							
TE-14: Aggregation of flexible energy resources for district heating management							

The following template is intended to collect standardized information from each TE. This information aims to streamline the integration of Technology Enablers with one another. The overarching objective is to generate new value through their integration.

Table 2: Asset template

Asset name	Name of Asset
DEDALUS partner	<name of the partner>
Functionality provided	<provide here a description of the main feature offered by your asset>



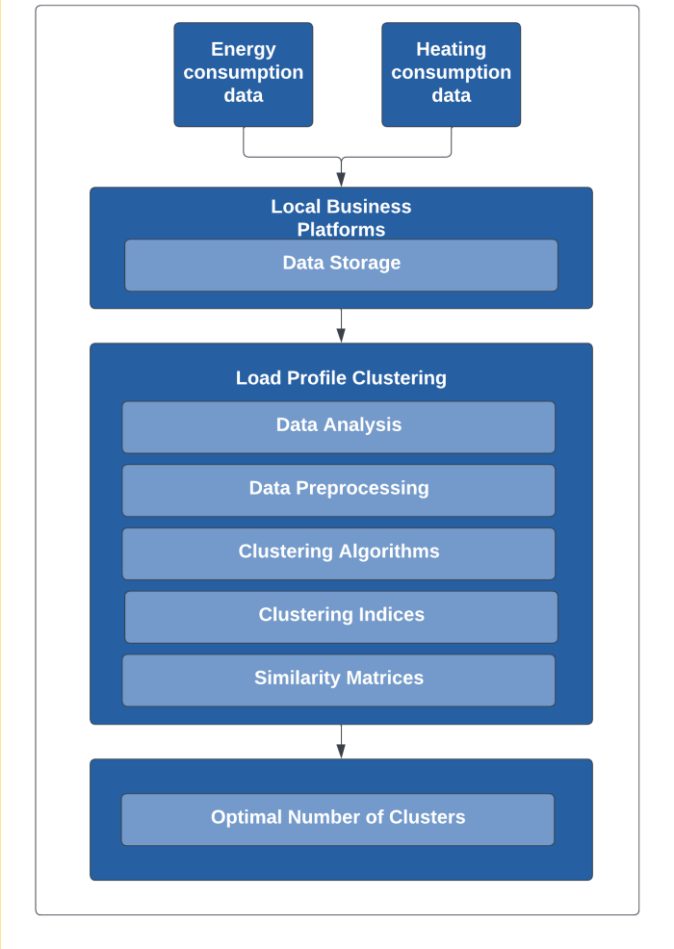
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Architectural aspect	<specify here if your asset is composed by some subcomponents, if useful a graphical representation of the component's architecture could be added too>
Provided interfaces	<provide here the interfaces vs. other components which the component provides its functionalities (exposed services)>
Dependencies /Required Interface	<provide here the interfaces from other components which the component requires its functionalities (exploited services)>
Input data	<provide here the information about input data and related data model>
Output data	<provide here the information about output data and related data model>
License	<specify here license of your asset> (e.g. proprietary, free, and open source); in case of an open-source license please specify the type
Technology Readiness Level (TRL)	<specify here the level of maturity of your asset >
Note	<If it is needed, use this field to write relevant notes about your asset>

Table 3: TE-1: Consumers Clustering and Segmentation Tools

Asset name	Electrical and Heating Load Profile Clustering
DEDALUS partner	National Technical University of Athens [NTUA]
Functionality provided	Data-driven approach for electrical and heating load profile clustering
Architectural aspect	

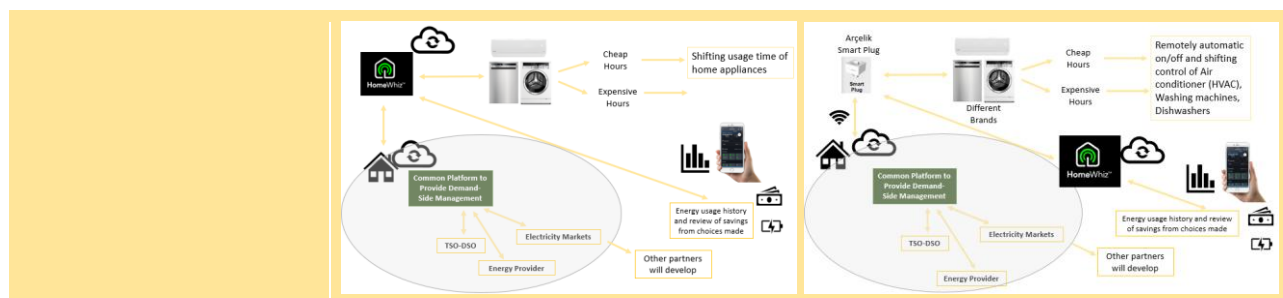


	
Provided interfaces	The model will be delivered to DR services of WP4 through Digital Twins and/or stand-alone interfaces in a dashboard will be provided depending on the pilot.
Dependencies /Required Interface	Local business platforms (data from the energy meters in each pilot) and web services.
Input data	Energy/Heating consumption metrics (building/apartment energy/heating metering, subsystems energy/heating metering).
Output data	Clusters of Consumers based on their electrical/heating loads tailored for DR programs.
License	No information about the license.

Technology Readiness Level (TRL)	n.a.
Note	n.a.

Table 4: TE-2: DR-ready connected smart appliances control and interoperability

Asset name	DR-ready connected smart appliances control and interoperability
DEDALUS partner	Arcelik [ARC]
Functionality provided	Collecting and managing energy consumption data from connected smart appliances via Arcelik's smart home management solution HomeWhiz in an interoperable way.
Architectural aspect	ARC produces connected home appliances (such as; washing machines, dryers, dishwashers, refrigerators, ovens, air conditioners, etc.) and these appliances can be controllable remotely by customers with smartphones or tablets with the help of ARC's smart home solution called HomeWhiz which has an application available for iOS and Android. These home appliances have ability to connect to the ARC cloud by Wi-Fi or Bluetooth in a secure way. Collected data sets are used for data analysis and understanding user-behaviour. Results are shared with customers as recommendations to decrease energy/water consumption and predict possible errors. HomeWhiz have also different energy-saving features. The wizard of HomeWhiz can recommend the most suitable and energy-efficient programmes to the customers (e.g for the washing machine case; if the customer can give information about the type of fabric, colour and degree of dirtiness, the wizard will recommend the most suitable and energy-efficient programmes) 



Provided interfaces	n.a.
Dependencies /Required Interface	MQTT brokers interfaces from energy assets to get monitored data
Input data	Data origins are; HomeWhiz Smart Plugs and HomeWhiz Gateway Data collection types are; web service and MQTT Functionality: Flexibility services Power consumption data collected from Arçelik's smart plugs that measure the consumption from installed devices/home appliances. Temperature and humidity data collected from Arçelik Gateways from room/environment.
Output data	Power consumption, temperature and humidity data
License	n.a.
Technology Readiness Level (TRL)	n.a.
Note	n.a.

Table 5: TE-3: FIWARE Context Broker building block

Asset name	FIWARE Context Broker
DEDALUS partner	ENG
Functionality provided	Technical interoperability. It allows to model, manage, and gather context information at large scale. Context information is described using Next Generation Service Interface (NGSI) [2] an ETSI standardized protocol; at the time of writing, the two NGSI versions most relevant, NGSIv2 [3] and NGSI-Linked Data (LD) [4].
Architectural aspect	Orion Context Broker is an implementation of the Publish/Subscribe Context Broker GE and offers access to it via NGSIv2 Representational



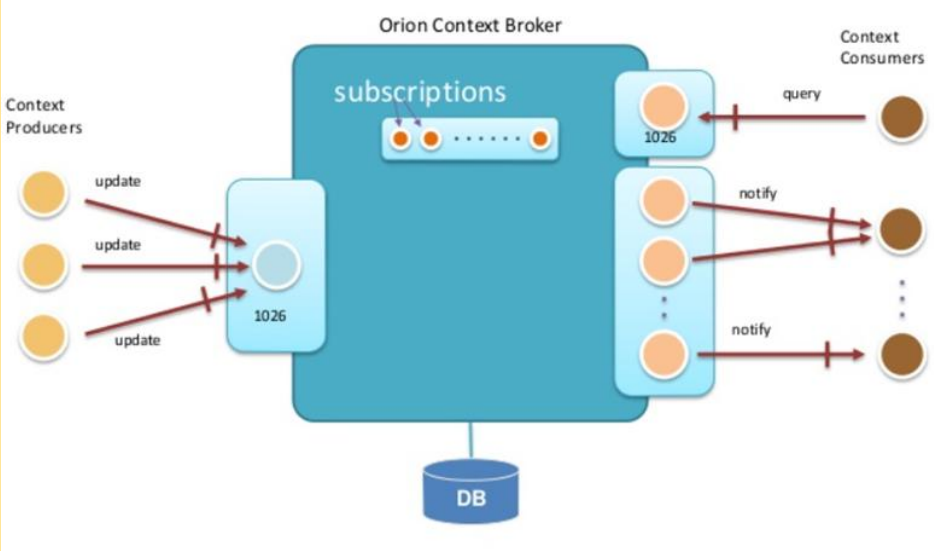
	State Transfer (REST) API, developed as a part of the FIWARE platform. It also owns a short-term persistent data store, As shown in Figure below, Orion Context Broker offers a set of operations used by context producers to publish and update context information and by context consumers to consume that information by means of synchronous or asynchronous tasks.  [5]
Provided interfaces	NGSI API [6], which allows clients to: • Query context information • Update context information • Get notified when changes on context information occur • Register context provider applications.
Dependencies /Required Interface	n.a.
Input data	n.a.
Output data	n.a.
License	Affero General Public License (AGPL) version 3
Technology Readiness Level(TRL)	n.a.
Note	-

Table 6: TE-3: FIWARE NGSI IoT Agent building block

Asset name	FIWARE NGSI IoT Agent
------------	-----------------------

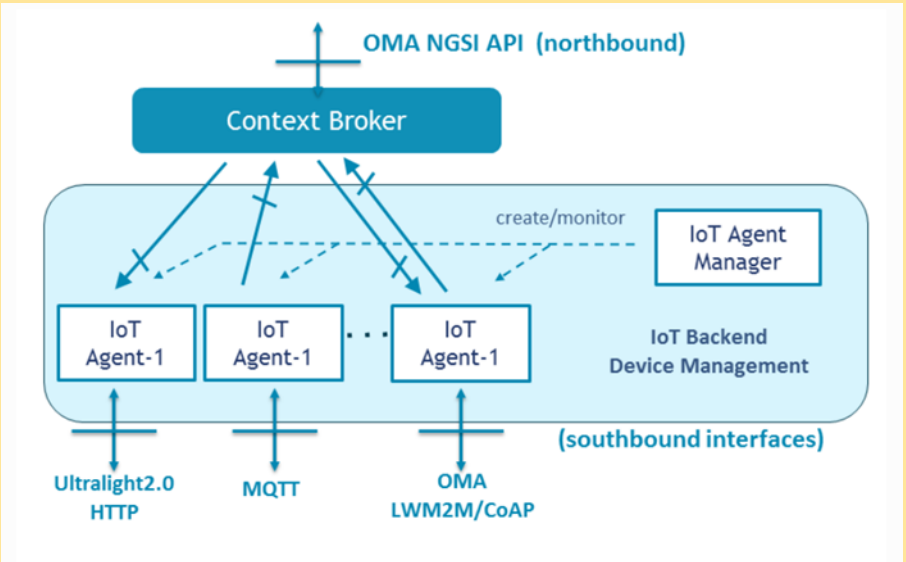
DEDALUS partner	ENG
Functionality provided	NGSI IoT Agents stay at the southbound of the Context Broker and are used by IoT integrators to connect devices. IoT Agents support several IoT protocols with a modular architecture. It is possible to create custom IoT Agent by using the IoT Agent library
Architectural aspect	 [7] IoT Agents also allows to send commands to devices.
Provided interfaces	n.a.
Dependencies /Required Interface	n.a.
Input data	n.a.
Output data	n.a.
License	n.a.
Technology Readiness Level(TRL)	n.a.
Note	-

Table 7: TE-3: OneNet Connector building block

Asset name	OneNet Connector
DEDALUS partner	ENG



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Functionality provided The OneNet Connector, based on TRUE Connector, aims to enable a European Energy Data Space, combining the IDS principles with the advantages of the FIWARE ecosystem ensuring a seamless and secure data exchange in a completely end-to-end decentralized approach.

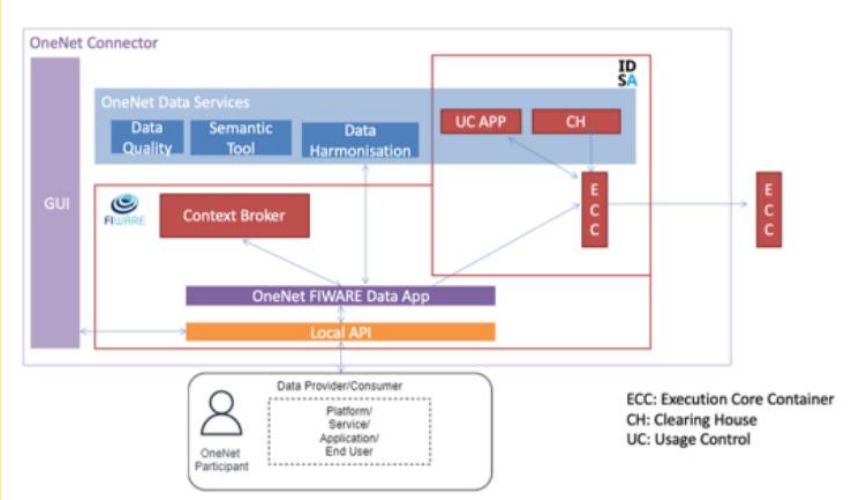
Architectural aspect	 The diagram illustrates the OneNet Connector architecture. It features a central 'OneNet Connector' box containing 'OneNet Data Services' (Data Quality, Semantic Tool, Data Harmonisation), a 'Context Broker', and 'OneNet FIWARE Data App'. A 'GUI' is connected to the 'Context Broker'. An 'ID SA' box contains 'UC APP' and 'CH'. A 'Local API' connects the 'OneNet FIWARE Data App' to a 'Data Provider/Consumer' (Platform/Service/Application/End User). A legend defines ECC as Execution Core Container, CH as Clearing House, and UC as Usage Control. [8]
Provided interfaces	n.a.
Dependencies /Required Interface	n.a.
Input data	n.a.
Output data	n.a.
License	» Open-source » Open-source – copyleft » Upon OneNet project conclusion, it will be open-source under a GPLv3 or similar license.
Technology Readiness Level(TRL)	TRL 7 (status Aug. 2023). The OneNet Connector was deployed and tested in 12 different European countries' environments, within the OneNet Demonstration phase. The target TRL at the end of the project is 8.
Note	-

