D^2EPC Framework Architecture and Specifications v3

The D^2EPC project has received funding from the EU's Horizon 2020 research and innovation programme under grant agreement No 892984

Project Acronym:	D^2EPC
Project Full Title:	Next-generation Dynamic Digital EPCs for Enhanced Quality and User Awareness
Grant Agreement:	892984
Project Duration:	36 months (01/09/2020 – 31/08/2023)

DELIVERABLE D1.9

D^2EPC Framework Architecture and specifications v3

Work Package:	WP1 – Foundations for next generation dynamic EPCs (dEPCs): Identifying challenges, needs and opportunities (M1-M36)
Task:	T1.4 System Technical Requirements, Specs & Architecture
Document Status:	Final
File Name:	D^2EPC_D1.9_D^2EPC Framework Architecture and Specifications v3_CERTH
Due Date:	31.08.2023
Submission Date:	30.08.2023
Lead Beneficiary:	CERTH

Dissemination Level	
Public	☒
Confidential, only for members of the Consortium (including the Commission Services)	☐

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Version History

v	Author	Date	Brief Description
2.1	**Nikos Katsaros**	**16.05.2023**	**First draft based on the previous version**
2.2	**Nikos Katsaros**	**25.05.2023**	**Updates regarding Sections 1-8**
2.3	**Nikos Katsaros**	**09.06.2023**	**Updates regarding the BS1 technical UCs**
2.4	**Nikos Katsaros**	**12.06.2023**	**Update regarding the BS2-BS4 technical UCs**
2.5	**Nikos Katsaros**	**12.06.2023**	**Document draft ready, sent to task partners for feedback collection**
2.6	**All authors**	**06.07.2023**	**Updated information based on input from partners**
2.7	**Nikos Katsaros**	**07.07.2023**	**Document ready for peer review**
2.8	**Nikos Katsaros**	**17.07.2023**	**Document updated based on the peer review comments**
3.0	**Nikos Katsaros, Panagiota Chatzipanagiotidou**	**25.08.2023**	**Final version ready for submission**

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Executive Summary

This report presents the final results of Task 1.4 – Architectural Design, Functional & Technical Specification describing the D^2EPC system architecture and constitutes the third and last version of the respective deliverable. It aims to provide finalized details on the D^2EPC system architecture, its building blocks, components, interdependencies among components and related constraints such as the development methodology, which were documented in the previous versions.

Starting with the methodology, a brief overview of the most commonly identified processes and standards is covered to understand and present the steps and the information that need to be covered towards presenting a system architecture that completely covered the needs of the D^2EPC framework. Following a four-step methodology, the user and market requirements extracted through previous WP1 activities were translated to business scenarios and technical use cases, along with functional and non-functional requirements. These were then used to update the overall concept and high-level conceptual architecture, which then guided the more careful and accurate definition of each individual component as a module and as part of the overall system. This version of the deliverable finalizes the technical use cases that were originally documented, as well as the user and market requirements.

Out of the examined approaches, four initial viewpoints were selected to be adopted from presenting the details of the D^2EPC architecture: i) Functional, ii) Deployment, iii) Information, and iv) Dynamic views.

Throughout the T1.4 activities, 4 business groups were identified, including in total six (6) business scenarios, further divided into 19 Technical Use Cases. At the same time, a more elaborate iterative approach, using the JIRA framework, revealed a first set of 44 requirements (34 functional and 10 non-functional), which are documented following the Volere Template. Both the Business Scenarios and the System Requirements introduced technical aspects that led to the re-design of the D^2EPC architecture. This deliverable version introduces the latest updates on the architecture design.

Following a layered approach, the D^2EPC architecture was divided into 4 layers, each hosting different D^2EPC components, as follows:

- The **Infrastructure or Physical Layer** consists of one of the core layers for dynamic EPC, especially for the operational rating. Within this layer, all devices, sensors, actuators, and in general Internet of Things, and systems (i.e., Building Management System – BMS, Energy Management System – EMS, or even Supervisory control and data acquisition - SCADA) are included for collecting the necessary building information for all upper layers. As weather data are also required, in the absence of accessible weather stations on site, external weather APIs were used to retrieve the necessary information.
- The **Interoperabity Layer** consists of one main D^2EPC component i.e., the *Information Management Layer*. This component is responsible for communicating with the building assets from the physical layer, retrieving the necessary information, translating it to a commonly accepted format and streaming it to the D^2EPC repository to be further utilized in other D^2EPC layers.
- The **Service/Processing Layer** consists of most D^2EPC components and sub-components responsible for delivering all the main functionalities envisioned:
  - *BIM-based Digital Twin,*
  - *D^2EPC Calculation Engine*
    - *Building Performance Module,*
    - *Asset Rating Module*, and
    - *Operational Rating module*,
  - *Added-value Services Suite for D^2EPC*
    - *Roadmapping Tool for Performance Upgrade*

        - *AI-driven Performance Forecasts*
        - *Performance Alerts & Notifications*
    - *Extended dEPCs Applications Toolkit*
        - *Building Energy Performance Benchmarking*
        - *Energy Performance and Credibility*
- The **Representation Layer** constitutes the layer offered for interaction with the end-users (engineers, building owners, registries, etc.) or third-party platforms / tools (i.e., b-logbooks, BIM design tools, etc.). Within this layer, three D^2EPC components are included, namely:
    - *D^2EPC Web Platform*
    - *D^EPC Web GIS, and*
    - *Credibility UI.*

Based on this layered architecture, functional, deployment and information viewpoints were provided and are now finalized, presenting a more detailed analysis of each individual component, along their in-between interactions.

Finally, the dynamic view covers several use cases per business scenario, each instantiated through specific requirements and sequence diagrams. The purpose of these sequence diagrams is to clarify how the D^2EPC platform works and which components are relevant to achieve different tasks.

Reaching the project closure and the corresponding completion of the technical work packages, the technical aspects of the D^2EPC framework have been clarified, thus, this deliverable now presents the final D^2EPC system architecture.

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List of Acronyms and Abbreviations

Term	Description
ADM	Architecture Development Method
AI	Artificial Intelligence
API	Application Programming Interface
BACS	Building Automation and Control System
BEPS	Building Energy Performance Simulation
BIM	Building Information Modelling
BMS	Building Management System
BS	Business Scenario
CRSs	Common Reporting Standard
CSS	Cascading Style Sheets
CSV	Comma-separated Values
DBMS	Database Management System
DHW	Domestic Hot Water
DoA	Description of Action
DODAF	Department of Defence Architecture Framework
DRY	Don’t Repeat Yourself
DSS	Decision Support System
DT	Digital Twin
EASME	Executive Agency for Small and Medium-sized Enterprises
EC	European Commission
EMS	Energy Management System
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
EPVC	Energy Performance Verification & Credibility
ESCOs	Energy service companies
GDPR	General Data Protection Regulation
GERAM	Generalized Enterprise Reference Architecture and Methodology

GIS	Geographic Information System
HC&W	Human Comfort & Wellbeing
IAQ	Indoor Air Quality
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IML	Information Management Layer
IoT	Internet of Things
ISO	International Organization for Standardization
IT	Information Technology
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
LCA	Life-cycle assessment
LCC	Life-cycle Cost
LIM	Land Information Management
MS	Management System
NUTS	Nomenclature of Territorial Units for Statistics
OGC	Open Geospatial Consortium
OS	Operating System
PWA	Progressive Web App
RE	Real Estate
SCADA	Supervisory control and data acquisition
SoA	Service-oriented Architecture
SQL	Structured Query Language
SVG	Scalable Vector Graphics
TOGAF	The Open Group Architectural Framework
UC	Use Case
UI	User Interface
VCUI	Verification and Credibility User Interface
VOC	Volatile Organic Compounds

WFS	Web Feature Service
WMS	Web Map Service
XML	Extensible Markup Language

1 Introduction

1.1 Scope and objectives of the deliverable

This deliverable intends to provide the high-level overview of the D^2EPC software architecture, summarizing the technical and functional design aspects. It deals with the delivery of a complete set of system requirements, addressing both functional and non-functional requirements.

Based on these requirements, the business scenarios, and the technical use cases, this report aims to present a concrete and concise definition and design of the D^2EPC System Architecture at the component and sub-component levels. It describes the basic functionalities of the D^2EPC platform and introduces functional descriptions of each component. The architectural description includes aspects related to the identification of the major system components, how they should interact and how their external interfaces should be defined. Beyond delivering a general overview of the D^2EPC system design, every component of the D^2EPC framework is detailed, covering a wide range of functional and technical specifications.

This report has acted as the foundation of all technical activities within the project. Through an iterative and agile approach, feedback was collected during their progress complementing and refining various aspects of the system architecture.

1.2 Structure of the deliverable

Towards optimally delivering the fundamental aspects of the D^2EPC system architecture, this report delivers step by step all the processes followed and their results for extracting technical requirements, functionalities and features of technical components and sub-components. To cover all these aspects, this report is structured as follows:

- **Chapter 2** introduces the methodology used to define and document the architecture that has been defined. All the design aspects that were analysed and adopted for presenting the D^2EPC system architecture are documented and explained.
- **Chapter 3** introduces the D^2EPC Business scenarios. These have been documented to address the market needs and challenges that have been identified through D1.1, D1.2 and D1.6.
- **Chapter 4** gives an overview of the conceptual architecture – a high-level description of the D^2EPC system architecture – introducing the basic components of the architectural layers. This part provides a high-level description of the aforementioned components.
- **Chapter 5** introduces the system requirements, both functional and non-functional as extracted and updated from the consortium interaction on the JIRA platform.
- **Chapter 6** is the Functional View, providing the high-level specification of each component, its functionality, and its interactions.
- **Chapter 7** presents the Information view, which documents information management including storage and distribution within the system.
- **Chapter 8** is the Deployment View, presenting information on the physical systems required to deploy each envisioned component. It provides an overview of the hardware requirements by describing how and where the system is deployed, which physical components are needed, what are the dependencies, hardware requirements and physical constraints.
- **Chapter 9** includes the Dynamic View in the form of the Technical Use Cases. Basic requirements and sequence diagrams per use case are documented towards clarifying how the D^2EPC platform works and which components are relevant to achieve different tasks.
- **Chapter 10** sums up the main conclusions and findings of this deliverable.