Table 8: TE-4: Flexibility modelling tools for residential DR

Asset name	Methodology for Energy Flexibility Prediction
DEDALUS partner	National Technical University of Athens [NTUA]

Functionality provided A tool that will provide flexibility assessment and prediction of building, apartment, or device level

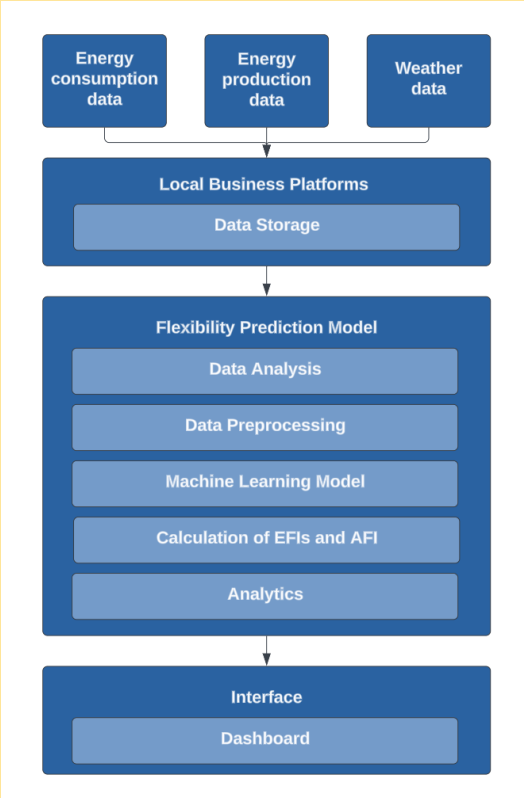
Architectural aspect	
Provided interfaces	The model will be delivered to DR services of WP4 and will be displayed on a specifically developed web service.
Dependencies /Required Interface	Local business platforms (data from the project's energy meters) and web services.
Input data	Energy consumption metrics (building energy metering, subsystems energy metering) and energy production metrics of the on-site renewables production. Additionally, web services are employed to retrieve weather data.
Output data	Prediction of the energy flexibility for different time horizons and calculation of relative Energy Flexibility Indicators (EFIs) and Aggregated Energy Flexibility Indicator (AFI).
License	No information about the license.
Technology Readiness Level(TRL)	TRL 5
Note	n.a.



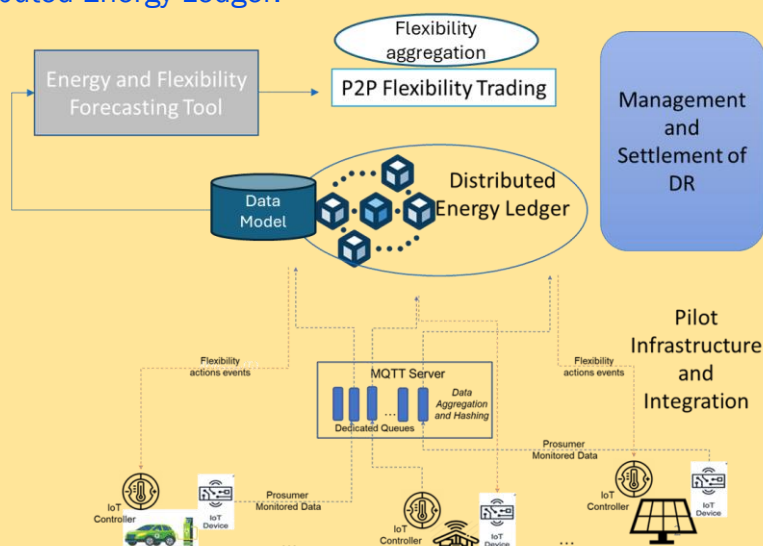
Table 9: TE-5: DLT/Blockchain/Smart contracts solution

Asset name	DLT/Blockchain/Smart contracts solution for decentralized machine learning, P2P flexibility tokenisation, and DR settlement
DEDALUS partner	TUC

Functionality provided TE-5 goal is to facilitate the implementation of decentralized DR programs and building flexibility aggregation. It leverages blockchain-based distributed ledger to securely store and digitally fingerprint energy demand and/or production data. Energy metering devices can be integrated through self-enforcing smart contracts, enabling the generation of energy transactions. These transactions are then recorded and shared in an immutable and tamper-proof manner on the blockchain. A forecasting component utilizes monitored data to predict energy demand and flexibility for the day-ahead. A P2P trading mechanism is used for building level flexibility aggregation while the smart contracts enable the injection of DR signals, to programmatically define the expected levels of energy flexibility, along with the associated remuneration. A DR settlement component use monitored data to trigger the appropriate financial / non-financial remuneration for flexibility providers. Smart contracts verify and compare the monitoring data against the commitments, generating the actual settlement based on these values. The platform offers tokenization for flexibility integration, encompassing rewarding schemes that can be extended to go beyond financial remuneration.

Architectural aspect

Subcomponents: Energy and flexibility forecasting tool; P2P flexibility trading component; Management and settlement of DR component; Distributed Energy Ledger.



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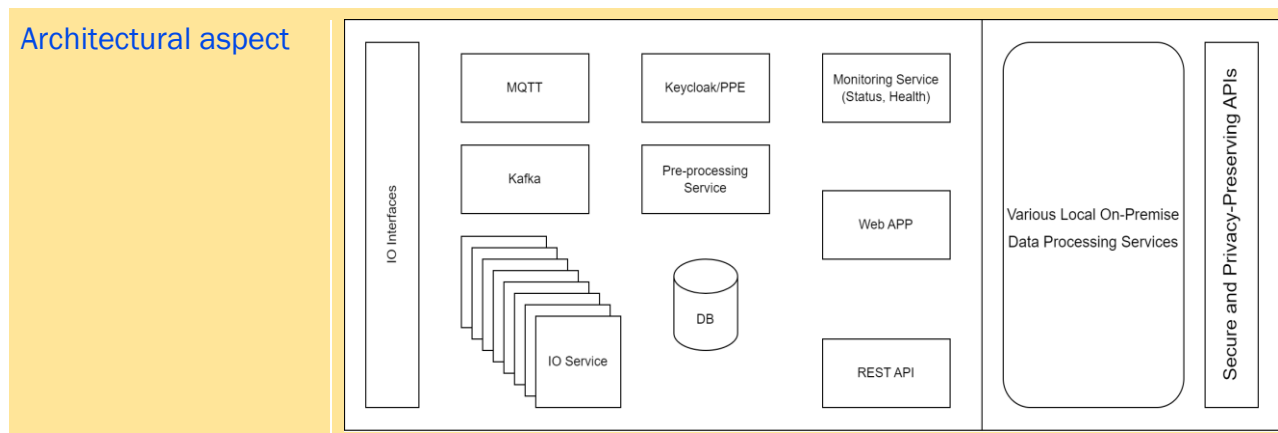
Provided interfaces	n.a.
Dependencies /Required Interface	MQTT brokers interfaces from energy assets to get monitored data Other interfaces available for getting the monitored data
Input data	Energy consumption, production data for energy assets (T3.1). Semantic vocabulary data space for data TE model compliance (T3.2/T3.3) ML based flexibility prediction models (T3.4)
Output data	Decentralized DR programs for buildings
License	Open source, LGPLv3
Technology Readiness Level(TRL)	TRL5
Note	TE-5 will be validated in Spain pilot and Romania multiplier.

Table 10: TE-6: Universal Secure Gateway

Asset name	Universal Secure Gateway
DEDALUS partner	COMS

- Functionality provided
- Integration of field assets with backend and data analytics services while supporting secure communications and standardised APIs.
 - Aims to provide solution for the pre-aggregation, orchestration and activation of flexibility and DR.
 - It supports limited amount of local, on-premises private data processing.

The Universal Secure Gateway (USG) is a software solution aimed at enabling arbitrary integration of field assets and legacy systems with backend and data analytics services, enhancing security over legacy protocols, and adopting standardised APIs to allow for the interoperability of traditionally disparate systems. The existing building blocks will be reused and enhanced to provide a plug & play solution for the pre-aggregation, orchestration and activation of flexibility via DR. The overall ambition is to enable the energy community manager to gather in real-time data from various sources, such as assets/systems, grid infrastructure, market and weather forecast, and make informed decision based on analytics services. Integrating the results of TE-3, the solution will support local, on-premises private data processing.



Provided interfaces	USG will provide the ground to integrate the services and interfaces developed in DEDALUS project. It will provide a platform, where data connectors can be deployed (to expose data and flexibility) and services for local data processing can be deployed.
Dependencies /Required Interface	Specifications of services and interfaces to be integrated
Input data	n.a.
Output data	n.a.
License	No information about the license
Technology Readiness Level(TRL)	TRL 5
Note	TE-6 will be validated at least in Austrian pilot

Table 11: TE-7: Secure and Privacy/confidentiality Preserving Data Transactions

Asset name	Secure and Privacy/Confidentiality Preserving Data Transactions
DEDALUS partner	COMS

- Functionality provided
- Identity and access management:
 - Authentication
 - Authorization
 - Auditing
 - Consent exchange
 - Policy/permission-based data exchange
 - Transaction auditing

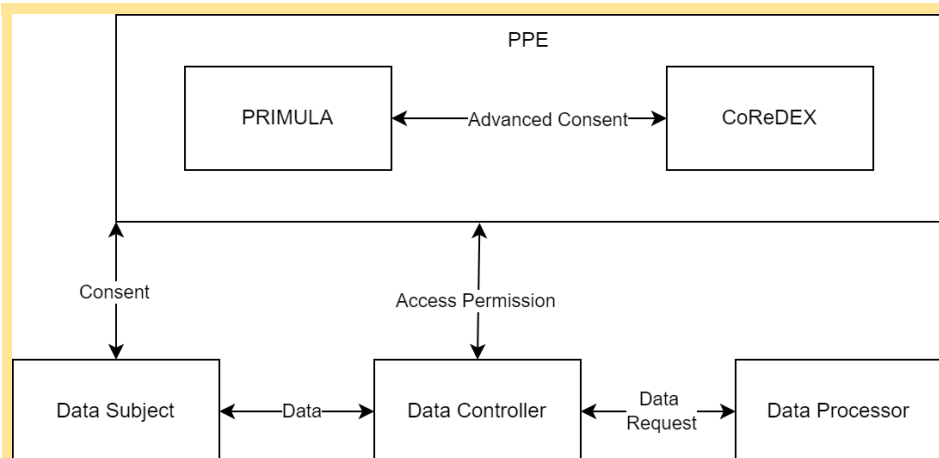
COMS has developed a blockchain-based Privacy Protection Enforcement (PPE) component that enables consent-driven sharing

and exchange of personal (GDPR-compliant) and confidential data among stakeholders and with data marketplaces. It provides:

- data registration,
- consent exchange,
- data access and
- usage policy definition,
- provision of permission-based mechanisms and protocols,
- comprehensive auditing functionalities,
- and actor reputation assessment.

Coupled with a service mesh like implementation approach, granular end-to-end data transaction policies may be imposed. This allows for private, secure, sovereign, and transparent data management over its entire data lifecycle.

Architectural aspect



- **PPE-Core:**
 - A standalone component that is able to detect events, manage consents and permission required by systems' participants, take track of requests, and notify other components according to specific rules
- **PRIMULA (Privacy, Reputation Mechanism and Mutual Auditability):**
 - Enables consent-driven exchange of data through managing the advanced consent among parties
 - Provides consent auditing functionalities
 - Provides reputation mechanisms to assess the party's reputation
- **CoReDEX (Compliant Regulatory Data Exchange):**
 - Enforces compliance rules and governance policies by acting as a mediator for data exchange among parties.
 - Implements mechanisms/protocols for data transfer authorization to other components

	○ Implements mechanisms/protocols for direct data transfer between two parties without intermediary channels ○ The authorization is dependent on advanced consent and reputation mechanisms from PRIMULA
Provided interfaces	Interface for giving and checking the consent for specific data sources
Dependencies /Required Interface	N.A.
Input data	Consent registration Check for authorization
Output data	Authorization given Authorization rejected
License	No information about the license
Technology Readiness Level(TRL)	TRL 5
Note	TE-7 will be validated at least in Austrian pilot

Table 12: TE-8: Digital Twins for consumer-aware optimal flexibility planning

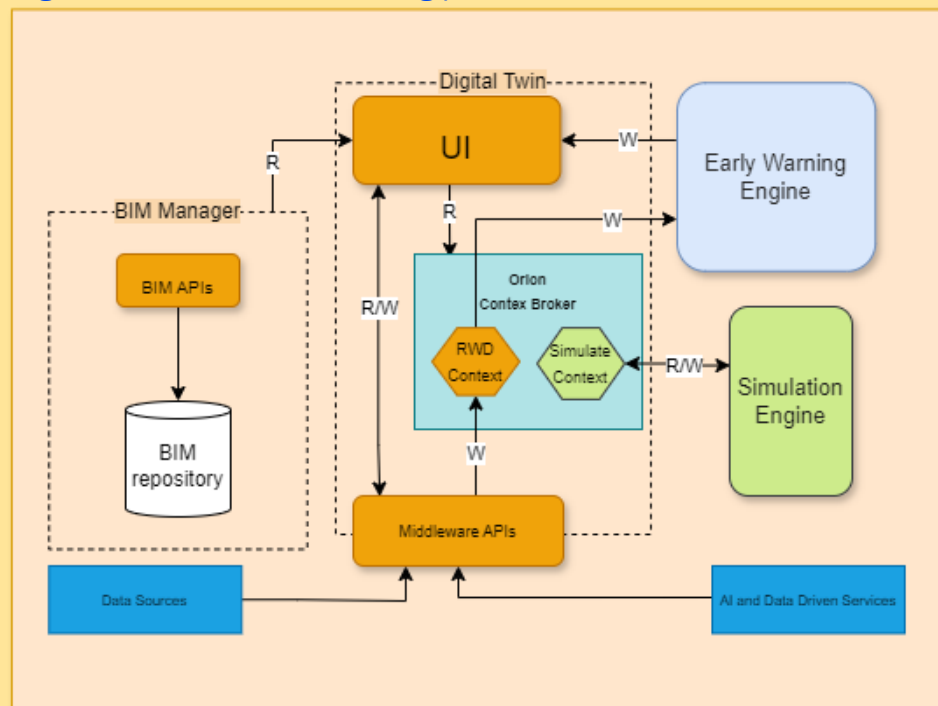
Asset name	Digital Twins for consumer-aware optimal flexibility planning
DEDALUS partner	ENG
Functionality provided	The Digital Twin (DT) serves as a versatile platform enabling various functionalities tailored to specific user needs. Each DT is capable of supporting users in different tasks, facilitated by a range of essential components. Among those components we can find: - Data Visualization Interface: A pivotal feature of the DTs is their ability to offer users a comprehensive overview of both real-time and historical data pertaining to various managed households or devices. This interface will enable users to easily understand and analyse data trends, aiding in informed decision-making and optimization of energy usage. - Simulation Interface: DTs will offer users the capability to simulate the behaviour of existing devices or spaces. This functionality allows for the estimation of future energy consumption, facilitating better energy planning and savings strategies. Moreover, it empowers users to harness flexibility

and demand response services effectively, thus optimizing energy utilization.

- **Fault Detection Engine:** this component provides users with proactive fault prevention capabilities. Integrated Fault Detection Services empower users to anticipate potential issues and strategically plan maintenance activities. Leveraging advanced prediction and fault estimation algorithms, the DT ensures optimized performance and minimizes disruptions by identifying and addressing faults in advance.
- **Middleware API Layer:** Serving as the central hub for communication, this layer seamlessly manages all incoming data from external sources to the DT. It serves as the access point through which every component is interconnected, while also functioning as a gateway for injecting data into the DT's system.
- **Context Broker:** Another pivotal element of the DT architecture lies within the Context Broker. This component empowers the system to ingest data in various formats and categorize them into distinct contexts. For instance, it can seamlessly differentiate between Real World and Simulated Contexts.

Architectural aspect

Given what has been previously described, a possible DT architecture might be similar to the following picture:



Provided interfaces	The primary access point to the DT Architecture is its User Interface. Through this interface, users can seamlessly access all functionalities offered by the DT's backend architecture.
Dependencies /Required Interface	AI and Data Driven Services
Input data	RT and Historical Data from the Pilot Edge Devices and/or AI services
Output data	AI and Data Driven Services Results Recommendations to support Decision Making
License	Open Source GPLv3
Technology Readiness Level (TRL)	TRL 5
Note	

Table 13: TE-9: Comfort-based flexibility model

Asset name	Comfort-based flexibility model
DEDALUS partner	Università Politecnica delle Marche [UNIVPM]
Functionality provided	Optimal trade-off among comfort, energy and building performance

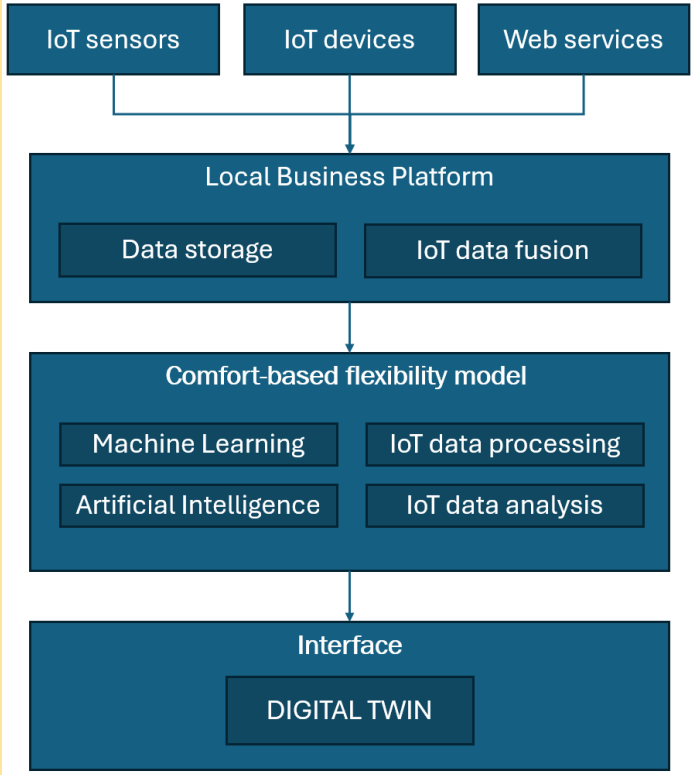
Architectural aspect	
Provided interfaces	The model will use the DIGITAL TWIN as main graphical user interface.
Dependencies /Required Interface	• Dependencies: Local business platforms (data from the project's IoT sensors and devices) and web services • Required interface: Digital Twin
Input data	Indoor parameters (air temperature, relative humidity, CO2 levels, light level), energy consumption metrics (metering, sub-metering, and smart plugs), and real-time data on on-site renewables production. Additionally, web services are employed to retrieve pertinent weather and grid data. Thermal sensation vote from the users (user preferences).
Output data	Thermal and energy conditions to deliver coaching solution for enhanced comfort and well-being during application of DR service.
License	Proprietary
Technology Readiness Level (TRL)	TRL5
Note	User feedback collection depends on pilots and users (elderly people in the Italian pilot)

Table 14: TE-10: Nudging application

Asset name	Nudging Apps for near real-time closed-loop residential consumers activation and multivector DR
DEDALUS partner	OurPower, DOMX
Functionality provided	Activation of residential consumers by nudging interventions
Architectural aspect	- Nudging application frontend: output to and input from user - Nudging application server: calculates nudging intervention recommendations; communicates with external services (e.g., meteorological service) and nudging application frontend
Provided interfaces	DOMX mobile application, Serve-U app
Dependencies /Required Interface	- Meteorological service for meteorological data and forecasts - EDA server for energy consumption and production data - Algorithm for nudging intervention calculation
Input data	- Basic asset data regarding energy consumption & production - Energy consumption data and forecasts - Energy production data and forecasts - Meteorological data and forecasts
Output data	Nudging intervention recommendations to the end-users
License	Proprietary
Technology Readiness Level(TRL)	TRL5-6
Note	-

Table 15: TE-11: Multi-value DR service

Asset name	Multi-value DR for virtual cluster of buildings
DEDALUS partner	HERON, NTUA
Functionality provided	A DR service that offers recommendations at appliance level for clusters of users defined based on a common characteristic



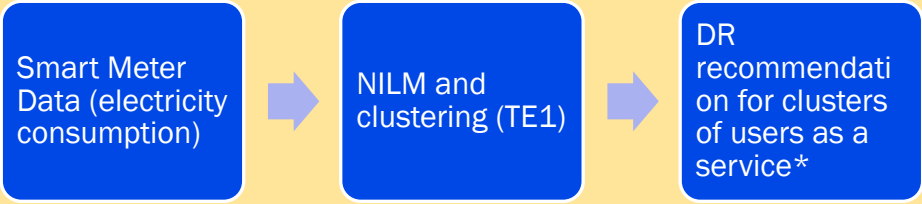
Architectural aspect	 * the service can be access via a REST API and integrated as input in other processes incl. mobile app notification or as part of a Digital Twin (TE-8).
Provided interfaces	HERON EnergiQ mobile application, HERON Energy Control smart monitoring / IoT platform available for the Greek pilot. Multiplier pilots will be provided with a REST API of the service so that they can inform their pilot participants based on their existing interfaces.
Dependencies /Required Interface	• Algorithm for clustering the consumers, • Algorithm for calculating disaggregated load profiles, • A tariff system based upon reward for DR participation will be calculated, • DR service as the solution of an optimisation model based on a given tariff system
Input data	• Smart meter data: energy, power, voltage • Smart plug data: power (in support and for the validation of NILM models)
Output data	• DR recommendation (on when to reduce consumption) for specific appliance
License	Proprietary
Technology Readiness Level (TRL)	TRL 7-8
Note	-

Table 16: TE-12: P2P digital platform

Asset name	P2P digital platform for trading pre-aggregated building flexibility
DEDALUS partner	OurPower
Functionality provided	Nation-wide marketplace for Renewable Energy System (RES) power with focus on citizen engagement



Architectural aspect	• P2P digital platform (incl. database) • Member dashboard • Administrative backend
Provided interfaces	-
Dependencies /Required Interface	• EDA connection for energy consumption and production data • Energy market service for energy market data
Input data	• Energy consumption data and forecasts • Energy production data and forecasts • Energy market data
Output data	• Energy matching data • Energy billing data
License	Proprietary
Technology Readiness Level(TRL)	TRL6
Note	-

Table 17: TE-13: District-level DR for self-consumption and cost optimisation

Asset name	District-level DR for self-consumption and cost optimisation
DEDALUS partner	CARTIF
Functionality provided	Optimal management of distributed flexible energy resources (generation, demand or storage) to maximize the self-consumption or minimize de operation cost at district level.
Architectural aspect	The service is composed by a Python library with a script containing the algorithm that solves the optimization and other supporting scripts for database access, configuration, data preparation or outputs showing among others. The library is programmed and deployed as a single module.
Provided interfaces	Outputs are provided in the database or can be inserted in any API based platform
Dependencies /Required Interface	• Prediction services (demand and generation) • Monitoring services
Input data	• Prediction of generated energy in the optimization horizon • Prediction of the demand in the optimization horizon

	- Prediction of energy cost in the optimization horizon - State of the energy devices Data model can be adapted to DEDALUS ontology developed in WP3
Output data	- Optimal operation profile for energy devices - Exchanged energy at district level Data model can be adapted to DEDALUS ontology developed in WP3
License	Proprietary
Technology Readiness Level(TRL)	TRL6
Note	-

Table 18: TE-14: Aggregation of flexible energy resources for district heating management

Asset name	Aggregation of flexible energy resources for district heating management
DEDALUS partner	NeoGrid
Functionality provided	Service/tool to monitor, administer and execute flexibility in district heating or electricity domain for single building or cluster of buildings. Control heat in apartment via smart thermostats together with central control with feedback from user/tenant as a basis for providing explicit flexibility from apartments and buildings.
Architectural aspect	Based on NeoGrid commercial platform including database. Modules developed will be Python modules that can be implemented into our Prefect cluster. Platform provides web gui for building administrator and tenants, external REST API for integrating with other external services. Within buildings a NeoGrid secure gateway are interfacing to the building systems and establishing a secure two way communication back to the cloud platform.
Provided interfaces	NeoGrid web app for tenants and building managers, In case of inputs from the Dedalus components (UC4), this can be achieved by REST based API's or at a later point in time the Dedalus interoperability layer. The same goes for the provided data outputs,
Dependencies /Required Interface	- Prediction services (demand and potential price or load forecasts) - Monitoring services - NeoGrid IoT gateway within buildings

Input data	• IoT sensor data from apartments and building (heating, electricity, temperature, CO2, humidity, radiator setpoints, radiator valve opening) • Indoor climate and flexibility requirements/preferences from tenants provided via web-app • Weather data • Price data (electricity or/and heat) • Load profiles of the grid or requirements for executing flexible load
Output data	• Control schedules for radiator valves, ventilation system and central heat and hot water production. • Forecasted heating, domestic hot water and flexibility
License	Proprietary
Technology Readiness Level(TRL)	TRL6
Note	Use cases will be implemented via NeoGrid commercial platform, however, interfaces to DEDALUS services (WP3 and WP4) will be investigated and developed. DEDALUS services can either be part of the value chain of TE-14 or an add on service providing new benefits for the user of the platform or the tenants.

2.3 Use cases

The main goal of this section is to perform an analysis of the pilots' and consumers' needs that will be formalised as use cases. Starting from the High-Level Use Case (HLUC) defined in D2.1, the main outcome of this analysis will be formalised in Use Case. In D2.1, 11 HLUCs were identified, divided into 5 domains: Data Management for efficient DR, Performance Assessment of DR strategies, Smart Controls for optimizing DR, DR Market, and User-Centered Interaction in support of DR.

In the following, a new Use Case (UC) naming convention is introduced. Whenever possible, the new UCs are mapped with the High-Level Use Case introduced in D2.1. The Table 19: Mapping HLUC and UC presents all 23 identified UCs along with their mapping to the HLUC divided into 6 domains, the 5 identified in the D2.1 plus the "Interoperability in the data space" domain. The UCs are described according to the template in the Table 20. By adopting the following Use Case Template, it enhances the clarity, consistency, and comprehensiveness of requirement specification, facilitating analysis and design, supporting testing and validation activities, and contributing to comprehensive system documentation and maintenance.

Table 20. Note that each UC represents specific functionalities of the DEDALUS system and may not be applicable to all demo sites.

Table 19: Mapping HLUC and UC

Domain	HLUC	UC
Data Management for efficient DR	HLCU1 - Clustering and market segmentation of consumers	UC1 - Questionnaire-based customer segmentation
		UC2 - Data-driven electrical load consumption clustering
		UC3 - Data-driven heating load consumption clustering
Performance Assessment of DR strategies	HLUC2 - Comfort-based flexibility model	UC4 - Comfort-Based Flexibility Model for Dynamic Adjustment in Buildings
	HLUC3 - Flexibility assessment for residential DR using AI library	UC5 - Flexibility prediction model
		UC6 - Device-level Flexibility prediction model
	HLUC4 - Digital Twins prediction of user energy profile and flexibility for consumer-aware optimal flexibility planning	UC7 - Digital Twins for building energy efficiency and flexibility evaluation
		UC8 - Digital Twins for 3D Building Representation and RT data monitoring
		UC9 - Digital Twins as simulation environment for the District Heating Network
		UC10 - Digital Twins for visualization of flexibility and clustering models
		UC11 - Digital Twin to provide assessment on the DR recommendations
		UC12 - Digital Twin of the market and simulation engine to integrate a virtual storage asset
	HLUC5 - Appliance specific Implicit and Explicit DR for residential users	UC13 - DR Recommendations and actions for residential users
Smart Controls for optimising DR	HLUC6 - DR-ready connected smart appliances control and interoperability	UC14 - Control of heat and ventilation in apartments via central control to save energy and to provide flexibility

Domain	HLUC	UC
	HLUC7 - DR for self-consumption and cost optimisation regarding the Gas pilot	UC15 - DR for self-consumption and cost optimisation regarding the Gas pilot
	HLUC8 - Reduction and shifting of heat consumption	UC16 - Reduction and shifting of heat consumption for building or cluster of buildings
		UC17 - Monitor and control of radiators in the apartments
	NA	UC18 - Smart control of flexibility assets in an energy community context
		UC19 - Smart control of a neighbourhood battery in an energy community context
DR Market	HLUC9 - P2P marketplace for pre-aggregated building flexibility	UC20 - P2P marketplace for trading pre-aggregated building flexibility
	HLUC10 - Building-level decentralized flexibility aggregation and tokenization for DR	UC21 - Blockchain solutions for DR management and flexibility aggregation
User Centered Interaction in support of DR	HLUC11 - Nudging for near real-time closed-loop residential consumers activation	UC22 - Nudging for near real-time closed-loop residential consumers activation
Interoperability in the data space	NA	UC23 - Data exchange

By adopting the following Use Case Template, it enhances the clarity, consistency, and comprehensiveness of requirement specification, facilitating analysis and design, supporting testing and validation activities, and contributing to comprehensive system documentation and maintenance.