1.3 Relation to Other Tasks and Deliverables

This task constitutes the first core technical activity of the project. It is closely related to other WP1 activities, and especially T1.2 and T1.3 since they represent the market and user needs, and the envisioned high-level scheme of the D^2EPC system, respectively.

This report is considered as the technical foundation of the D^2EPC software architecture and development framework. Hence, activities in other technical WPs (WP2-WP4), as well as the demonstration (WP5), have used this report as reference, but also provided feedback on its iterative procedures towards finalizing its context.

2 Software Architecture Design Methodology

This section presents the background check that proceeded the architecture definition as well as the design methodology that was adopted for the D^2EPC architecture definition. The basic principles that were followed throughout the activities of T1.4 and considered during the documentation of all the versions of this report are all outlined. Through these, the final technical guideline of the overall D^2EPC framework was documented, presenting in detail the dependencies, the input/output flows and the specifications of the individual architecture components.

In alignment with the project's results, the D^2EPC system architecture reached the expected level of detail. This final version of the system architecture completes the design and provides highly detailed technical information on each component individually but also their in-between interactions, based on the outcomes of other technical work packages (i.e., WP2-WP4).

An overview of the approach used to achieve the D^2EPC system architecture description is presented in Figure 1. The first phase of this approach was originally performed in coordination with other WP1 activities and revisited to identify possible updates. For phase 2, the conceptual architecture introduced in version 1 of the report, which was originally based on the DoA, is re-introduced to consider the final interaction among components and adjust the system's structural view in Phase 3. Specifications of the architectural components are elaborated under Phase 4.

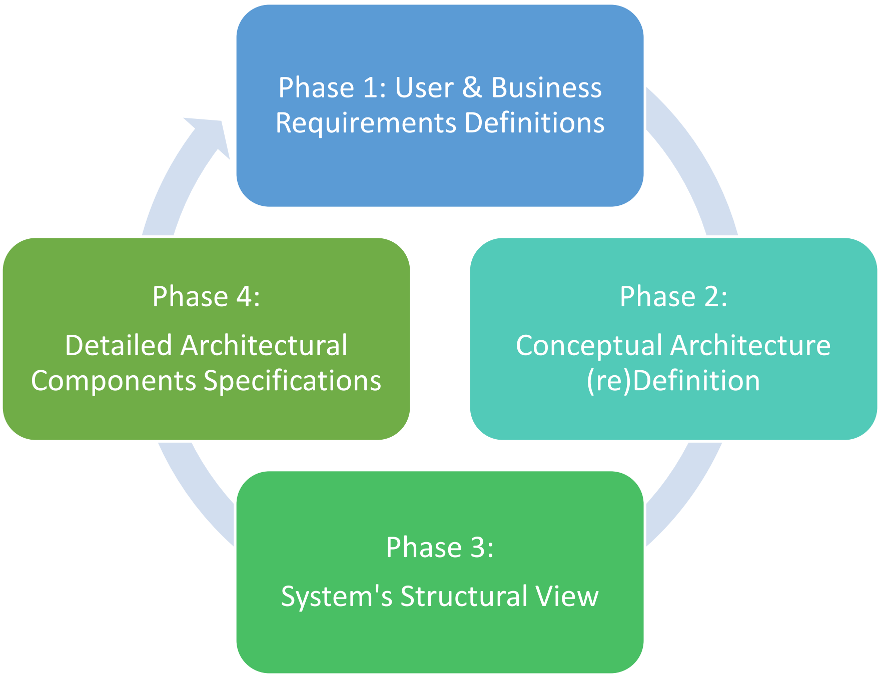

Figure 1. Design high-level approach for the D^2EPC System Architecture

2.1 Background

The term architecture refers to the configuration and design of a system to ensure the integration (physical communication) and interoperation (logically communicate) of its components [1]. According to the standard ISO/IEC/IEEE 42010:2011 [2] architecture is defined as the sum of the system's fundamental concepts or properties in its environment embodied in its elements, relationships, and in the principles of its design and evolution.

The architecture of a system is specified by the specific domain of application or the community of stakeholders [2]. An *architecture framework* is a prefabricated knowledge structure used to guide the architecture development phase. More specifically, an architecture framework consists of a determined set of rules, principles, and practices used to define and analyze the architecture descriptions.

An architecture framework is identified by *architecture viewpoints*, that architects use to organize an architecture description into *architecture views*. Viewpoints are methods and techniques for solving certain kinds of architecture description problems derived from best practices. Many existing practices express architecture through collections of models, and models are further organized into cohesive groups, called *views.* A view can be defined as a "*work product expressing the architecture of a system from the perspective of specific system concerns"* [2]. Viewpoints refer to the conventions for expressing an architecture with respect to a set of concerns. The terms architecture view and architecture viewpoint are central to the standard [2]: *"A viewpoint is a way of looking at systems; a view is the result of applying a viewpoint to a particular system-of-interest"*.

In the following the most common used system architecture frameworks are presented briefly the most common used system architecture frameworks:

Zachman: this framework is used in the field of information systems architecture. The purpose of the framework is to provide a basic structure which supports the organization, access, integration, development, management and changing of a set of architectural representations of the organization's information system. The framework is defined by a matrix of 6 rows and 5 columns [3]. The columns comprise the architecture concerns and have the following names: Data (what), Function (How), Network (Where), People (Who), Time (When) and Motivation (Why). The rows represent the systems stakeholders and are named: labelled Planner, Owner, Designer, Builder, Programmer, and User. Each cell of the matrix depicts a perspective, or way of viewing the subject. Each cell can be understood as a model type.

DODAF: DoDAF stands for U.S. **D**epartment **of D**efence (DoD) **A**rchitecture **F**ramework and its purpose is to provide guidance for describing architectures for both warfighting operations and business operations and processes. DODAF defines three "views" – Operational, Systems and Technical – or viewpoints according to ISO/IEC 42010. DODAF does not distinguish views and viewpoints, which significantly complicates their exposition. As viewpoints, the DODAF's definitions are incomplete: stakeholders and concerns are not identified. This makes it difficult for DODAF users to understand why they are modeling, and when they are done. DODAF defines 29 architecture products in detail: each related to a view(point). These architecture products correspond to architecture models in ISO 42010 terms. The DODAF also has some products that can be considered as correspondences between the views [4].

GERAM: The Generalized Enterprise Reference Architecture and Methodology found in ISO 15704:2000 is an architecture framework (in the sense of this paper) for enterprise reference architectures. It identifies areas of concern to stakeholders in the domain of industrial automation. It specifies modeling properties for use in that domain and several specific viewpoints to be modeled that produce architectural and operational views for a manufacturing enterprise. It makes use of correspondence relationships, principally in the context of the enterprise life cycle, model genericity, and modeling viewpoint, to form a cohesive framework [5].

Kruchten's 4+1: The 4+1 architecture defines 5 viewpoints: Logical, Development, Process, Physical and Scenarios. At this framework there are addressed the "correspondences between the views" such as "logical to process", "logical to development" and "process to physical". The level of success in an architecture description can be defined by the coherence of the above associations.

The Open Group Architectural Framework (TOGAF): The Open Group Architectural Framework (TOGAF) was first developed in 1995 and was based on the Department of Defense's Technical Architecture Framework for Information Management [6]. TOGAF focuses on mission critical business applications that use open systems building blocks. "A key element of TOGAF is Architecture Development Method (ADM) that specifies a process for developing enterprise architecture" [7]. TOGAF explains rules for developing good principles, rather than providing a set of architecture principles. The three levels of principles support decision making across the entire enterprise; provide guidance of IT resources; and support architecture principles for development and implementation.

Based on the above approaches, there have been also those that adjust their work without introducing a separate framework, but simply aligning their system to the standard IEEE 42010 'Systems and software engineering — Architecture description'

2.2 D^2EPC Architecture Design Methodology

2.2.1 Design Principles

Through the various standards and methodologies explored, a set of general design principles have been identified and followed for the D^2EPC system architecture. By adhering to these principles, D^2EPC aims to deliver an open and modular platform, that all vendors, suppliers and potential users will be able to exploit as much as possible. The system architecture designed is considered to be as technology independent as possible, based on existing standards and incorporate (where feasible) the use of generic and standardized solutions for which several key technologies (open source, commercial, etc.) are available.

These design principles are:

- **Minimised Upfront Design:** The design of more functionalities and methods than the ones needed for the system under design should be avoided. This principle mainly refers to the early stages of the architecture development process, when the design is likely to change over time. All requirements are implemented in the initial architecture but 'nice to haves' are avoided until the initial design is finalized.
- **Separation of Concerns:** The overall system should be divided into distinct features with as little overlap in functionality as possible. The ultimate goal of this principle is, on the one hand, to minimize interaction points and, on the other hand, to ensure increased cohesion and low coupling.
- **Single Responsibility:** Each architectural element shall be responsible for only a specific feature or functionality, or even aggregation of cohesive functionality
- **Least Knowledge:** An architectural element should not directly have access to the internal details of other architectural elements.
- **Don't Repeat Yourself (DRY):** Avoid repeating the same functionality or intent in more than one architectural element of the system under design. Thus, according to this principle, common functionalities are addressed in more general architectural elements or components, which can be utilized by each separate element in order to "access" or "deliver" the required functionality.