Table 20: Use case template

USE CASE	
ID	<a sequential reference number>
Name	<short name of the use case>
Goal(s)	<the functionality or behaviour that is expected to be provided by the system once the use case is executed>
Actors	<the individuals and their means that trigger system reactions>
Trigger events	<the main action that starts the use case execution>
Preconditions	<those actions that must occur before the execution of the use case to obtain the described behaviour>

Basic Flow	Description	‘Basic Flow’ or ‘Main Scenario’ is the normal workflow in the system. It is the flow of transactions done by the Actors on accomplishing their goals. When the actors interact with the system, as it’s the normal workflow, there won’t be any error and the Actors will get the expected output.
	Postconditions	those conditions that could occur once the use case has been executed and the system continues its operations>
Alternative flow and exceptions		Major alternative flows or exceptions that may occur in the flow of event
ID of related use case in D2.1		

Table 21: UC1: Questionnaire-based customer segmentation

USE CASE		
ID		UC1
Name		Questionnaire-based customer segmentation.
Goal(s)		Identify user groups with distinct features that shall help pilots understand their consumer target groups better and thus form tailored outreach strategies.
Actors		End users.
Trigger events		In-person or online request to fill in the questionnaire.
Preconditions		Participants are in-scope energy consumers for each pilot.
Basic Flow	Description	Steps: • Collect questionnaire responses for each pilot. • Align responses groups and annotations for consistency purposes. • Visualize total pilot data with interactive dashboards in Microsoft Power BI. • Analyse the dashboard information together with the original datasets to explore segmentation prospects per pilot. • Produce dashboards dedicated to each segment by filtering total pilot dashboards accordingly. • Synthesize info drawn from dashboards to report the features, DR prospects and outreach strategies per pilot and per pilot segment.
	Postconditions	Interactive dashboards that enable delving into the questionnaire-based segmentation analysis, as well as exploring data further through custom filtering.
Alternative flow and exceptions		Data-driven segmentation also helps splitting consumers into segments, although on different axes and based solely on energy consumption monitored data.

ID of related use case in D2.1	HLUC1
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Table 22: UC2: Data-driven electrical load consumption clustering

USE CASE	
ID	UC2
Name	Data-driven customer clustering based on Electrical Loads.
Goal(s)	Identify user groups with distinct features in their electrical consumption patterns that shall help understand their consumer target groups better and thus form tailored DR strategies.
Actors	Facility manager, grid operators
Trigger events	Cluster Users to create more tailored DR programs
Preconditions	- The buildings under investigation are classified as residential. - Information about building or apartment features are provided. - Access to at least one zone of the building to get input data regarding the consumptions of apartments or buildings. - The building or apartment has historical electricity consumption data available.
Basic Flow	Description Step 0: Definition of the available data and create the necessary features for the Machine Learning algorithms. Step 1: Machine learning model development for clustering the consumers based on the features created in the last step, to have user groups with that correspond to the same DR program. Step 2: Similarity matrices to assess the performance of different clustering algorithms. Step 3: Classification algorithm that is trained based on the labels provided by the clustering algorithms. Step 4: AI provides insights into the factors that clustered the uses into the same group.
	Postconditions Witness the results of the DR programs on those clusters.
Alternative flow and exceptions	Questionnaire-based customer segmentation could help when data is unavailable.
ID of related use case in D2.1	HLUC1

Table 23: UC3: Data-driven heating load consumption clustering

USE CASE	
ID	UC3
Name	Data-driven customer clustering based on Heating Loads.
Goal(s)	Identify user groups with distinct features in their heating consumption patterns as well as different dimensions of the

		problem that shall help understand their consumer target groups better and thus form more tailored DR strategies.
Actors		Facility manager, heating operators
Trigger events		Cluster Users to create more tailored DR programs.
Preconditions		- The buildings under investigation are classified as residential. - Information about building or apartment features are provided. - Access to at least one zone of the building to get input data regarding the consumptions of apartments or buildings. - The building or apartment has historical heating consumption data available as well as smart sensor data concerning temperature and weather-related aspects.
Basic Flow	Description	Step 0: Definition of the available data and create the necessary features for the Machine Learning algorithms. Step 1: Machine learning model development for clustering the consumers based on the features created in the last step, to have user groups with that correspond to the same DR program. Step 2: Similarity matrices to assess the performance of different clustering algorithms and different dimensions of the problem. Step 3: Output correlating and optimal dimensions for the problem at hand.
	Postconditions	Witness the results of the DR programs on those clusters.
Alternative flow and exceptions		Questionnaire-based customer segmentation could provide assistance when data is not available.
ID of related use case in D2.1		HLUC1

Table 24: UC4: Comfort-Based Flexibility Model for Dynamic Adjustment in Buildings

USE CASE	
ID	UC4
Name	Comfort-Based Flexibility Model for Dynamic Adjustment in Buildings
Goal(s)	Supporting the building manager in optimizing energy usage while safeguarding occupants' comfort. This is achieved through the integration of indoor sensors, the application of machine learning techniques to customize the comfort-based flexibility model, and the dynamic adjustment of energy demand in residential settings.
Actors	Building manager.
Trigger events	- The building manager should guarantee thermal comfort, IAQ and adequate light levels to occupants. - The building manager wants reduction of energy consumption and costs.
Preconditions	Internet connection should be guaranteed in the building.

		• The building is provided of specific IoT sensors and devices measuring temperature, relative humidity, CO2 and light levels, and energy consumption metrics. • The building is provided with advanced hardware components like actuators and gateways for enabling control and communication functionalities within the system. • The building manager can access the Digital Twin dashboard.
Basic Flow	Description	1. The building manager accesses the recommendation section of the comfort-based flexibility model on the Digital Twin or the service dashboard. 2. The building manager sees the comfort status of the users in the building. 3. The building manager sees a list of recommendations to achieve an optimal compromise between comfort, energy and building performance.
	Postconditions	• The building manager can have a clear understanding of the building's potential flexibility. • The building manager can assess user comfort in each flat. • The building manager knows how to increase energy efficiency and reduce energy costs, without affecting users' comfort levels.
Alternative flow and exceptions		• Limited sensor availability: if the building lacks specific sensors for monitoring certain comfort parameters (e.g., IAQ, thermal comfort, visual comfort), the model will focus on the available parameters. • Automatic actuators not available: in this case the system encounters limitations in its ability to dynamically adjust settings for HVAC systems, control solar protection and shading devices, and automate windows. This absence of actuators may restrict the implementation of active and passive thermal comfort strategies. The system notifies the building manager by recommending alternative intervention strategies, such as manually adjusting the thermostat or opening windows. Below are the pilots engaged in UC4, with the services developed for each taking into account the available sensors: 1. Pilot 2 a. Service: provide energy consumption recommendations while prioritizing occupants' comfort. b. Sensors available: environmental sensors (temperature, relative humidity, CO2) and energy meters. 2. Pilot 3

	a. Service: offer thermal comfort values to enhance Demand Response (DR) strategies, linked with Task 4.3. b. Sensors available: environmental sensors (temperature, relative humidity, CO2 levels, and light levels) and energy meters 3. Pilot 4 a. Service: provide recommendations and alerts to the building manager concerning energy consumption while considering occupants' comfort. b. Sensors available: environmental sensors (temperature, relative humidity, CO2 levels, and light levels) and energy meters. No automatic actuators are available. 4. Pilot 5 a. Service: offer energy consumption recommendations with a focus on occupants' comfort. b. Sensors available: environmental sensors (temperature, relative humidity) and energy meters.
ID of related use case in D2.1	HLUC2

Table 25: UC5: Flexibility prediction model

USE CASE	
ID	UC5
Name	Flexibility prediction model
Goal(s)	The goal is to create a flexibility prediction model for Demand Response (DR) services, optimizing energy efficiency in buildings. This involves integrating energy consumption and production data into a cloud-based platform, applying machine learning models to predict the baseline consumption and the maximum and minimum flexibility for a weekday analysis. Additionally, it involves calculation of specific Energy Flexibility Indicators (EFIs) to quantify the potential flexibility across hours and different time intervals, ultimately enabling understanding the flexibility dynamic of each apartment or building.
Actors	Facility manager, sustainability stakeholders, end users
Trigger events	1)The facility manager wants reduction of energy consumption. 2)The facility manager wants reduction of energy costs.
Preconditions	• The buildings under investigation are classified as residential. • Information about building features is provided.

		- Access to at least one zone of the building to get input data regarding the consumptions of apartments, buildings, or PV production if available. - The building is provided of specific IoT sensors (smart meters).
Basic Flow	Description	Step 0: Definition of user requirements and technical requirements Step 1: Machine learning model development for predicting the flexibility of the energy consumption and production if available of the apartment or building. Step 2: Flexibility prediction model collects energy consumption and production time-series from local business platforms. Step 3: Calculation of EFIs across hours and specific time intervals. Step 4: Delivery of the results to a stand-alone platform or the Digital Twin platform.
	Postconditions	Monitoring of the performance of the model to ensure accuracy and effectiveness.
Alternative flow and exceptions		Depending on the data availability we may alter our approach by looking into similar datasets containing sufficient historical data provided by the respective building manager.
ID of related use case in D2.1		HLUC3

Table 26: UC6: Device-level Flexibility prediction model

USE CASE	
ID	UC6
Name	Device-level Flexibility prediction model
Goal(s)	The goal is to develop a device-level energy flexibility prediction model to optimize energy efficiency and demand response services. This involves integrating consumption time-series data from the main meters into a cloud-based platform, disaggregating these time-series data from the main meter into individual device time-series and applying machine learning models to predict the flexibility of each device's energy consumption, including the baseline consumption and the maximum and minimum flexibility. Additionally, it involves calculation of specific Energy Flexibility Indicators (EFIs) to quantify the potential flexibility across hours and different time intervals, ultimately enabling understanding the flexibility dynamic of each device.
Actors	Facility manager, sustainability stakeholders, end users
Trigger events	1)The end user wants reduction of energy consumption at the device level. 2)The end user wants reduction of energy costs.

Preconditions		- The buildings under investigation are classified as residential. - The building is equipped with smart meters or similar IoT sensors capable of capturing detailed energy consumption data. - Information about building features or devices are provided.
Basic Flow	Description	Step 0: Definition of user requirements and technical requirements Step 1: Develop machine learning models tailored to disaggregate energy consumption time-series data from the main meter into individual device time-series. Step 2: Energy disaggregation model collects main meter energy consumption time-series from local business platforms. Step 3: Implement the device-level energy flexibility prediction model to forecast the flexibility of each device's energy consumption. Step 3: Calculate specific Energy Flexibility Indicators (EFIs) for each device, quantifying their potential flexibility across various time intervals. Step 4: Delivery of the results to a stand-alone platform or the Digital Twin platform.
	Postconditions	Monitoring of the performance of the model to ensure accuracy and effectiveness.
Alternative flow and exceptions		Depending on the data availability we may alter our approach by looking into similar datasets containing sufficient historical data provided by the respective building manager.
ID of related use case in D2.1		HLUC3

Table 27: UC7: Digital Twins for building energy efficiency and flexibility evaluation

USE CASE	
ID	UC7
Name	Digital Twins for building energy efficiency and flexibility evaluation.
Goal(s)	Support the building manager (BM) in the evaluation of the overall building energy efficiency, to estimate the flexibility potential, without affecting the user's comfort.
Actors	Building (Energy) Manager
Trigger events	- Building manager want to check the energy efficiency of the building. - Building manager is interested to enter in the flexibility market and needs to know the flexibility potential of the building.

Preconditions		- Sensors for measuring building and apartment consumptions. - Monitoring of energy costs related to thermal comfort, indoor air quality, and maintenance. - Monitoring of comfort in indoor spaces.
Basic Flow	Description	1. The building manager access the Digital Twin 2. The BM sees RT data of the buildings (consumptions measured for each apartment), and consumption forecasting. 3. The BM access the recommendation system. 4. The BM sees the RT users' comfort status in the building. 5. The BM sees a list of recommendations aimed at obtaining an optimal trade-off among comfort, energy and building performance
	Postconditions	1. The BM can have a clear understanding on the potential flexibility of the building. 2. The BM can perform an assessment of the users' comfort in each apartment. 3. The BM knows how to increase the energy efficiency while reducing energy costs, without affecting the users' comfort levels.
Alternative flow and exceptions		n/a
ID of related use case in D2.1		HLUC4 – Italian Pilot

Table 28: UC8: Digital Twins for 3D Building Representation and RT data monitoring

USE CASE		
ID		UC8
Name		Digital Twins for 3D Building Representation and RT data monitoring
Goal(s)		Provide a 3D visualization of the building, with the possibility to monitor RT data.
Actors		Building Manager (BM)
Trigger events		- Building Manager wants to see RT data nested in the 3D visualization
Preconditions		- Building .ifc file available - RT Data available
Basic Flow	Description	1. The Building Manager access the Digital Twin 2. The BM sees the 3D representation of the building. 3. The BM browses the 3D model and clicks on a device. 4. The BM sees the RT data (temperature, energy consumption) provided by the device.
	Postconditions	1. The BM can have a clear representation of RT data in the building

		2. The BM can have an easy overview of performance based on overlays
Alternative flow and exceptions		If the monitored energy consumption or the temperature is highest than a predefined value, this information is shown to the BM through the 3D visualization of the building
ID of related use case in D2.1		HLUC4 – Danish Pilot

Table 29: UC9: Digital Twins as simulation environment for the District Heating Network

USE CASE		
ID	UC9	
Name	Digital Twins as simulation environment for the District Heating Network (DHN)	
Goal(s)	Provide a simulation environment to allow the evaluation of the efficient operation of DHN, in order to minimize the supply/return temperature, without affecting user comfort.	
Actors	Facility Manager (FM)	
Trigger events	- The FM needs to understand the impact of supply/return temperature changes (e.g. lower the temperature below a defined threshold) in the managed district, and subsequently on the residents of the apartments. - The FM need to understand the operational limits of the DHN (e.g. excessive low/high supply temperature).	
Preconditions	- Building Management System Historical Data (e.g. indoor temperature data, supply/return temperature data). - The BM has the possibility to monitor comfort in indoor spaces.	
Basic Flow	Description	1. The FM access the DT. 2. The FM selects the Simulation Environment. 3. The FM launch a simulation. 4. The FM sees the possible optimization strategies.
	Postconditions	1. The FM evaluates the results of the simulation. 2. According to the results of the simulation, the FM can set the optimized supply/return temperature.
Alternative flow and exceptions	n/a	
ID of related use case in D2.1	HLUC4 – Danish Pilot	

Table 30: UC10: Digital Twins for visualization of flexibility and clustering models

USE CASE		
ID	UC10	
Name	Digital Twins for visualization of flexibility and clustering models	
Goal(s)	Integrate the flexibility models and the clustering models in the DT	