2.2.2 Bottom-Up and Top-Down Processes

The second iteration of T1.4 presented the refinement of the preliminary Business Scenarios and Technical Use Cases that were documented in the first version. The aforementioned accurately capture and depict the necessary aspects of the D^2EPC Architecture and were finalized in this third and last version of the report, which exploits all the work performed under the technical work packages WP2, WP3 and WP4 as well as the deployment work under WP5.

During the first iteration, the architecture definition process involved besides technology exploration, two main phases, the bottom-up and the top-down. Following input derived from D1.2 and D1.3, an investigation of related projects, platforms and solutions were performed towards identifying core functionalities and components. In the *bottom-up* phase, the initiation of the architecture definition process was carried out based on technologies and software modules brought by partners that were considered necessary for the D^2EPC platform. Going beyond what has been presented in the DoA, partners were asked to fill in a set of templates for their existing solutions, as well as their initial understanding and plans for the D^2EPC components. In the meantime, a preliminary set of Business Scenarios and Technical Use Cases was drafted following the lead of various experts within the consortium. These allowed the *top-down* phase to be initiated, towards more clearly defining the functionalities required for meeting the project's objectives. Both phases have been complemented during the second and third iteration; on the one side, partners have been requested to provide updated plans for the D^2EPC components and information on how their existing solutions were adapted to be aligned with the advancements of the project. On the other side, the re-evaluation of the Business Scenarios and Technical Use Cases has been carried out towards completing the definition of the functionalities that were developed.

2.2.2.1 Bottom-up Process

This phase (M3-M5) aimed to collect and categorize the technologies and software components that the individual partners of the D^2EPC project introduced to the project. A set of templates has been distributed, requesting information on relevant tools, as well as expectations and updates to be included in the D^2EPC components. At the same time, partners' expertise was identified and used as best as possible in this first process. This process presented certain necessary changes to the architecture, leading to an updated D^2EPC conceptual architecture.

During this process, another task performed was the identification and definition of the project's Business Scenarios and Technical Use Cases. Again, building on previous knowledge and iteratively engaging with multiple partners within the consortium, a preliminary list of Business Groups, Business Scenarios, and Technical Use Cases was documented. This subtask was addressed again during the second iteration of T1.4 (M19-M21), where the aforementioned list was updated and delivered in Section 3.

2.2.2.2 Top-down Process

This phase (M6-M7) strongly focused on the individual and integrated functionalities required for meeting the project's objectives and delivering the necessary tools for addressing the needs and challenges for the Business Scenarios. This allowed to more clearly define the core functionalities of each component, their interaction and integration, as well as to draft the sequence diagrams for each of the technical use cases identified. Updated content has been introduced within this second iteration and is presented in the corresponding sections.

2.2.3 Architecture Activities

Besides frequent communication among technical partners, three main events were organized towards discussing and extracting requirements, elaborate on functionalities, define and refine the D^2EPC system architecture. These events include:

- Online preliminary Workshop on 11th November 2020;
- Online Workshop during the Plenary Meeting on 9th December 2020;
- Online Workshop on 19th February 2021.

During the second and third iteration of T1.4, the project partners participating in the task were prompted again to provide updates on the aforementioned information, through several meetings and platform integration workshops taken place during consortium meetings as well as individually with each partner.

2.3 System Requirements

Preliminary user and system requirements stem from the activities performed from T1.2 *Elicitation of user and stakeholder requirements & market needs* and T1.3 *Definition of the dynamic EPC scheme*, which have been documented in D1.2 *Next-generation EPC's user and stakeholder requirements & market needs* and D1.3 *Aspects of Next generation EPC's definition v1/* D1.6 *Aspects of Next generation EPC's definition v2,* respectively.

Towards effectively collecting and managing functional and non-functional requirements for the D^2EPC system, the Volere methodology was followed (Template shown in Table 1) in an effort to make a set of requirements that is standardised, trackable, and prioritised. To facilitate further the requirements extraction and management from the consortium members, CERTH deployed a JIRA framework. By doing so, a formalised process was introduced, allowing the efficient tracking of each requirement individually, but also in regards to other ones. This also facilitates the requirement refinement as technical activities progress, to quickly adapt to changing or upcoming requirements.

System requirements influence the architectural design process in that they frame the architectural problem and explicitly represent the stakeholders' needs and desires. **Functional requirements** define what the system, or its components should do, i.e., the specific behaviour between inputs and outputs. **Non-functional requirements** describe criteria that can be used to judge the functions of a system, also known as quality attributes. Non-functional requirements might be further subcategorised to: Look&Feel, Usability, Accessibility, Performance, Accuracy, Scalability, Stability, Reliability, Interoperability, Security, Privacy, and Maintenance. Both Functional and Non-Functional requirements need to be carefully selected to ensure that they are clear and meaningful in the context of the final outcome envisioned for meeting the project objectives, in accordance with the perspective of all technical partners. Requirements should be testable, consistent, unambiguous and rational; and should always keep the various actors in mind.

Table 1. Requirements Volere-based Documentation Format

ID	Unique ID
Summary	A one sentence statement of the intention of the requirement
Requirement Type	**Functional:** Something the system should do **Non-functional:** How the system works (several sub-types are pre-defined)
Priority	A rating of the customer value. Scale: Blocker, Critical, Major (= default), Medium, Minor, Trivial, Nice to have
Rationale	A justification of the requirement. Why is the requirement important? What contributions does it make to the product's purpose?
Source	From where this requirement was extracted or presented (could be a report, a publication, a survey, etc.)
Fit Criterion	A measurement of the requirement such that it is possible to test if the solution matches the original requirement
Originator	The person or partner who raised this requirement

Custom Labels	Any labels that can further help
Description	A more detailed description of the requirement if needed.
Component/s	Components defined as of March 2021 are shown in Section 4 and 6.
Requirement Links	Dependencies from other requirements

2.4 Viewpoints

As presented in the background section, quite a few approaches in software architecture design employ the practise of viewpoints. As defined in several of them, a *view* is a representation of a system from the perspective of a related concern held by one or more of its stakeholders, whereas a *viewpoint* is a pattern or template for constructing individual views. It establishes the guidelines, principles, and template models for the construction and analysis of a particular view.

For the D^2EPC project three main viewpoints have been considered for adequately describing all necessary aspects of the overall system architecture. These are the functional, the deployment, and the information views. All diagrams have been provided both as simple graphs within MS Power Point, but also as models designed through the online draw.io[1] tool for making updating easier.

2.4.1 Functional View

The Functional View of the system describes the architectural components that deliver the system functionality. These components are represented as functional elements based on their responsibilities and their primary interactions with other elements. A functional model does not rely on operations that may occur during runtime since it can only express time-free and sequential execution semantics. This is usually the most important viewpoint, as it reflects the quality properties of the system and influences the performance, the maintainability and the extensibility of the system.

To fully cover the functional view, three specific sub-sections are presented:

i) **a high-level description/overview** of the component, with more details for any sub-components that are included and are required for effectively delivering the functionality expected;
ii) **a component diagram** that not only presents the component and its sub-components but also the communication and interaction with other components, and
iii) a table with the **interfaces** that enable communication with other components/ or external services.

In general, a component diagram entails a description of an individual component and the integrated sub-components, while also highlighting cross-component dependencies. An example of a component diagram is presented in Figure 2. In the example, the component Energy Performance Verification and Credibility which is comprised of 2 sub-component/modules (i.e., Network Monitoring and Data Quality Tool), receives information from the Information Management Layer component (input) and provides information (output) to the Credibility UI and the D^2EPC Performance Alerts and Notifications components. The component also interacts (both input and output) with the D^2EPC BIM-based Digital Twin.

[1] https://app.diagrams.net/

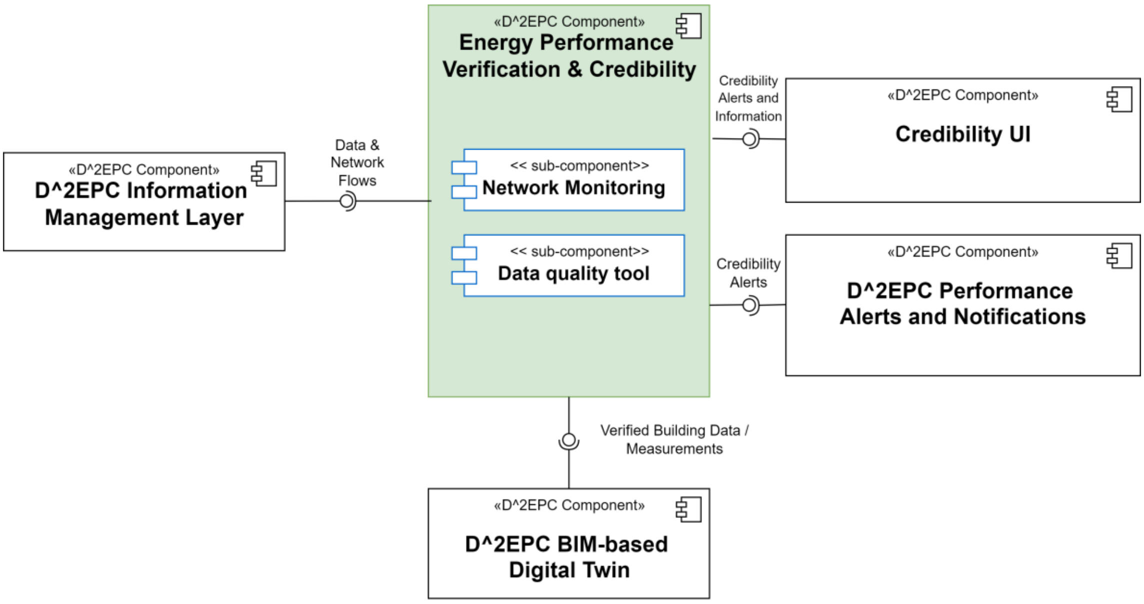

Figure 2 Example of a functional diagram

2.4.2 Deployment View

The Deployment view documents the physical environment into which the system is deployed and the dependencies the system has on its environment. Specifically, it captures (i) the hardware/software environment of the system (e.g. general-purpose hardware to execute the main functional elements of the system, storage hardware to support databases, hardware that allows users to access the system, network elements required to meet certain quality properties such as firewalls for security, etc.) (ii) the associated technical environment requirements (e.g. the type of operating system that run on the devices) and (iii) a mapping of the components to the runtime environment. The technical infrastructure used to execute the system is described by infrastructure elements like geographical locations, environments, computers, processors, channels and net topologies.