Actors		Facility Manager, Network Operator
Trigger events		The FM needs to have a clear understanding of more tailored DR programs.
Preconditions		- Outcome of TE-1 and TE-4 available
Basic Flow	Description	1. The FM access the DT. 2. A clustering and segmentation of consumers/prosumers takes place, specifically tailored for DR programs. 3. The flexibility assessment and prediction take place for each different cluster proposed in the previous step. 4. The flexibility is showcased in the DT for each different cluster, providing visual insights.
	Postconditions	1. The FM can assess the flexibility proposed for each t cluster of consumers.
Alternative flow and exceptions		n/a
ID of related use case in D2.1		HLUC4 - Danish Pilot

Table 31: UC11: Digital Twins to provide assessment on the DR recommendations

USE CASE		
ID		UC11
Name		Digital Twins to provide assessment on the DR recommendations
Goal(s)		Evaluate the efficiency and application of the DR recommendations in the grid and basing on their follow-up rate, calculate flexibility potential for consumers
Actors		Aggregator (AGG)
Trigger events		The Grid Operator (GO) wants to know the rate of application of DR recommendations that have been suggested to the consumer
Preconditions		Availability of flexibility recommendation (developed in the context of Task4.3) Availability of needed data to understand if the recommendations have been followed.
Basic Flow	Description	1. The AGG access the DT 2. The AGG access the dashboard showing how much the DR recommendation have been followed by the consumer 3. KPIs related of consumer flexibility potential are computed and compared to the benefit of applied recommendations
	Postconditions	The AGG has clear understanding of consumer profiles according to the real application of flexibility recommendation The AGG knows the benefit of DR recommendations on the grid based on their real application The GO knows the potential energy capacity provided by the followed flexibility recommendation

Alternative flow and exceptions	n/a
ID of related use case in D2.1	HLUC4 – Greek Pilot

Table 32: UC12: Digital Twins of the market and simulation engine to integrate a virtual storage asset

USE CASE	
ID	UC12
Name	Digital Twins of the market and simulation engine to integrate a virtual storage asset
Goal(s)	Exploit a Digital Model of an electricity Storage System to evaluate the impact on the grid of two possible configurations: a. behind the meter in support of EN.A's 500 kW PV, and b. a stand-alone asset providing shared storage using the residual part of a primarily merchant storage asset
Actors	Aggregator (AGG), DER Owner (DERo)
Trigger events	The DERo wants to simulate the presence of a storage system in the market to understand the possible impact on decarbonising the AGG's portfolio and to evaluate the potential financial gain from different storage usage
Preconditions	- Availability of storage system specification - Availability of smart meter data - Availability of market (day-ahead) and system (TSO) data
Basic Flow	Description
	1. The AGG and DERo access the DT 2. The AGG and DERo select the simulation page 3. The AGG and DERo run a simulation based on the selected storage configuration 4. The AGG and DERo see the results of the simulation
	Postconditions
	1. The DERo can understand the potential financial gain by optimising the use of storage under the two configurations given the available flexibility in order to decarbonise the AGG's portfolio. 2. The AGG can understand the potential impact of the presence of a storage system in its effort to decarbonise its portfolio.
Alternative flow and exceptions	n/a
ID of related use case in D2.1	HLUC4 – Greek Pilot

Table 33: UC13: DR Recommendations and actions for residential users

USE CASE	
ID	UC13
Name	DR recommendations and actions for residential users

Goal(s)		Provide DR actions as a stand-alone service to be integrated in third-party applications and systems. DR actions may refer to Implicit DR recommendations or explicit DR actions given remote control capabilities.
Actors		Aggregator, End-user
Trigger events		A tariff system for Implicit DR, Events set by the aggregator for Explicit DR.
Preconditions		Smart Metering equipment and smart appliances. For Explicit DR agreement with the pilot's end-users to allow remote handling of selected appliances.
Basic Flow	Description	1. Disaggregate customers' electricity consumption (only applicable for the electricity vector), 2. Forecast at 24h horizon customers' consumption and derive flexibility potential, 3. Identify DR trigger a. For Implicit DR determine a market or a sustainability tariff 24hrs ahead, b. For Explicit DR monitor for possible events (imbalance spikes), 4. Activate DR service a. Activate Implicit DR based on TSO/ Market data, b. Activate Explicit DR if event is triggered. 5. Quantify environmental impact of any possible DR action, 6. Determine whether DR actions has been followed (given baseline calculations), 7. Quantify environmental impact for followed DR actions.
	Postconditions	Validate whether DR recommendations (Implicit DR) or DR actions (Explicit DR) are actually followed by the customers.
Alternative flow and exceptions		n/a
ID of related use case in D2.1		HLUC5

Table 34: UC14: Control of heat and ventilation in apartments via central control to save energy and to provide flexibility

USE CASE	
ID	UC14
Name	Control of heat and ventilation in apartments via central control to save energy and to provide flexibility
Goal(s)	Enabling the Building Manager (BM) to have an intelligent control of heat, domestic hot water and ventilation with feedback from user/tenant, temperature sensors and smart radiator thermostats in the apartment, that optimizes the temperature schedules to

		minimize the energy and cost of energy for the building and apartments.
Actors		BM
Trigger events		Starting the energy controller where after the system runs continually and when flexibility should be provided
Preconditions		Smart energy management system will be connected to heating installations within the building (central district heating unit, the ventilation system and radiator thermostats in the apartments. Flexibility and/or DR models have been established (T3.3)
Basic Flow	Description	1. Data from central district heating unit are logged into the NeoGrid Platform (Energy consumption (heat, dhw), primary and secondary flow and return pipe temperatures, valve openings) 2. Data from apartments are logged into the NeoGrid Platform (Temperature, RH, CO2, setpoint from radiator thermostat, valve opening, temperature, ventilation system flow, temperature) 3. Electricity Price data from TSO 4. Heating price data from District heating company (price pr. kWh, fees if return temperature send back to grid is too high) 5. Local weather forecast Data (outdoor temperature, wind, sun radiation on building) from weather service via API 6. Using ML algorithms to train thermodynamical model of the building and apartment energy use under different external conditions 7. Using ML algorithms to forecast heating and ventilation requirement based on tenant comfort, flexibility settings, outdoor weather 8. Optimize heating and ventilation schedule to minimize energy cost while maintaining the required indoor climate (flexibility settings) indicated by the tenants and enabled by the BM 9. Automatically actuating the schedule without involving the tenant 10. Use ML algorithms to estimate and forecast flexibility in electricity and heat consumption – that will be different temperature schedules and energy consumption schedules providing different outcome spaces which provide the required comfort settings. 11. Calculate discomfort price as the difference between the optimized schedule and proposed flexibility schedule (we know the prices for either heat or electricity) 12. Visualize flexibility for each apartment via NeoGrid smart energy system GUI e.g. forecasted temperature schedules

		with min/max constrains – can be accessed by the tenant via the app 13. Visualize flexibility for building as a whole via NeoGrid smart energy system for GUI BM – baseline load (energy) time series, min/max constraints on energy, energy stored in the thermal mass of the building compared to a max. Level 14. Activate flexibility on demand from building and apartments. This is done automatically based on pre-sets of the building provided by the BM and Service provider (NeoGrid). At this stage neither the BM nor the Tenant have to do something. 15. Quantify realized energy savings or provided flexibility via the GUI's of the Smart energy platform. This is mainly shown to the BM, we need to investigate how this can be relevant to show to the tenant.
	Postconditions	BM can after an event via the smart energy system see the provided flexibility and for the general energy optimization that runs continually, the BM can see the energy savings provided compared to a baseline.
Alternative flow and exceptions		Follow the same procedure without applying the DR to the pilot users, just estimate the potentially flexibility and still optimize and control according to minimize energy cost and consumption of energy
ID of related use case in D2.1		HLUC6

Table 35: UC15: DR for self-consumption and cost optimisation regarding the Gas pilot

USE CASE		
ID		UC15
Name		DR for self-consumption and cost optimisation regarding the Gas pilot
Goal(s)		Enable optimal DR for gas pilot users
Actors		pilot users, DR enablers
Trigger events		Request from flexibility operator to activate DR
Preconditions		Agreement with the pilot's end-users to automatically update their heating configurations to attain optimal DR. Flexibility and DR data models/ontologies from T3.3.
Basic Flow	Description	The goal of this UC is to enable optimal DR for the gas pilot end-users. To do so we will follow the following steps which are mainly part of the T4.3. Steps: Analyse pilot's end-users' characteristics

		- Calculate the energy consumption of each home under different heating balance settings employing the DOM-X dynamic load simulator - Identify households with high potential energy savings - Activate DR in the selected households - Quantify the achieved energy-savings
	Postconditions	Ability to share the achieved energy-savings
Alternative flow and exceptions		Follow the same procedure without applying the DR to the pilot users, just estimate the potentially achieved energy-savings for each household
ID of related use case in D2.1		HLUC7

Table 36: UC16: Reduction and shifting of heat consumption for building or cluster of buildings

USE CASE		
ID	UC16	
Name	Reduction and shifting of heat consumption for building or cluster of buildings	
Goal(s)	Tool to monitor, administer and execute in district heating domain for single building or cluster of buildings with focus on reduce and shifting the heat consumption (heating and domestic hot water production), to reduce the overall peak load of the building or a cluster of buildings. The tool should aim to provide services to district heating grid like: - Peak reduction - Reduce return temperature, maximizing cooling - Optimize heat consumption with respect to constrains from district heating grid/company - Optimize according to prices	
Actors	Building manager (BM) and Platform Operator (PO)	
Trigger events	BM or PO to enable the services	
Preconditions	Flexibility and DR data models/ontologies have been established (T3.3)	
Basic Flow	Description	- Data from central district heating unit are logged into the NeoGrid Platform (Energy consumption (heat, dhw), primary and secondary flow and return pipe temperatures, valve openings) - Data from apartments are logged into the NeoGrid Platform (Temperature, RH, CO2, setpoint from radiator thermostat, valve opening, temperature, ventilation system flow, temperature) - Heating price data from District heating company (price pr. kWh, fees if return temperature send back to grid is too high)

		4. Local weather forecast Data (outdoor temperature, wind, sun radiation on building) from weather service via API 5. Using ML algorithms to train thermodynamical model of the building and apartment energy use under different external conditions 6. Use ML algorithms to estimate and forecast heat consumption and flexibility for a single and cluster of buildings – that will be different temperature schedules and energy consumption schedules providing different outcome spaces which provide the required comfort settings and constrains for the district heating grid. 7. Visualize flexibility for building as a whole or cluster of buildings via NeoGrid smart energy system for GUI BM – baseline load (energy) time series, min/max constraints on energy, energy stored in the thermal mass of the building compared to a max. level 8. Execute schedule automatically via Smart energy platform providing specified services 9. Quantify realized energy savings or provided flexibility via the GUI's of the Smart energy platform. This is mainly shown to the BM
	Postconditions	Actuating heating schedules for district heating (heating and hot water) minimizing the overall peak load of more than one building, and providing the specified services for district heating grid/company.
Alternative flow and exceptions		Run without actuating the schedules, using fall back set points
ID of related use case in D2.1		HLCU8

Table 37: UC17: Monitor and control of radiators in the apartments

USE CASE	
ID	UC17
Name	Monitor and control of radiators in the apartments
Goal(s)	Provide possibility to use Smart Radiator Thermostats in the overall intelligent control of heating in the building focusing on: • Using temperature and valve feedback to central building controller • Individual pr. apartment heating and flexibility preferences for heating flexibility • Provide ability for tenant to provide heating set point preferences back to central building controller (EMS) • The BM has the possibility to monitor comfort, set points in indoor spaces and to see which apartment who are

		demanding more heat than currently is supplied to the apartments.
Actors		Tenant, Building manager (BM) and Controller
Trigger events		• Tenant via the app indicate flexibility preferences • Tenant via the app indicate temperature setpoints • Tenant via adjusting the Thermostat directly • BM to change system settings
Preconditions		• Building Management System Historical Data (e.g. indoor temperature data, supply/return temperature data). • Thermostat data (e.g. temperature set point, valve setting,...)
Basic Flow	Description	Tenant direct: 1. Change setpoint directly on a radiator thermostat Tenant via app: 1. Open the application on a mobile device or PC 2. Navigate to zone and change set-point 3. OR Navigate to flexibility preferences tab and change slider in steps between economic and indoor climate BM: 1. Access the NeoGrid EMS system 2. Sees an overview of the building showing temperature, set-points and valve opening 3. Sees information of building and apartment flexibility
	Postconditions	• Tenant have changed the set-point or the flexibility preferences • BM can have a overview of how district heating flow is distributed around in the building • BM can have an overview of which apartments participates in flexibility events • BM can have an overview of forecasted heating schedules for building and apartments
Alternative flow and exceptions		n/a
ID of related use case in D2.1		HLUC4, HLUC6 and HLCU8

Table 38: UC18: Smart control of flexibility assets in an energy community context

USE CASE	
ID	UC18
Name	Smart control of flexibility assets in an energy community context
Goal(s)	To maximize the community self-consumption using the flexibility capacity of the installed assets To provide flexibility by shifting the demand and generation profiles of the building-as-community.

		The flexibility assets considered in the optimization will be the district battery and the EV chargers.
Actors		Energy cooperative, Energy Solution
Trigger events		There are two possible trigger options: a. Daily execution b. Flexibility event
Preconditions		Next data must be calculated and available through API endpoint: 1. Demand prediction of the energy community in the desired time horizon 2. Generation prediction of the PV panels in the desired time horizon 3. State of the battery (SOC) at the initial time 4. Price electricity in the desired time horizon
Basic Flow	Description	1. Read the data required for the optimization from the demo data repository: • Demand prediction • Generation prediction • Battery SOC • Price electricity • Flexibility event requirements 2. Execute the optimization problem: 2.1. Build the initial conditions constraints 2.2. Build the constraints equations according to the prediction data and flexibility event 2.3. Build the objective equation according the electricity prices and flexibility event 2.4. Build the optimization problem 2.5. Execute the optimization algorithm 3. Write the recommended profile for flexibility assets in the demo data repository
	Postconditions	The recommended profile is sent to the EMS The EMS applies the required setpoints
Alternative flow and exceptions		If any of the required data is not available, the algorithm will not be executed and the battery will operate according to the local control (charging the energy surplus and discharging when demand is higher than generation) If the optimization algorithm does not converge to an optimal solution the battery will operate according to the local control (charging the energy surplus and discharging when demand is higher than generation)
ID of related use case in D2.1		-

Table 39: UC19: Smart control of a neighbourhood battery in an energy community context

USE CASE	
ID	UC19
Name	Smart control of a neighbourhood battery in an energy community context
Goal(s)	To minimize the bill of the community members through an optimized use of the PV production and battery storage capabilities. To provide flexibility services to the DSO if needed by shifting the demand and generation profiles of the community as a whole.
Actors	DSO, aggregator (if existing), Energy Management System
Trigger events	There are two possible trigger options: a. Daily execution b. Grid service event
Preconditions	Next data must be calculated and available through API endpoint: 1. Demand prediction of the energy community in the desired time horizon 2. Generation prediction of the PV panel in the desired time horizon 3. State of the battery (SOC) at the initial time 4. Price electricity in the desired time horizon
Basic Flow	Description 1. Read the data required for the optimization from the demo data repository: • Demand prediction • Generation prediction • Battery SOC • Price electricity • Grid service event requirements 2. Execute the optimization problem: 2.1. Build the initial conditions constraints 2.2. Build the constraints equations according to the prediction data and grid service event 2.3. Build the objective equation according the electricity prices and flexibility event 2.4. Build the optimization problem 2.5. Execute the optimization algorithm 3. Write the recommended battery operation profile in the demo data repository
	Postconditions The recommended profile is sent to the battery The local control battery applies the required setpoints
Alternative exceptions	flow and If any of the required data is not available, the algorithm will not be executed and the battery will operate according to the local control (charging the energy surplus and discharging when demand is higher than generation)

	If the optimization algorithm do not converge to an optimal solution the battery will operate according to the local control (charging the energy surplus and discharging when demand is higher than generation)
ID of related use case in D2.1	-

Table 40: UC20: P2P marketplace for trading pre-aggregated building flexibility

USE CASE		
ID		UC20
Name		P2P marketplace for trading pre-aggregated building flexibility
Goal(s)		Successfully traded flexibilities
Actors		Building operator (as pre-aggregator), Market operator
Trigger events		Request flexibility activation
Preconditions		The P2P marketplace is operational with capabilities for participant registration, profile management and analysis, flexibility activation and account settlement. Flexibility and DR data models/ontologies that have been established will be used.
Basic Flow	Description	Steps • Register participants and create detailed profiles • Aggregate and list available flexibility on the marketplace • Analyse flexibility demand • Manage bid submissions • Evaluate and select bids • Notify activation requests • Obtain activation confirmations • Optimize schedules and activate • Monitor and adjust • Settle accounts
	Postconditions	Activation requests are notified, and confirmations obtained, schedules optimized and activated, ongoing operations monitored and adjusted, and finally, accounts are settled.
Alternative flow and exceptions		-
ID of related use case in D2.1		HLUC9

Table 41: UC21: Blockchain solutions for DR management and flexibility aggregation

USE CASE	
ID	UC21
Name	Blockchain solutions for DR management and flexibility aggregation

Goal(s)		Validate on top of the available pilot infrastructure/data a blockchain framework for DR program management: • The use of blockchain energy ledger to immutability store and share the energy transactions based on the data provided by BEMS from buildings. • The automated definition of DR programs using smart contracts and signals agreed via P2P flexibility trading. • Aggregation of flexibility in decentralized fashion via the P2P flexibility trading to meet the DR constraints. • The DR program energy and (non) financial settlement via lockable and non-fungible tokens
Actors		Building owners, apartment residents
Trigger events		In case of a DR event the building operator will communicate the request for flexibility to apartment renters via blockchain P2P flexibility trading to decrease their demand for an interval
Preconditions		Energy data can be gathered through energy assets provided interfaces. The distributed energy ledger is operational and can store the buildings energy data in tamper proof manager. The prediction tool is operational and integrated with the existing data sources
Basic Flow	Description	‘Basic Flow’ or ‘Main Scenario’ - Building owners enrol in the platform and as well as the apartments residents. - Data is collected from energy meters and integrated in the data model. Through self-enforcing smart contracts blockchain energy transactions are generated. - The prediction component utilizes monitored data to forecast energy demand and flexibility for day-ahead. - In case of a DR event the building owners will publish a request for energy flexibility for the next day on the P2P flexibility trading component. - The apartments residents will answer with flexibility offers generated considering the predicted flexibility. - A matching mechanism will aggregate the needed level of flexibility and will generate the flexibility transactions. - The building DT simulates the potential DR actions that can be taken within the apartments and calculates the expected impact of these actions on energy usage levels. - Smart contracts enable the injection of DR signals based on the agreed flexibility transactions. - DR settlement component triggers the appropriate (non) financial remuneration for flexibility providers. - Smart contracts verify and compare the DT output levels with monitoring data and commitments to trigger the remuneration.

		- Tokens are being distributed to buildings apartments based on their actual contribution to the total aggregated flexibility.
	Postconditions	Buildings can aggregate and trade their flexibility in DR programs and can receive (non) financial incentives in a secure manner.
Alternative flow and exceptions		• If not, enough flexibility is aggregated educate students about the benefits and mechanisms of the use case to encourage broader adoption and cooperation. • In case of energy data is not available in the distributed ledger the DR event is cancelled • The prediction component can be supplemented by a building DT to provide estimates of energy demand on individual apartment.
ID of related use case in D2.1		HLUC10

Table 42: UC22: Nudging for near real-time closed-loop residential consumers activation

USE CASE		
ID	UC22	
Name	Nudging for near real-time closed-loop residential consumers activation	
Goal(s)	Executed nudging interventions	
Actors	building managers, dwellers (occupants), grid operators and citizens/communities	
Trigger events	Request from flexibility operator to activate DR	
Preconditions	The user interfaces depend on other HLUCs so data can be presented to the user when using the application. So, the following steps are necessary to implement the different features within the application: • Identify each actor (building managers, occupants, grid operators and citizens/communities) requirements. • Receive the data that will be collected, processed, and stored by the application and • Identify the different functionalities needed for each of the profiles that will be created on the application • Involve the actors in the development of the application interfaces	
Basic Flow	Description	Steps: • Collect and analyse the details for each pilot site (existence of nudging App, details about users/buildings, baseline consumption, flexibility ability, etc.) • Use input by the segmentation questionnaires as well as by the facility manager questionnaires • Realize the co-creation workshops for every pilot site

		- Collect feedback from the co-creation workshops - Design nudging interventions based on the above steps - Deploy nudging services
	Postconditions	Dashboards to present relevant data such as energy profile, local weather data, building energy, energy flows and energy consumption.
Alternative flow and exceptions		-
ID of related use case in D2.1		HLUC11

Table 43: UC23: Data exchange

USE CASE		
ID	UC23	
Name	Data exchange	
Goal(s)	- Enable the data exchange - Allow the discovery of data sources and services - Definition of common vocabularies for improving interoperability - Manage data exchange in a secure and trusted way	
Actors	- Data Provider - Data Consumer - Broker Service Provider - Clearing House	
Trigger events	On demand/Periodically	
Preconditions	Data Provider and Data Consumer have received their identity (identity token) by the Identity Provider and have registered their connectors to the Broker Service Provider. These processes are done through the following steps: Steps: I) The identification of a participant is made by requesting to the Identity Provider an identity token using a certificate. The Identity provider return an Identity Token that can be used for requesting an Access Token. The Access Token is used for any data access request. II) The participant (through the connector) makes a request to the Broker Service Provider to register its details. III) The Broker Service Provider validates the associated data and adds them to the Broker registry.	
Basic Flow	Description	Steps: ON DEMAND 1. The Data Provider publishes metadata about data it can provide to the Broker Service Provider.

		2. The Data Consumer queries to the Broker Service Provider for data sources or searches for a specific dataset. 3. The Broker Serviced Provider returns information about data sources. 4. The Data Consumer is able to pull data directly from the Data Provider. 5. The data exchange is logged into Clearing House.
	Postconditions	The data consumer has got the data needed for consuming/using.
Alternative flow and exceptions		PERIODICALLY 4.a The Data Consumer subscribes for specific dataset to Broker Service Provider and this information is shared with the Data Provider. 5.a The Data Provider create a listener for the specific dataset. 6.a Each time the Data Provider publishes data, it transfers them to the Data Consumer. 7.a Data exchanges are logged into Clearing House.
ID of related use case in D2.1		-

2.4 Consolidated functional requirements

Starting from requirements defined in D2.1, and according to use cases defined in the previous section, this section aims to provide the consolidated version of functional requirements that will be defined according to the following template in Table 44. Functional requirements outline the functions or features essential for the DEDALUS framework to satisfy the requirements of its users. These requirements are derived from users through comprehensive gathering of information regarding desired functionalities and features. Use cases offer concrete insights into how users will engage with the system to reach specific objectives.

Table 44: Functional requirements

Functional Requirement ID	Description	Related Use case	DEDALUS Technology Enabler	Note
TE1-FR1	(Interactive) Dashboard with questionnaire-based segmentation for building operators.	UC1	TE1	Interactive dashboards will be provided if the appropriate

Functional Requirement ID	Description	Related Use case	DEDALUS Technology Enabler	Note
				licencing can be acquired.
TE1-FR2	The dashboard will be published and shared using PowerBI or similar tool.	UC1	TE1	
TE1-FR3	Report/Infographic with the results of the data-driven clustering approach for building operators (electricity consumption data)	UC2	TE1	Sufficient historical data are required
TE1-FR4	Report/Infographic with the results of the data-driven clustering approach for building operators (heating consumption data)	UC3	TE-1	
TE3-FR1	The system must be able to manage and certificate the identity of each Data Space participant	UC23	TE-3	
TE3-FR2	The system must be able to register/unregister a connector	UC23	TE-3	
TE3-FR3	Each participant must be uniquely identified using certification	UC23	TE-3	
TE3-FR4	Each connector have a unique certificate and identifier	UC23	TE-3	
TE3-FR5	The connector must be able to send metadata of a data source to the Brokers	UC23	TE-3	
TE3-FR6	The Connector must be able to search for metadata connecting to a Broker	UC23	TE-3	

Functional Requirement ID	Description	Related Use case	DEDALUS Technology Enabler	Note
TE3-FR7	The Connector must be able to exchange data with other connectors using pull and/or push mechanisms	UC23	TE-3	
TE3-FR8	The system should be able to log any data transaction between any participant to the Data Space	UC23	TE-3	
TE3-FR9	The system should be able to perform a semantic validation of the data processed	UC23	TE-3	
TE4-FR1	The system should integrate real-time or near real-time data on electricity consumption and PV production	UC5	TE-4	PV production data is available on a subset of Pilots
TE4-FR2	The systems should be a web-based application which offers the day-ahead flexibility prediction.	UC5	TE-4	Deployed on NTUA servers
TE4-FR3	The system must provide users with the ability to adjust the forecast horizon for the flexibility assessment.	UC5	TE-4	Different forecast horizons may include 12h, 24h, 48h, and 72h ahead.
TE4-FR4	The system should allow users to select pilot assets to determine the level of flexibility provision for buildings, apartments, or devices.	UC5	TE-4	

Functional Requirement ID	Description	Related Use case	DEDALUS Technology Enabler	Note
TE4-FR5	The system should allow users to upload their data using a CSV file format. A sample CSV will be provided as reference, guiding users on the required format and structure of the data. For users with existing business platforms supporting API calls, direct integration will be available.	UC5	TE-4	Data Sharing
TE4-FR6	Access to the system will require login authentication.	UC5	TE-4	Different credentials for each pilot.
TE5-FR1	Building owners shall be able to place bids for energy flexibility on blockchain trading platform	UC21	TE5	
TE5-FR2	Residents shall be able to place offers for energy flexibility on blockchain trading platform	UC21	TE5	
TE5-FR3	The flexibility trading component shall aggregate flexibility offers to match the flexibility bid	UC21	TE5	
TE5-FR4	Flexibility transactions shall be generated and stored on the blockchain	UC21	TE5	
TE5-FR5	Flexibility transactions shall be settled using energy monitored data	UC21	TE5	
TE5-FR6	Tokens shall be distributed to users' wallets based on actual values of flexibility delivered	UC21	TE5	

Functional Requirement ID	Description	Related Use case	DEDALUS Technology Enabler	Note
TE8-FR1	Digital twin with an interface that will visualise the different cluster of consumers and the flexibility assessment for each cluster	UC9	TE-1, TE-4, TE-8	
TE8-FR2	Digital twin will deliver analytics (environmental/energy) to the energy manager.	UC9	TE-8	
TE8-FR3	Digital Twin will provide recommendations/alerts (not direct control) to the energy manager based on energy consumption, while considering their comfort preferences.	UC10	TE-8	
TE8-FR4	Digital Twins will enhance the district visualization by providing a 3D visualization basing on IFC Files, enabling direct connection with monitoring real time data of different assets.	UC7	TE-8	
TE8-FR5	Digital Twin will provide a simulation environment in order to optimize the management of district heating networks and enable the possibility to develop and integrate Digital Models of assets	UC11, UC8	TE-8	
TE8-FR6	Digital twin of thermal dynamics must enable controller to follow user comfort preferences while minimising heating cost and emissions	UC16	TE-8	
TE9-FR1	The system will deliver personalized energy-saving recommendations to users while prioritizing their comfort preferences.	UC10	TE-9	

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Functional Requirement ID	Description	Related Use case	DEDALUS Technology Enabler	Note
TE11-FR1	Implementing an environmental-based dynamic hourly tariff to incentivize demand shifted when renewable energy surplus periods appears	UC11	TE-11	
TE14-FR1	The system will have direct control over the equipment.	UC16	TE-14	

3. DEDALUS Framework High-Level Architecture Specification

The aim of this section is to specify the DEDALUS framework with regards to the high-level architecture. Each architectural layer will be described and the mapping with the related DEDALUS TE and data driven services will be provided as well.

3.1 Methodology

The DEDALUS architecture is derived from the interconnection of the available TE. The construction of the DEDALUS architecture follows a structured methodology outlined as follows:

- Analysis of the use cases.
- Analysis of Functional and Non-functional Requirements.
- Identifying each component essential for the architecture.
- Arranging the components into the architecture.
- Identification of the data/message flows among the components.