Even though deployment diagrams are often used to capture such information, due to the nature of the D^2EPC framework, which is expected to operate as a single platform with ancillary services, deployment characteristics are captured and documented as the required deployment environment, mainly with regard to physical characteristics. The physical architecture of the system is specified, to inform the mapping between that and the logical operations. This provides an overview covering the hardware requirements of the software modules and used tools. The table below lists the hardware requirements concerning the main D^2EPC components.

Table 2. Component Deployment View Information Outline Example

Component Name	Responsible Partner	Associated Task(s)	Supporting Partners	Deployment Platform	Hardware requirements	Interaction
A Component is a modular part of a system whose behavior is defined by its provided and required interfaces	Lead beneficiary	Action Tasks	Support Beneficiaries	It could be a device or an execution environment.	Properties or guiding parameters that must be defined for deployment to occur	With which components it interacts

The deployment view of the platform might depend highly on already existing software and hardware. A brief description of the already existing components is required along with their associated requirements.

2.4.3 Information View

This viewpoint generally aims to describe in a complete but abstract way the information flow among the various system components. Specifically, the information view documents information management including storage and distribution within the system. Similarly, to a high-level ontology, the information view aims to provide a unique and consistent interpretation of the lifecycles of the information objects handled by the infrastructure. The objective of this analysis is to answer the big questions around structure, content, ownership, and data migration.

The Information View includes a description of the different kinds of data and data formats consumed and produced by the different components and the semantic mapping between them (where available), including the type of the data objects and the relationships between them. The focus lies exclusively on the data exchanged and not their use by the various components.

This view is closely linked with the activities of T2.5 D^2EPC Information Model and T3.3 Buildings Digital Twin for EPC issuance, through which the necessary data model is defined. The delivery of the data models within T3.3 provides additional updates on the information flows.

Information flow diagrams represent how information is exchanged (or "flows") among the main components of the D^2EPC platform. Their main purpose is to describe the circulation of information within systems so that sources that send and receive information can be displayed and analysed in different situations. Successful information flow diagrams should highlight gaps that need improvement, display inefficiencies in information, highlight risks such as data confidentiality, display insecure mediums, and they should also provide clarity about who should receive which information when, where and how.

2.4.4 Dynamic View

Contrary to previous system's views, the dynamic view analysis provides insights and defines how the system actually works within the runtime environment and how it performs in response to external (or internal) signals. The interactions between the system's actors and the system's components are usually data flows representing the information exchanged in parallel or sequential execution of internal tasks.

In order to properly identify all aspects that define a technical use case, the template presented in Table 3 was prepared and used for defining the core aspects of each technical use case. The ensemble of all technical use cases delivers the most out of each business scenario.

Table 3. Requirements Documentation Format

Use Case #	Unique ID
Use Case Name	A very specific name that aids in easy understanding of the scope of the UC
Intent	Describe the purpose of the use case
Version/Action/Author	Stage the Application Scenario has reached / Changes/Modifications happened / Who documented the Application Scenario

Last Update	When was the use case been updated
Actors Involved	Main and Secondary actors involved in the use case
Brief Description	Please describe the series of steps for the defined use case in a clear, concise manner. Include in the description what the system shall do for the involved actor to achieve a particular goal.
Assumptions	Please list any assumptions relative to the use case
Pre-conditions	Please list the Pre-conditions. Pre-conditions define all the conditions that must be met (i.e., it describes the state of the system) to meaningfully cause the initiation of the use case.
Trigger	The event that starts the use case
Goal (Successful End Condition)	The ultimate aim and end condition(-s) of the Use Case
Post-conditions	The effects of this UC on the overall state of the system or of its core architectural elements.
Related Use Cases	e.g., UC-2.1

2.5 Service-oriented Architecture (SOA)

The D^2EPC components are designed, implemented and integrated following a Service-oriented architecture, exposing services at component and platform levels, towards allowing robust communication with each other and external entities, across different platforms, programming languages, execution environments, and development methods. Following the SoA design principles, the D^2EPC solution aims towards interoperability and uniform integration, independent of products, vendors and technologies. The most critical SoA principles that act as guidelines for the D^2EPC system architecture are:

- **Service contract:** Communication among services follows defined service description documents that describe the technical interfaces of services also known as service contracts. A technical service contract specifies an API of the service's functionality;
- **Loose coupling:** Services have the ability to remain independent of the implementation of other services. The facilitated dependencies between services are realized by the implementation of well-defined interfaces which allow the transmission of information without breaking the service contract;
- **Reusability:** Services should be designed to provide reuse of functionality to reduce the time spent during the development process significantly; and
- **Service abstraction:** The service contract defines the interaction between services by hiding as much of the underlying details as possible. Loosely coupled relationships invoke services by requiring no other information or knowledge of implementation details.

3 D^2EPC Business Scenarios Definition

A business case or scenario (BS) captures the need or problem that enables the understanding of the business value. It may also capture the reasoning that facilitates a decision to start a project. A common practise that is followed for properly identifying and defining business scenarios, is that it has to be "SMART":

- **Specific**, by defining what needs to be done in the business
- **Measurable**, through clear metrics for success
- **Actionable**, by clearly segmenting the problem, and providing the basis for determining elements and plans for the solution
- **Realistic**, in that the problem can be solved within the bounds of physical reality, time and cost constraints
- **Time-bound**, in that there is a clear statement of when the solution opportunity expires

In order to further facilitate understanding of the business value offered by D^2EPC, three business groups have been introduced, targeting specific market needs, as identified from T1.1 and T1.2 activities. As these scenarios target specific end-users, the list of D^2EPC stakeholders that have been identified in T1.2 is also included below in the Table 4.

Table 4. Description of D^2EPC Stakeholders

Stakeholder	Description
Standardization Bodies	The main responsibility of standardization bodies is to develop and deliver the methodology and technical specifications for evaluating the energy performance of the buildings.
State/Governmental Departments – Public Bodies	Goals and policies are set by policy makers in national policy statements, national plans, executive decrees or other formal official announcements. National policies and legal framework set the scope (tasks) for regulation.
EU Commission	The Energy Performance of Buildings Directive (EPBD) is the European Union's principal legislative instrument for the promotion of improvements in the energy performance of buildings within communities.
R&D sector Researchers/Academia	Researchers/Academia/R&D sector may support the development of the methodology and perform further research upon request from competent Authorities.
Software tool Developers	These companies develop and sell software for the implementation of Energy performance certification based on the respective standards adopted by the National legislation. Their important buyers are mainly ESCOs, engineering firms, Architects and professional consultants.
Energy service companies (ESCOs)	Energy service companies (ESCOs) play a significant role in the promotion of energy efficiency improvements. The Energy

	performance certification is among their important services offered by ESCOs.
Professional Consultants (Architectural and Engineering firms)	The Professional consultants implement the Energy performance certifications for their projects according to the National legislation of their countries.
Real estate agents (Rental and sales of buildings)	The energy performance certification affects property value in the real estate business. Energy efficiency is considered an important purchasing/rental criterion for the sale and rental of buildings. Therefore, real estate owners will have a motivation to build with greater energy efficiency.
Owners/users/tenants	The energy performance certificate will raise awareness of Owners/users on the energy consumption and may trigger energy-saving improvements. Especially the owners, who want to increase the property value for rental/sale.
Building services Industry	Building Services Industries affected by the legislation on the energy efficiency of buildings for their future technological services.
Suppliers	Suppliers that are affected by the legislation on the demand and the quality of their products.
Building Material Industry	Building Material Industries that are affected by the legislation on energy efficiency of buildings for their future material development pathways.
Energy Agencies	Energy agencies act as policy advisers and assist governments in improving standards. They provide advice on the development, implementation and impact assessment of efficiency policies. Through actively engaging relevant stakeholders, energy agencies could play a significant part in the successful implementation of the EPC scheme.
Environmental/Social campaigning organisations, **Researchers/ Academics,** **Media** **Designers** **Potential users/clients for future projects**	The stakeholders under this category may be interested in the outcomes and methodology for EPCs for different applications according to the context.

Towards delivering these business scenarios, it is necessary to further break them into smaller, more technical-oriented steps. These are the technical use cases. A use case is a list of event steps typically defining the interactions between a system and an actor in order to accomplish a specific goal (i.e., business scenario). The technical Use Cases are delivered in Section 9, as part of the Dynamic View, following the definition of requirements and system components.

3.1 Business Group A: Issuance of Energy Performance Certificates

This business group is the main set of scenarios that aims to deliver the core functionalities of the D^2EPC framework. Focusing on two important aspects (asset and operational rating), these scenarios deliver an EU-based platform for issuing energy performance certificates.

3.1.1 BS1: Definition of buildings energy class and whether minimum requirements are met for Asset Rating

This Business Scenario aims to deliver one of the core functionalities of the D^2EPC platform which is the Asset Rating, or otherwise known as Calculated or As-Designed. Expanding current methodologies while adopting the most recent standards, this scenario showcases the importance of BIM-based assessment, including certain dynamic aspects and the new indicators that were introduced through WP2 activities. As already highlighted, the main differences with current practices lie mainly in the use of BIM for providing for all the available necessary information from the infrastructure assessed, while also introducing new KPIs and practices for holistically addressing the building performance.