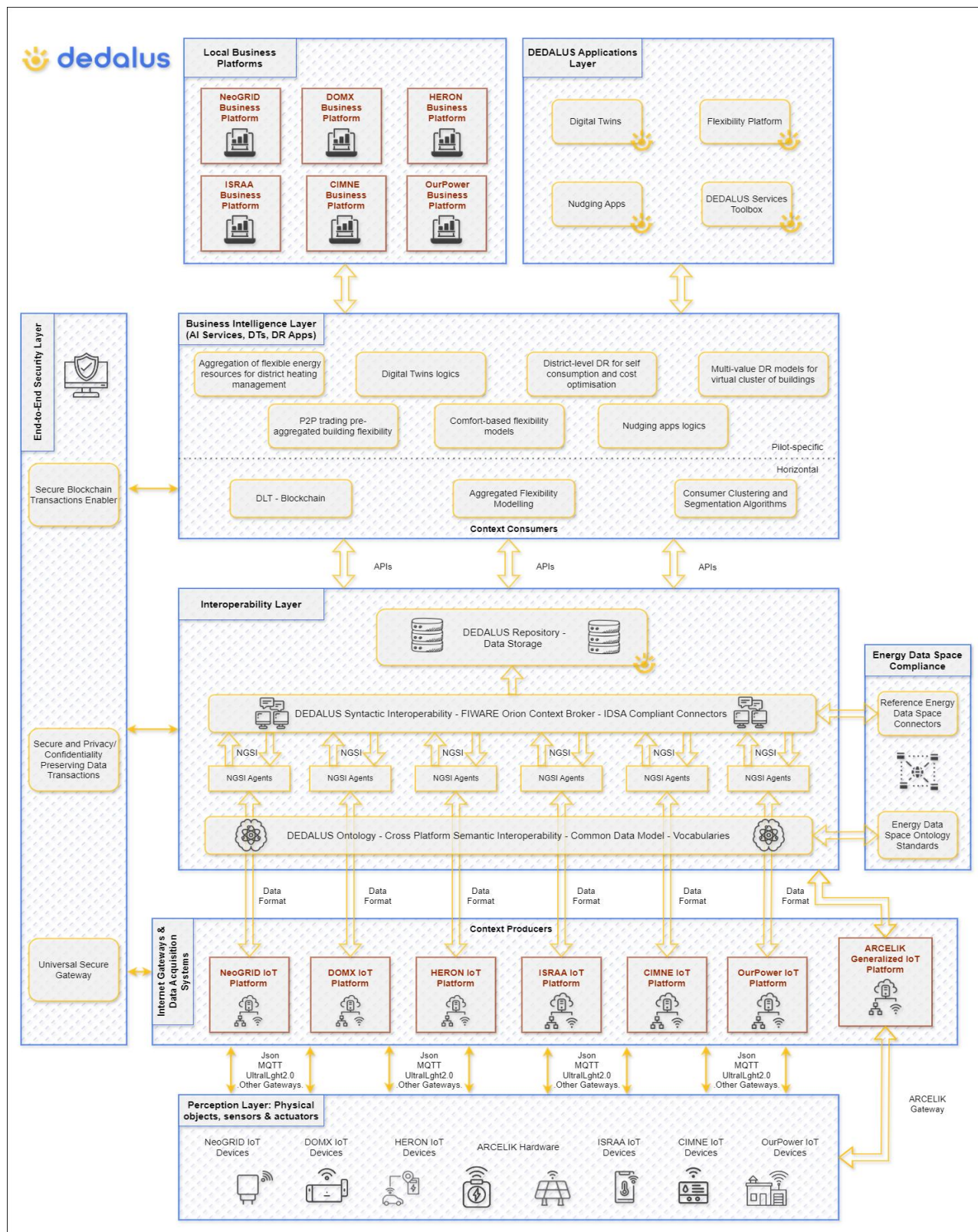
By adhering to these steps, the DEDALUS Architectural diagram was refined.

3.2 Architectural diagram

The objective of this section is to present the high-level architecture of DEDALUS, delineating the specifications of each architectural layer:

- Perception Layer: Physical objects, sensors & actuators
- Internet Gateways & Data Acquisition Systems
- Interoperability Layer
- Business Intelligence Layer (AI Services, DTs, DR Apps)
- Local Business Platforms
- DEDALUS Applications Layer
- End-to-End Security Layer

Plus, the Energy Data Space Compliance. Through this architecture, the DEDALUS framework laying the groundwork for informed decision-making and strategic alignment with organizational objectives. A comprehensive understanding of its architecture is useful for effective implementation and utilization.



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Figure 1: DEDALUS Architecture

Each layer of the Architecture represented in Figure 1 is described from bottom to top.

The **Perception Layer: Physical objects, sensors & actuators** comprises all the IoT data sources and physical devices that provide data, encompassing physical objects, sensors, and actuators. These sources include energy consumption meters, battery status monitors, humidity sensors, temperature sensors within apartments, and other environmental sensors. Each pilot encompasses a distinct array of devices, affording the potential to gather disparate datasets.

Connected to this layer is the **Internet Gateways & Data Acquisition Systems**, serving as conduits for data collection and transmission, ensuring seamless integration into the system. This layer comprises the IoT Platforms. The layer incorporates 7 platforms: NeoGrid Platform, DOM-X IoT Platform, HERON IoT Platform, ENEA IoT Platform, CIMNE IoT Platform, OurPower IoT Platform and ARCELIK Generalized IoT Platform. Main communication protocol and data format are:

- The MQTT (Message Queuing Telemetry Transport) protocol is a lightweight messaging protocol designed for constrained devices and low-bandwidth, high-latency, or unreliable networks. The MQTT protocol is well-known in the IoT environment due to its features.
- The FTP (File Transfer Protocol) protocol it is a standard network protocol designed for transferring files between a client and a server.
- CSV (Comma-Separated Values) is a file format used for storing tabular data.
- JSON (JavaScript Object Notation) is a lightweight data interchange format based on the key-value pairs paradigm. It is well-known for its simplicity, readability, and ease of use across different programming languages and platforms.

Specific information about each platform is presented in Table 45.

The ARCELIK Generalized IoT Platform is a crucial aspect of DEDALUS in terms of DR and IoT-enabled domestic appliances, and data collection. It utilizes scalable architecture and data management techniques to facilitate sustainable and efficient home management. ARCELIK Generalized IoT Platform enables remote control over a wide range of smart appliances via mobile devices, enhancing user convenience and energy efficiency. It leverages user data to optimize energy usage, apply preventive maintenance, and enhance the user experience. ARCELIK Generalized IoT Platform 's integration with a diverse array of smart home devices positions it as a cornerstone in the smart home ecosystem, highlighting its significance in the IoT appliance domain. The communication between home appliances and cloud are done via HTTP and MQTT protocols. For transmitting data and commands MQTT is utilized for static data such as appliance profiles and configurations there are cases where HTTP is used. The data transmitted in the JSON format between devices and the cloud. For the interoperable data collection within pilots, MQTT protocol and JSON data format will also be kept used.



Table 45: Platform information

Pilot name	Platform name	Platform license	Communication protocol	Data Format	Data frequency
Pilot 1 (Austria)	OurPower	Proprietary Software License - Commercial use	MQTT and/or REST API	JSON, CSV	15 minutes
Pilot 2 (Denmark)	NeoGrid PreHEAT Platform	Proprietary Software License - Commercial use	MQTT and/or REST API	JSON, CSV	5 min
Pilot 3 (Greece)	DOMX	Proprietary Software License - Commercial use	MQTT and/or REST API	CVS	1 minute
	HERON	Proprietary Software License - Commercial use	MQTT and/or REST API	JSON	30 sec
Pilot 4 (Italy)	ENEA	Proprietary Software License - Commercial use	MQTT and/or REST API	CVS	1 minute
Pilot 5 (Spain)	CIMNE	Proprietary Software License - Commercial use	MQTT and/or REST API	JSON	1 hour
Pilot 6 (Ireland)	CENTRICA	Proprietary Software License - Commercial use	MQTT and/or REST API	CSV	15 minutes
Pilot 7 (Romania)	Siemens WinCC	Proprietary Software	FTP	CSV	15 minutes

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Pilot name	Platform name	Platform license	Communication protocol	Data Format	Data frequency
------------	---------------	------------------	------------------------	-------------	----------------

License -
Commercial
use

The first two layers establish the groundwork for subsequent layers to leverage and build upon, enabling higher-level functionalities such as data analysis, decision-making, and business intelligence.

The **Interoperability Layer** acts as a bridge, enabling smooth communication and data exchange. The interoperability is divided into technical interoperability and semantic interoperability. The technical interoperability ensures efficient handling and distribution of data across various layers and components. The technical interoperability comprises the IoT Agent and the Context Broker, which collectively manage and facilitate the exchange of data within the system. Semantic interoperability aims to enable mutual understanding among two or more systems by employing shared data models. This entails structuring data exchanges and encoding data with standardized vocabularies, allowing receiving systems to interpret the data in accordance with the intended semantics. It comprises the DEDALUS Ontology. These components are instrumental in structuring and organizing domain-specific knowledge and data, enabling intelligent decision-making and analysis within the system. In particular, the Pilot Data Repository is used to store persistent data. More information about the interoperability is reported into the document (see [9]).

The **Interoperability Layer** is connected with the **Energy Data Space Compliance**. The **Energy Data Space Compliance** facilitates interoperability with external data spaces, allowing integration with external systems and data sources.

Building upon this foundation is the **Business Intelligence Layer**, housing advanced AI services, Digital Twins (DTs), and Decision Support (DR) applications, which harness data to derive actionable insights and optimize processes. The **Business Intelligence Layer (AI Services, DTs, DR Apps)** has the goal to deploy all the DR services that are part of the project, which make use of the ontology to consume data for applying artificial intelligence. This layer consists of all the value-added services that enhance the functionality and capabilities of the DEDALUS project. These services provide additional value by offering functionalities and features tailored to specific use cases and requirements.

The **Local Business Platforms** serve as interfaces for users to interact with the system, presenting insights, recommendations, and data in a user-friendly manner.

The **DEDALUS Applications Layer** comprises the following components: the Digital Twins, the Flexibility Platform, the Nudging Apps and the DEDALUS Services Toolbox. The DT are virtual representations of physical objects, processes, or systems. They mimic the behaviour of their real-world counterparts, allowing for simulation, analysis, and optimization of various scenarios without directly impacting the physical environment. The Flexibility Platform is a web-based

service which provides the flexibility potential for a variety of assets in the different contexts of the DEDALUS pilot sites. The Nudging Apps influence the user behaviour to promote positive outcomes. The DEDALUS Services Toolbox is a collection of tools, utilities, and services provided within the DEDALUS ecosystem. It offers a comprehensive set of functionalities for developing, deploying, and managing applications and services within the DEDALUS architecture.

The **End-to-End Security Layer** is positioned as a transversal layer across the entire architecture, it is linked with the Internet Gateways & Data Acquisition Systems layer, the Interoperability Layer, and the Business Intelligence Layer. It ensures the security and integrity of data, processes, and interactions within the system, implementing robust security measures to safeguard against threats and vulnerabilities. More information about this topic is available in Chapter 4. Data Privacy, Ethics and Cyber Security. The layer comprises three main components:

- The Secure Blockchain Transactions Enabler
- The Universal Secure Gateway (USG)
- The Privacy Protection Enforcement (PPE)

These components are functional to:

- Implements security measures to ensure the integrity, confidentiality, and authenticity of data transmitted between IoT devices and the system.
- Enforces authentication and authorization mechanisms to control access to sensitive data and functionalities.
- Utilizes encryption techniques to secure data both in transit and at rest.

This architecture provides a comprehensive framework for building and deploying a system that leverages IoT data, knowledge management, value-added services, and presentation interfaces while prioritizing security and interoperability.

3.3 Dynamic view

The aim of this section is to provide information about the workflow and data exchange between the different architectural layer.



Figure 2: DEDALUS Dataflow

A description of Figure 2 is reported below.

- The IoT devices represents the physical devices equipped with sensors that collect data such as heating consumption, electricity usage, and so on. The first step involves collecting data from IoT devices and storing it, including cleaning, and organizing the data.

- The Business Platform serves as central repository for data collection from the IoT devices. The second step involves intelligent data exchange with other systems through technical and semantic interoperability.
- The Interoperability has the objective of for ensuring seamless communication and data exchange between different systems. It handles both semantic interoperability (ensuring that data from diverse sources can be understood and interpreted correctly) and technical interoperability (ensuring that systems can exchange data effectively using common protocols and standards). The third step leads from the interoperability to services that add value to the process.
- The Services has the objective to extract valuable insights and provide added value to the process through various techniques, including machine learning and artificial intelligence. This may involve predictive analytics, optimization algorithms, or other data-driven methods. From the Services, after the data are analysed and a decision is made there are two steps that can be made. When a decision is made and transmitted to IoT devices, such as activating a smart device, the pathway is traced backward until reaching the IoT devices. The fourth step is the one that is going to the presentation.
- The presentation is responsible for presenting the insights derived from the data in a user-friendly and understandable format. This could include charts, graphs, dashboards, or other visualizations that enable stakeholders to interpret and act upon the information effectively.

The outlined steps illustrate the typical flow of data within the DEDALUS architecture. The interoperability, as illustrated in Figure 2, comprises the combination of the Middleware Layer and the Knowledge Layer represented in the DEDALUS Architecture (see Figure 1).

4. Data Privacy, Ethics and Cyber Security

This chapter explores the crucial intersection of data privacy, ethics, and cybersecurity within the framework of modern technology. It involves an analysis of the TE related to the cyber security and strategies for ensuring compliance and safeguarding sensitive information. The overarching goal of this chapter is to cultivate a deeper comprehension of the ethical and security challenges inherent in the DEDALUS project.

With data privacy we refer to the protection of individuals' personal information and the proper handling of sensitive data. Instead, the cybersecurity has the objective to safeguard against unauthorized access, data breaches and other actions that could compromise the integrity and confidentiality of data.

With ethics we refer to the principles of right and wrong that guide an individual or group's behaviour. It encompasses the moral values, beliefs, and standards that govern how people interact with others and make decisions. Ethical considerations often involve concepts such as fairness, honesty, integrity, respect, and responsibility.

4.1 Methodology

The proposed methodology involves the following steps:

- Identification of datasets to determine if personal data are involved.
- Identification of tools and techniques that can ensure the cybersecurity and data privacy of the system.

4.2 Datasets

The aim of this section is to provide an overview of datasets managed in the project underling if personal data belongs to the pilot datasets. A specific survey will be provided to pilot leaders to collect feedback about the owner of the data, what permissions are required to access that data and if the pilot requires personal data acquisition, curation, processing, or modification. A summary of data sets will be provided as follows:

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Table 46: Dataset overview

Dataset Name	Description	Pilot country	Personal data within the datasets
Pilot1_electricity_individual	The electricity consumption and production data are collected for individual apartments and PV systems, with readings recorded every 15 minutes.	Austria	Yes
Pilot1_electricity_aggregated	The electricity consumption and production data are collected for each building floor, with readings recorded every 15 minutes.	Austria	No
Pilot2_electricity_consumption	The data is collected for individual apartments, with readings recorded every 5 minutes.	Denmark	Yes
Pilot2_heating_consumption	The data is collected for individual apartments, with readings recorded every 5 minutes.	Denmark	Yes
Pilot2_indoor_climate	The data (Temperature, Humidity, CO2) is collected from individual apartments and rooms with readings recorded every 5 minutes	Denmark	Yes
Pilot3_heating_consumption	Heating data collected by individual households both from gas boiler systems and from heat-pump systems. The resolution of the collected data is less than 1 minute.	Greece	No
Pilot3_electricity_consumption	Electricity consumption data collected by individual households. The resolution of the collected data is less than 1 minute.	Greece	No

Dataset Name	Description	Pilot country	Personal data within the datasets
Pilot3_IoT_devices	Data set from IoT devices including electricity consumption of smart plugs. The resolution of the collected data is less than 1 minute.	Greece	No
Pilot3_indoor_air_quality	Indoor air quality data collected by individual households. The resolution of the collected data is less than 1 minute.	Greece	No
Pilot4_electricity_consumption	Electricity consumption data collected for individual apartments in two buildings. Data can be monitored real-time	Italy	No
Pilot4_indoor_air_quality_and_light_intensity	The indoor conditions data (temperature, humidity, CO2, particulate matter, barometric pressure, light intensity) are collected for individual apartments in two buildings. Sampling rate 10 seconds.	Italy	No
Pilot5_electricity_consumption	Energy consumption collected from the users collected daily with DSO meters, with hourly sampling rate, and real-time data collected with smart meters.	Spain	Yes
Pilot5_DER	Data set information regarding the battery status and operation and photovoltaic panels generation.	Spain	No
Pilot5_IoT_devices	Data set from IoT devices including temperature, humidity and consumption of the smart plugs.	Spain	No
Pilot6_space_heating_data	Heat pump data regarding measured indoor temperature,	Ireland	Yes

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Dataset Name	Description	Pilot country	Personal data within the datasets
	target indoor temperature and energy consumption for space heating		
Pilot6_water_tank_heating_data	Heat pump data regarding measured water tank temperature, target water tank temperature and energy consumption for water heating	Ireland	Yes
Pilot6_outdoor_temperature	Outdoor temperature measured by each heat pump	Ireland	No
Pilot7_energy_consumption	Energy consumption time series data collected with BEMS from two buildings (at building level) and a heating unit.	Romania	No

4.3 Non-functional requirements

The non-functional requirements pertaining to security, privacy, and ethical considerations of data are integral to ensuring comprehensive and responsible data management practices. Table 47 presents a list of non-functional requirements, while Table 48 a list of data ethics requirements presents in the document (see [10]).