To fully cover this scenario the following technical use cases have been identified. These, along with the main actor and other related stakeholders are depicted in Figure 3.

- UC1.1 – Extract and Verify Data from BIM
- UC1.2 – Issue a D^2EPC asset EPC
- UC1.3 – Issue an SRI report
- UC1.4 – Asset Rating Indicator Assessment Report (LCC, LCA)
- UC1.5 – Provide Design recommendations for performance improvements
- UC1.6 – Asset Rating as a service

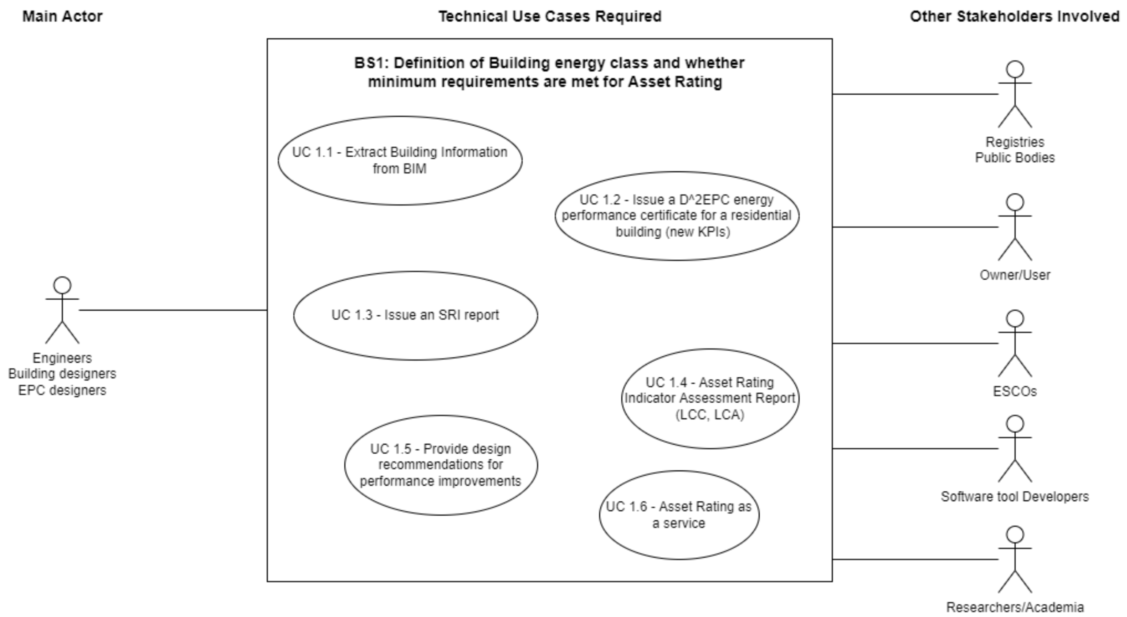

Figure 3. BS1 - Definition of buildings energy class and whether minimum requirements are met for Asset Rating

3.1.2 BS2: Definition of buildings energy class and whether minimum requirements are met for Operational Rating

This second business scenario aims to deliver for the Operational rating, or otherwise Measured or In-Operation. In contrast to the asset rating, here (near) real information flow from the building is crucial for the assessment of the operational building's performance. In addition, the indicators that are exploited towards delivering this scenario are not the same with the ones expected to be used in BS1, although certain overlapping may arise. Again, in this scenario, recommendations are provided to the main actor towards improving the overall experience and transferring the required knowledge. As a more dynamic procedure than the Asset Rating, the data required are extracted from the complete building Digital Twin.

This Business Scenario, in alignment and as an extension of BS1, consists of the following technical Use Cases:

- UC2.1 - Extract and Verify Data from Measurements for the Digital Twin
- UC2.2 – Issue a D^2EPC operational EPC
- UC2.3 – Operational Rating Indicator Assessment Report (LCC, HC&W)
- UC2.4 – Provide Operational recommendations for performance improvements
- UC2.5 – Operational Rating as a service

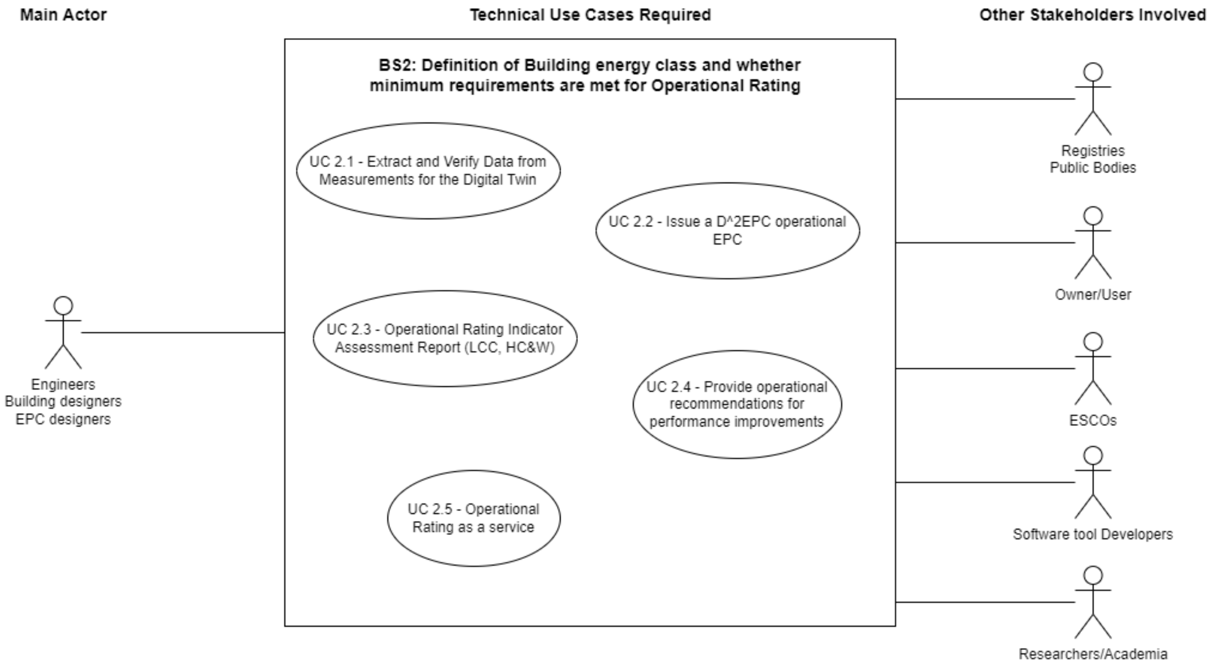

Figure 4. BS2 - Definition of buildings energy class and whether minimum requirements are met for Operational Rating

3.2 Business Group B: EPC Monitoring, Evaluation & Recommendation

This group covers another critical business need, and therefore the business value of the D^2EPC platform, which is the capability to monitor and evaluate real-time information from the building. Hence, the performance of the infrastructure after the EPC has been issued can be dynamically re-evaluated and provide for the necessary notifications and recommendations in terms of deviations, improvements, or in general preventive and corrective actions.

3.2.1 BS3: Provision of (near) real-time building information, deviations, and recommendations

As stated above, this business scenario aims for the provision of real-time information to the end-users. Starting from simple monitoring either of raw data or performance indicators/metrics, to more thorough visual analytics that properly introduces identified deviations and recommendation, a user centered approach is followed for regularly supporting the building's operation. Through this business scenario, it is also possible for authorities or public bodies to effectively and automatically monitor both asset (indirectly) and operational (directly) rating.

This Business Scenario (Figure 5), consists of the following technical Use Cases:

- UC3.1 – Provide (near) real-time building's energy performance information
- UC3.2 – Provide information on as-designed/in-operation deviations
- UC3.3 – Provide regular recommendation for improving operational energy performance & conditions in terms of health and comfort.

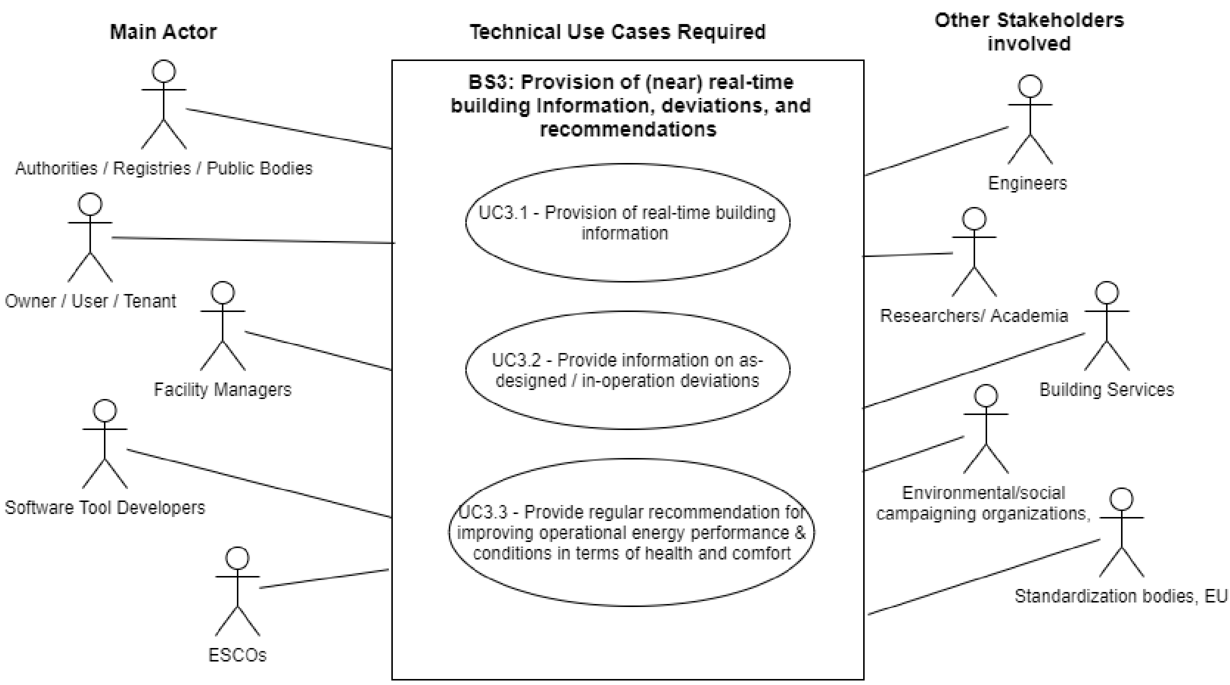

Figure 5. BS3 - Provision of (near) real-time building information, deviations, and recommendations.