Table 47: DEDALUS data security and privacy requirements

ID	LABEL	DESCRIPTION	REMARKS
NF1	Security	Transactions based on energy data should be stored in a tamper proof manner on blockchain	In relation with TE5
NF2	Privacy	Transactional data may be encrypted on the blockchain platform	This is more a nice to have feature

The ethical considerations into DR programs are essential for ensuring that they not only effectively manage energy demand but also respect the principles of fairness, transparency, privacy, and environmental responsibility. In Table 48: DEDALUS data ethics requirements the most important ethical aspects for the DEDALUS project were discussed.

Table 48: DEDALUS data ethics requirements

ID	LABEL	DESCRIPTION
ER1	Equity	DR programs aim to balance energy supply by incentivizing consumers to adjust their energy request during peak times. Ethical considerations arise concerning the fairness of these programs. For example, it is important to ensure that the burden of reducing energy consumption does not disproportionately fall on vulnerable participants.
ER2	Transparency	Ethical DR initiatives should operate transparently, ensuring that participants understand the terms of their involvement and any potential impacts on their energy bills or lifestyle. Transparency helps build trust and ensures that participants can make informed decisions.
ER3	Environmental Impact	DR strategies may prioritize reducing energy consumption during peak times to avoid relying on fossil fuel power plants, thus reducing greenhouse gas emissions. Ethical considerations come into play when evaluating the environmental impacts of different DR approaches and ensuring they align with broader sustainability goals.
ER4	Ethical AI Decision-Making System	The AI Decision-Making systems should consider the ethical aspects. For example, AI algorithms used in DR systems must consider fairness and equity to ensure that energy-saving incentives and benefits are distributed equitably among participants.

4.4 Assessment and recommendations

The attainment of security and privacy within the DEDALUS project will be achieved through the utilization of three distinct tools: Keycloak, the Privacy Protection Enforcement (PPE), and the Universal Security Gateway (USG). A description of each tool, along with its usage within the DEDALUS project, is provided below.

Keycloak [11] provides authentication, authorization, and other security features for the DEDALUS platform. It enables developers to secure their applications by managing user authentication and authorization centrally. Keycloak is based on standard protocols and provides support for OpenID Connect, OAuth 2.0, and Security Assertion Markup Language (SAML). Keycloak supports various authentication methods such as username/password, social login, and multi-factor authentication. Additionally, it offers features like single sign-on (SSO), crucial for the nature of the DEDALUS project, allowing users to access multiple applications with a single set of credentials. Moreover, Keycloak provides user management capabilities, including user registration, profile management, and password reset functionalities. By leveraging Keycloak, DEDALUS framework applications can integrate robust security features without the

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need to develop them from scratch. Keycloak neatly organizes its functionality into features that can be enabled or disabled based on their applicability within the DEDALUS project.

Privacy Protection Enforcement (PPE) component is a component developed in [12] that enables handling and management of data in compliance with EU Regulatory Framework based on the PPE data envelope concept. The PPE component focuses on two main aspects supported by its own individual subcomponents:

- Privacy, Reputation Mechanisms and Mutual Auditability toolbox (PRIMULA) enabling consent-driven data exchange.
- Compliant Regulatory Data Exchange (CoReDEX) acting as a mediator for data exchange among parties enforcing the compliance rules and governance policies.

The PPE component implements the following security, privacy, and functional mechanisms:

- **Confidentiality:** CoReDEX allows only authorized data exchanges as defined by consents managed by PRIMULA sub-component.
- **Auditability:** All consent and permission changes as well as any related actions are recorded on PPE DLT.
- **Transparency:** All personal and privacy-sensitive data is registered with PPE. All operations – including processing and sharing – are recorded on PPE Distributed Ledger Technologies (DLT). CoReDEX provides access to data whereas PRIMULA provides advanced consent management.
- **Consent-based exchange rules:** CoReDEX permits or prohibits data exchange according to advanced consent from PRIMULA as well as additional CoReDEX compliance rules and governance policies.
- **Advanced consent:** Data subject (e.g. energy community participant) signs consent with its specification which are both recorded in PRIMULA. Upon data request, CoReDEX checks whether the requesting party has the rights to access data.
- **Change requests:** PRIMULA allows withdrawal or change of consent. CoReDEX allows change of exchange rules.
- **Status notification:** All data exchanges are recorded on PPE DLT and the parties are notified by PRIMULA about the data exchange.

PPE virtually serves as an authority and mediator between entities with assigned GDPR roles, such as data subjects, data controllers and data processors (Figure 3). In the scope of DEDALUS project, the PPE component will be modified and extended to provide secure and trusted data exchange over secure API provided by CoReDEX subcomponent and to provide identity and fine-grained access management with modified PRIMULA component. The PPE framework will be potentially extended to support decentralised profile identifiers instead of centralized identity management.

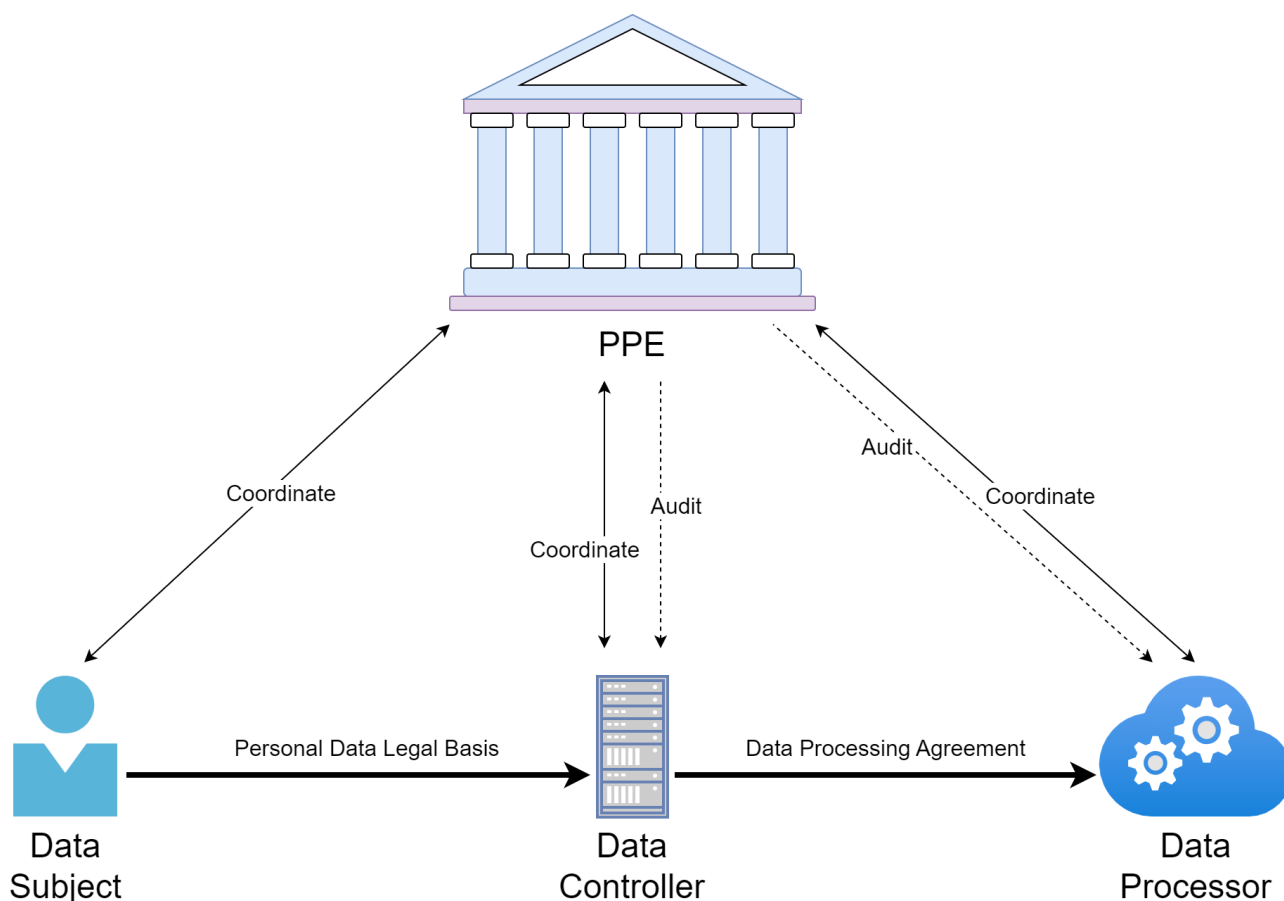


Figure 3: PPE as a GDPR authority and mediator.

Universal Secure Gateway (USG) in a DEDALUS project is a software platform that enables integration of field assets and legacy systems with cloud backend and data analytics services deployed in cloud and on an edge. In DEDALUS, to support the local, on-premises private data processing as specified by IDSA, a software solution will be developed by reusing and enhancing the existing building blocks that will enable plug & play solution for deployment of pre-aggregation, orchestration, and activation of flexibility. The ambition is to enable the energy community manager to gather real-time data from various sources (assets, grid, weather, market, etc.), and make informed decision based on analytics services developed in various tasks in DEDALUS project.

The USG is deployed as a collection of Docker containers organised in a Docker Compose file providing a deployment recipe that can be replicated on any compatible personal computer, server machine or cloud-based computing instance preferably running GNU/Linux operating system with Docker Engine installed. The USG (Figure 4: High-level architecture of USG software platform) connects to the user energy assets, DER resources, smart meters and other data sources using specialised IO microservices that support data collection and calling control action execution on devices and resources. MQTT broker enables unbuffered data collection that are routed to the Kafka event streaming unit that supports data buffering and routing of data streams to specific local services by relying on topics and their partitions. Pre-processing service makes a pre-processing on input data and stores them to the local data base. Data is stored in

local PostgreSQL data base with Timescale DB extension to support both relational and time series data storage. Stored data is exposed to locally deployed data processing services and web UI over local API. Web UI provides the visualisation of user household consumption and flexibility-related data and as well enables the community manager to assess the flexibility and expose it to relevant parties on energy and flexibility markets.

The USG, as well as other components, contains an identity and access management together with secure and privacy-preserving API to provide user management and user-based access management to relevant data by managing special resource-related consents and permissions that enable GDPR-compliant data exchange based on functionalities provided by Privacy Protection Enforcement (PPE) component. USG will also be able to host P2P interfaces developed in DEDALUS.

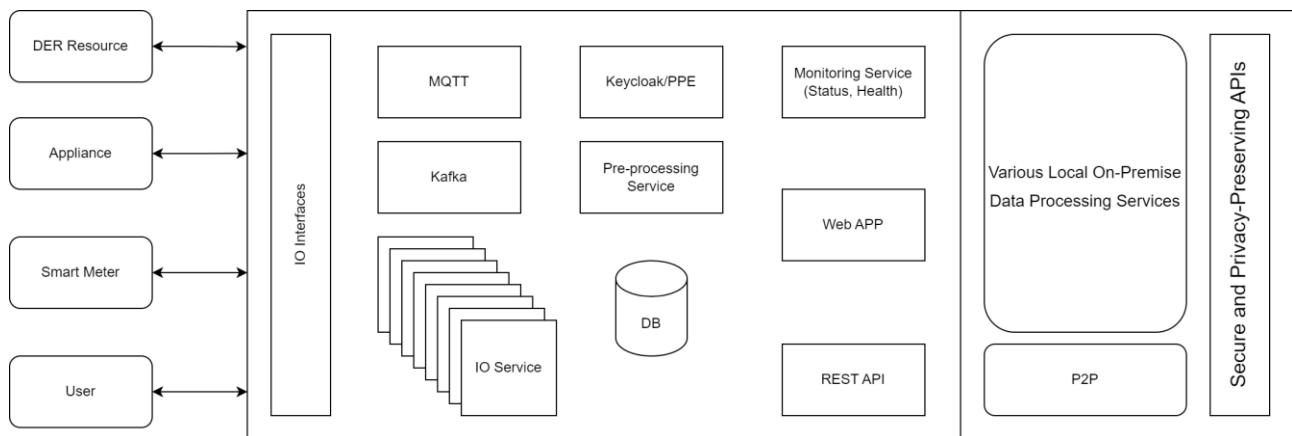


Figure 4: High-level architecture of USG software platform

The most effort for extension of USG platform in the DEDALUS project will be focused on extending the existing functionality in a way to support various asset interfaces, input sources and pilot-specific integrations by supporting common DEDALUS data models and providing secure, privacy-preserving communication with external components and actors.

5. Conclusions

In conclusion, this deliverable is about a software specification document that represents the culmination of extensive research, analysis, and collaboration among the partners of the project.

The delineation of high-level requirements for the DEDALUS project as social, technological, and business framework represents a critical step towards its successful implementation and operation of the project. This document provides a solid foundation for the development and deployment of DEDALUS project by specification of an architectural diagram, functional requirements, non-functional requirements, and the UCs.

In summary, information about each TE was collected. Use cases were specified, and a software architecture is proposed. By the definition of the UC, different strategies were highlighted to achieve effective the DR, reflecting a thorough understanding of the system's requirements and objectives. Additionally, ethics and security aspects were analysed and introduced.

The aspiration, by the usage of the DEDALUS platform, is to cultivate an inventive, enduring, and socially conscientious ecosystem adept at accommodating the dynamic exigencies of our diverse stakeholders and objectives in the field of DR.



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