3.3 Business Group C: Evaluation and Benchmarking of more certificates for policy making / marketing / business purposes

Following the dynamic aspects introduced by D^2EPC, additional added value services are introduced. These are covered within this group of business scenarios, where energy performance is anonymized and is provided as a service in quantity. Other by employing GIS-based representation or statistics that are presented through enriched visual analytics, the two business scenarios introduced, cover added-value services that have been identified and can introduce quite a few potential business models and revenue streams.

3.3.1 BS4: Provision of regional level of EPC statistics for third party stakeholders

The energy poverty or wealth of a region can be considered quite valuable information, towards multiple stakeholders. Hence, D^2EPC through the envisioned Web GIS tool is able to deliver such services, enhancing the information offered with additional dimensions, such as time (3D) and level of details (5D).

Another aspect covered through this scenario is the use of such provided information for benchmarking and standardisation purposes.

This Business Scenario (Figure 6), consists of the following technical Use Cases:

- UC4.1 – Regional Level Visualisation of dynamic (aspect of time) energy performance information for asset-based EPCs
- UC4.2 – Regional Level benchmarking and statistics comparison between regions
- UC4.3 – Building performance statistics for operational rating of pilot buildings and 3d visualisation

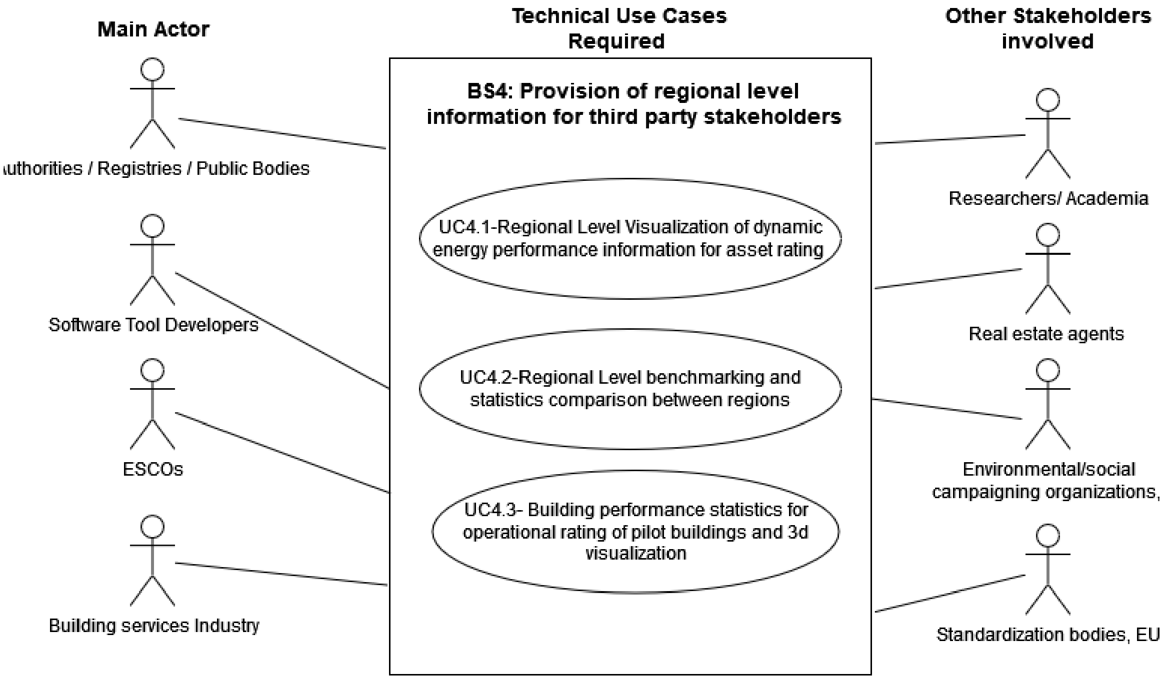

Figure 6. BS4 - Provision of regional level of EPC statistics for third party stakeholders

3.3.2 BS5: Provision of dEPC statistics related to materials, assets, etc. for promoting "greener" equipment campaigns

With time, information deriving from dynamic EPCs, and in general building performance, both in terms of asset or operational ratings, is expected to gain significant business value. In fact, various stakeholders that are closely related to building performance but need to be more actively engaged with EPCs, might require services that will introduce new revenue streams. As such, within D^2EPC, one additional business scenario has been identified and is documented below towards presenting this potential. This scenario and its actors are graphically presented in Figure 7. Two main technical use cases have been also included:

- UC5.1 – Provision and Visualisation of correlation of building materials and energy performance
- UC5.2 – Provision and Visualisation of correlation of building assets/systems and energy performance

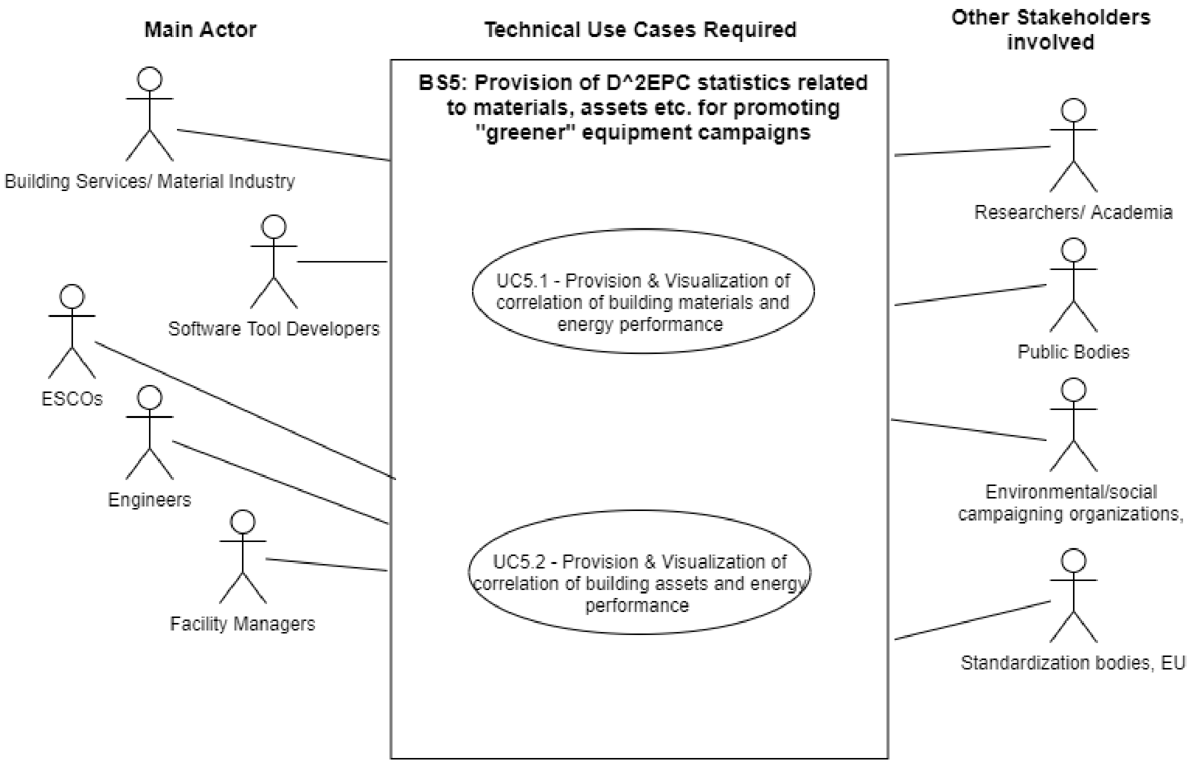

Figure 7. BS5 - Provision of dEPC statistics related to materials, assets, etc. for promoting "greener" equipment campaigns

4 Conceptual Architecture

The preliminary D^2EPC conceptual architecture has been provided from the very first steps of the project, when it was still at the ideation level. After the first six months, this architecture has been updated and has been customized towards better addressing market needs and business requirements that have been identified from WP1 activities. Within the last iteration of the T1.4 during M34-M36, minor updates of the system's architecture have been introduced in alignment with the project's progress.

D^2EPC aspires to deliver the next-generation of dynamic EPCs for the operational and regular assessment of buildings energy performance through a set of cutting-edge digital design and monitoring tools and services. D^2EPC relies upon and adjusts accordingly to the smart-readiness level of the buildings and the corresponding data collection infrastructure and management systems. It subsequently builds upon actual data and the 'digital twin' concept to calculate energy, environmental, financial and human comfort indicators and through them the EPC classification of the building in question. In this context, D^2EPC is based on Level 3 6D-BIM literacy, integrating smart meters, actual performance-related data and activities profiling into the buildings' digital twins. The proposed scheme provides sufficient background for the redefinition of EPC related policies, through regular benchmarking and upgrade of the reference buildings, as well as with the integration of geolocation and "polluter pay" practices into the EPC rationale. The implementation of the proposed project has attempted to foster the energy saving consciousness of buildings' users, through their regular information on the actual energy performance of their buildings and suitable incentivisation.

The proposed D^2EPC scheme has been designed with the aim to transform EPCs into a user-friendly, reliable and cost-effective informative tool for both the wide public (building users, occupants, owners, etc.) and professionals (building managers, engineers, designers, etc.), as well as to establish the grounds for turning EPCs registries into consistent policy feeding mechanisms.

The initial, high-level conceptual architecture that was originally drafted to deliver this vision, is depicted in Figure 8.

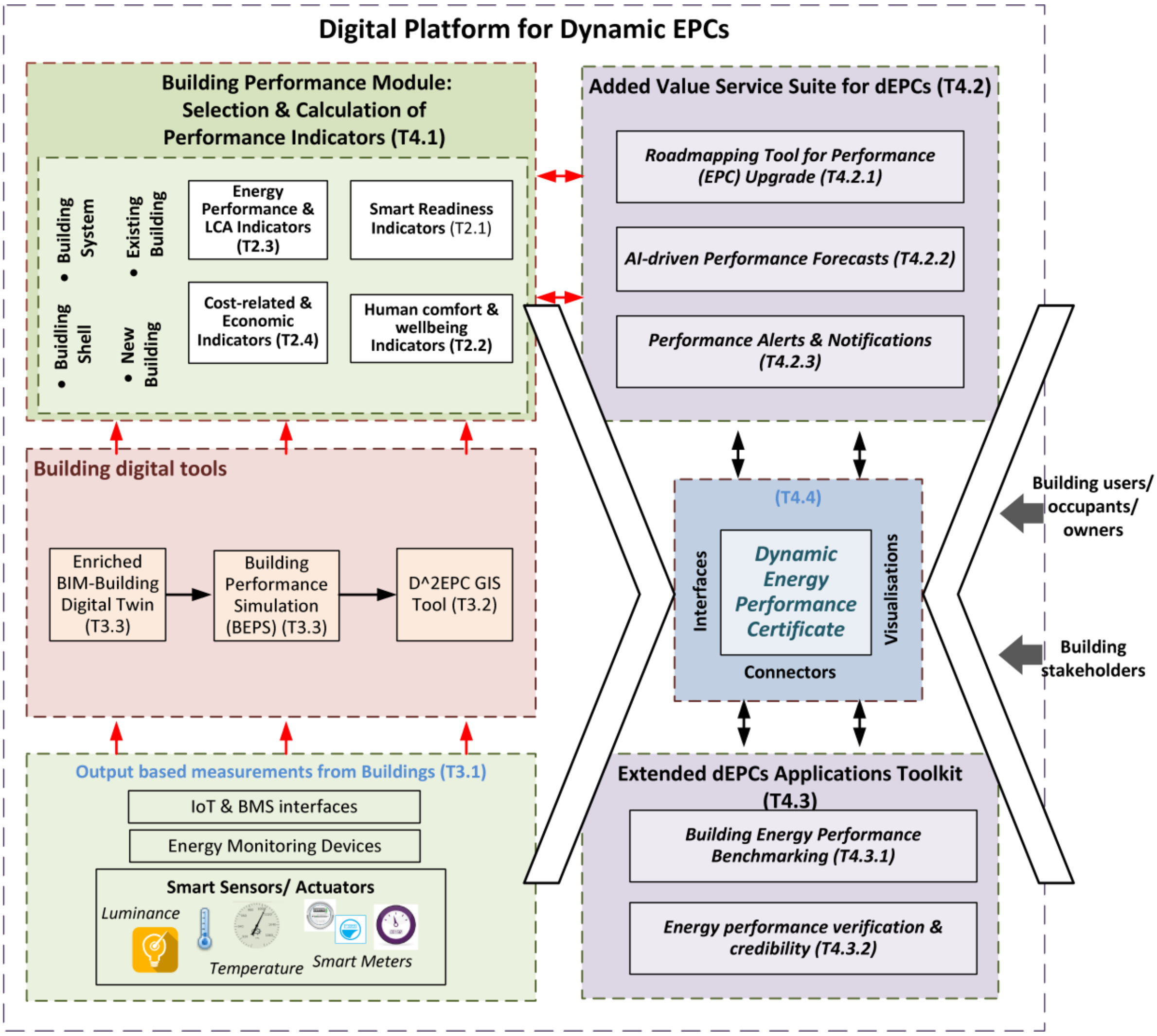

Figure 8. D^2EPC Initial Conceptual Architecture

As the project progressed, and architecture activities took place, the conceptual architecture has been revised, with certain components being re-named, delivering a more specific layered architecture, introducing also some information flows, as shown in Figure 9. In this last version of the task's deliverable, the interaction between the consisting components has been updated again according to the modified specifications of the latter.

Going further into the details, D^2EPC aims to deliver the above vision by introducing certain innovative aspects that are currently missing, require updates, or even required re-definition. These key aspects are summarized below:

1. **BIM-based Digital Twin (Obj. 4):** all building related information possible is retrieved from level 3 cloud-based BIM documents, and provide for the creation of the basic characteristics of a Digital Twin. All information required for the dEPC is retrieved from the created DTs, whereas any additional or missing information is provided through a user-friendly interface.
2. **Enhanced multi-parameter assessment by inclusion of new indicators (Obj.3 & Obj.5):** A set of new indicators (energy, smartness, sustainability, comfort, financial) enriches the current methodologies for both asset and operational rating. Investing on existing methodologies and standards, indicators are integrated unobtrusively to the dEPC process. As any novel

procedure, a **benchmarking** methodology delivers for the necessary measures of validation across different buildings.

3. **Delivery of Dynamic Energy Performance Certificates (Obj. 1):** Smart IoT devices are employed for the near-real time asset and operational energy assessment of the building, delivering new perspectives in the exploitation of EPCs (allowance of pollutants pay and incentive policies, awareness of users). The use of 6D BIM coupled with a state-of-the-art IoT ecosystem supports the automated extraction of the required information for ad-hoc real-time asset and operational rating results, as well as regular assessment of the building's operational status.
4. **Added value regional information through intelligent GIS:** GIS is used mainly for effectively visualising energy performance results for control purposes by public authorities and can spatially represent EPC-based energy consumption information.
5. **Improved AI-driven assessment recommendations (Obj. 6):** As an integral part of the EPC process, recommendations for improvements and more efficient energy performance are delivered in an automated and user-oriented approach. Exploring multiple alternative scenarios and AI-driven energy performance analysis, recommendations are provided towards optimal comfort and energy efficient building operation.

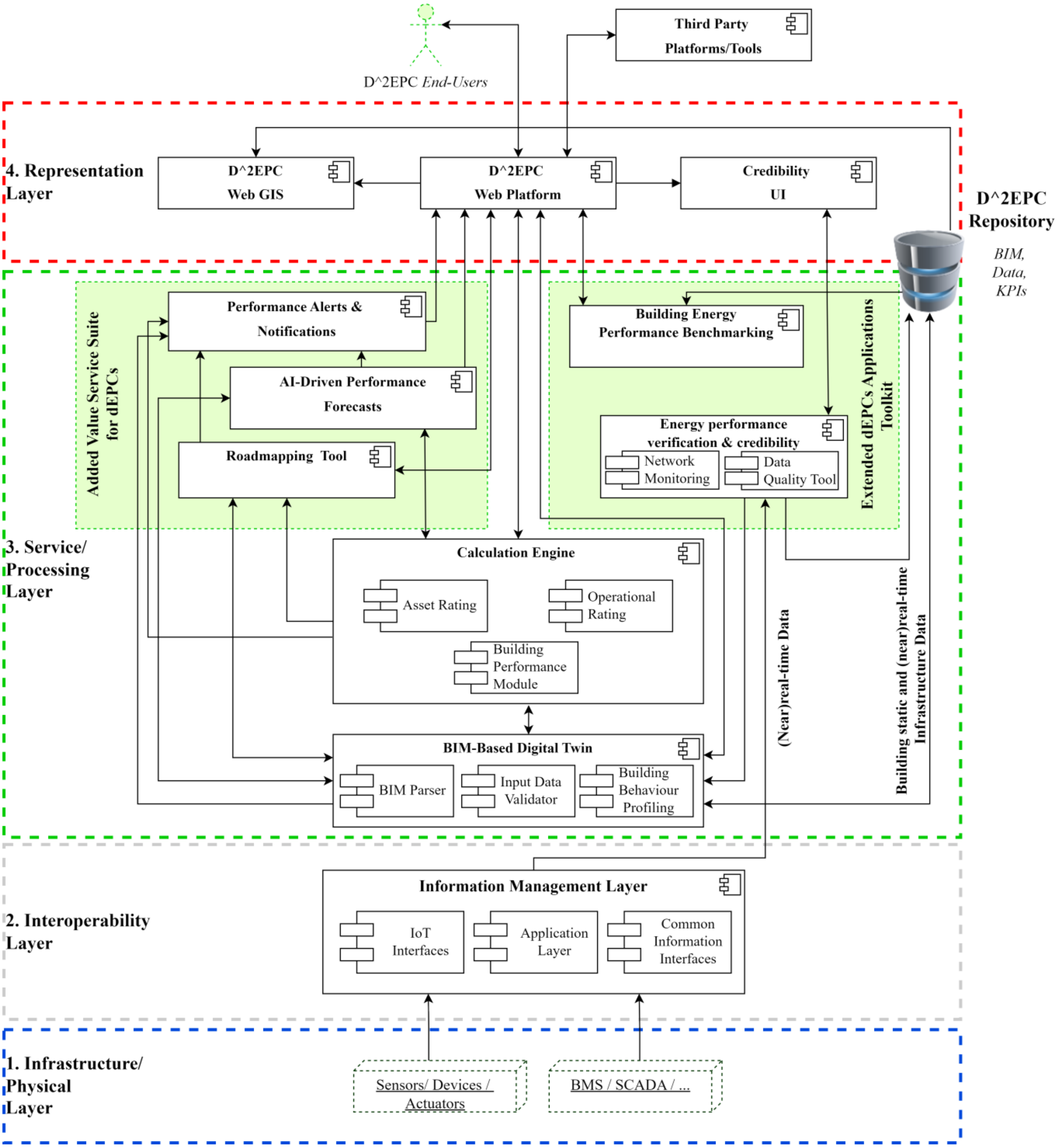

Figure 9. D^2EPC Layered Conceptual Architecture

The layers shown in Figure 9 are meant to fulfil the following goals:

- The **Infrastructure or Physical Layer** consists of one of the core layers for dynamic EPC, especially for the operational rating. Within this layer, all devices, sensors, actuators, and in general Internet of Things, and systems (i.e., Building Management System – BMS, Energy Management System – EMS, or even Supervisory control and data acquisition - SCADA) are included for collecting the necessary building information for all upper layers.
- The **Interoperability Layer** consists of one main D^2EPC component, i.e., *Information Management Layer*. This component is responsible for communicating with the building assets from the physical layer, retrieving the necessary information, translating it to a commonly

accepted format and streaming it to the D^2EPC Repository through the Energy Performance & Credibility component to be further utilised in other D^2EPC layers.

- The **Service/Processing Layer** consists of most D^2EPC components and sub-components responsible for delivering all the main functionalities envisioned:
  - *BIM-based Digital Twin,*
  - *D^2EPC Calculation Engine*
    - *Building Performance Module*
    - *Asset Rating Module*
    - *Operational Rating module*
  - *Added-value Service Suite for D^2EPC*
    - *Roadmapping Tool for Performance Upgrade*
    - *AI-driven Performance Forecasts*
    - *Performance Alerts & Notifications*
  - *Extended dEPCs Applications Toolkit*
    - *Building Energy Performance Benchmarking*
    - *Energy Performance and Credibility*
- The **Representation Layer** constitutes the layer that is offered for interaction with the end-users (engineers, building owners, registries, etc.) or third-party platforms / tools (i.e., b-logbooks, BIM design tools, etc.). Within this layer, three D^2EPC components are included, namely:
  - *D^2EPC Web Platform*
  - *D^2EPC Web GIS, and*
  - *Credibility UI.*

The D^2EPC Web Platform provides redirected access to the two other components, with a common (D^2EPC Web GIS) or separate (Credibility UI) user authentication service. A more efficient and dynamic interaction with end-users is considered through the mobile-friendliness feature of the developed components.

All the above components and sub-components, along with their functionalities and high-level information exchange are explained in detail in the following sections.

5 System Requirements

Following the design methodology, and in parallel with other WP1 activities, the technical and user requirements have been extracted towards better identifying the functionalities of the D^2EPC architecture to deliver the Business Scenarios that have been described in Section 3. This chapter provides an overview of the D^2EPC conceptual architecture as it has been redefined to better depict the information and decision flow within the D^2EPC framework.

To facilitate understanding of the requirements gathered, certain clusters/groups have been created based on the identified challenges that the D^2EPC framework addresses.

5.1 Functional Requirements

5.1.1 Dynamic concept - real time EPCs issued on regular basis

ID	Description	Partner	Rationale	Origin/ Source	Fit Criterion	Customer Satisfact. (CS)	Customer Disatisfact. (CD)	Priority
DEPC-15	The platform should be able to read (near) real-time data from smart sensors for the extraction of the operational rating of buildings on a regular timeframe or upon request	FRC	Need to develop an interface for reading and interpreting operational data for the operational rating of the building	Proposal	At least hourly data should be available from the IoT sensors /meters from the building	-	-	Critical
DEPC-16	Users receive information on the actual operational performance of their buildings via a (near) real-time platform	CLEO	Need to provide a real-time visualization of the building's energy consumption for the users. This requirement increases the amount of information received by the user	D1.2	Users should be able to see their current status vs their operational rating certificate at least every hour, or on-demand	1	4	Critical

ID	Description	Partner	Rationale	Origin/ Source	Fit Criterion	Customer Satisfact. (CS)	Customer Disatisfact. (CD)	Priority
DEPC-17	The platform should be able to support upon request Asset Rating EPC issuance based on BIM data	KTU	Need to include different time steps for the calculation of EPCs as presented by National Methodologies of each country. This requirement increases the credibility of the solution	D1.2	Compare the calculation results of selected EPC software against the results produced by the D^2EPC solution	-	-	Mediu m

5.1.2 Indicator based EPCs

ID	Description	Partner	Rationale	Origin/ Source	Fit Criterion	CS	CD	Priority
DEPC-18	Provision of Comfort & Indoor Air Quality (IAQ) indicators also including thermal conditions	CLEO	Need to include comfort & IAQ related indicators for the users which improves the overall EPC usability beyond issuance	D1.2	Calculate and compare these indicators with contextual information collected at the pilot sites such as heating/cooling energy consumption, indoor ambient temperature, VOC etc., over a period of time to identify the indicators validity in terms with real-life conditions.	1	4	Critical
DEPC-19	Information on the estimated return of investments, cost of renovation measures, the impact of renovation options on thermal comfort conditions and information related to the maintenance and operational cost of renovation measures	KTU	Need to present costs and return of investments of renovation measures as well as the impact of such measures on comfort levels. This requirement improves health levels, increase the rate of energy renovations and the information received	D1.2	Calculate these values based on current methodologies and compared the values provided by the D^2EPC solution as a mean of validation of the requirement	1	4	Critical

ID	Description	Partner	Rationale	Origin/ Source	Fit Criterion	CS	CD	Priority
DEPC-20	Monetary indicators of the whole life cycle cost of heating, cooling, lighting and appliances	KTU	Need to provide to the users financial indicators which include information on interest rates, bond yields and exchange rates of building systems	D1.2	Calculate these values based on current methodologies and compared the values provided by the D^2EPC solution as a mean of validation of the requirement	1	4	Critical
DEPC-21	Environmental assessment of buildings regarding LCA indicators	KTU	Need to include the parameterization of the embodied energy and primary energy demand of the building systems and to improve and optimize the environmental performance of the building, based on changes to be integrated at the initial design stages of the building.	DoA	Information on environmental aspects should be presented to the end-user through the web-dashboard.	-	-	Critical
DEPC-26	The platform should be able to measure SRIs information based on Building Automation and Control System (BACS) input from the BIM	FRC	Need to provide the inventory of buildings asset data and actual energy consumption measurements from smart meters with the constant flow of data coming from the building.	DoA	Provision of SRI indicators both as an input for the assessment process, as well as performance metrics to the end-users through the Web Platform. Provision also of an SRI report based on EU guidelines.	-	-	Critical

5.1.3 BIM based EPCs using input from Digital Twins

ID	Description	Partner	Rationale	Origin/ Source	Fit Criterion	CS	CD	Priority
DEPC-23	The platform should be able to read information on building geometry, orientation, climatic data, building materials and building systems from a BIM document	FRC	Need to develop a plugin that converts information from different BIM documents to required input for the calculation of the asset rating of the building.	DoA	Check the validity of the heating and cooling loads manually with the outcomes provided by the platform.	-	-	Critical

ID	Description	Partner	Rationale	Origin/ Source	Fit Criterion	CS	CD	Priority
DEPC-24	The system automatically verifies the data accessibility, timeliness, credibility, accuracy & completeness of the collected values	KTU	Data need to be verified by a tool combining the monitoring of the infrastructure health and the data quality of the collected information.	D1.2	Compare the current verification methods against the D^2EPC verification	-	-	Medium
DEPC-25	Digital links to other databases (e.g., B-Logbook)	KTU	Need for a common data repository for building energy-related data on cloud	D1.2	Depends on the API provided by third-party platforms. All necessary information according to EU guidelines should be able to be exported to another platform.	1	2	Nice to have

5.1.4 EPCs used as policy making tools

ID	Description	Partner	Rationale	Origin/ Source	Fit Criterion	CS	CD	Priority
DEPC-27	Visualisation of generated EPCs in a GIS environment, empowering users to perform various types of spatial and attribute queries	KTU	Need to include visualisation of EPC data in a GIS environment for the users which also allows comparison vs the statistics of the region	DoA	Provision of a geospatial database integrated with the updated inputs	1	3	Critical
DEPC-28	The GIS tool shall be able to make queries and analysis for regions, assisting and providing insight to policy makers	GSH	Need to provide valuable insights on buildings energy efficiency to NUTS regions which allows policy makers to monitor and introduce further energy-related policies	DoA	Access to additional descriptive data related to the building environment (approximate location, NUTS regions)	-	-	Major
DEPC-29	Capability of assessing individual apartments in multi-storey buildings	KTU	Current EPC methodologies are inefficient at assessing individual apartments in multi-storey buildings. This requirement	D1.2	Dynamic information should be provided at apartment level, instead of building level.	-	-	Nice to have

ID	Description	Partner	Rationale	Origin/ Source	Fit Criterion	CS	CD	Priority
			increases the accuracy of EPC results					
DEPC-30	The solution shall visualize buildings in a 2D mode and in its exact location, on a unified common coordinate system	GSH	Need to include 2D building mode and common coordinate system which enables visualization	DoA	Check the validity of the visualization deriving from different sources and CRSs, ensuring minimal distortions	-	-	Nice to have
DEPC-31	EPCs should alert public authorities in case of (i) overconsumption of buildings in order to enforce penalty measures or (ii) underconsumption for incentive procedures	FRC	Need to include incentivisation and restriction practices for the enhanced user awareness and engagement on buildings' energy efficiency. This requirement introduces further energy-related policies.	DoA	Deviations identified should be available to third-party platforms through an API.	-	-	Critical

5.1.5 Feedback on new EU standards on operational rating

ID	Description	Partner	Rationale	Origin/ Source	Fit Criterion	CS	CD	Priority
DEPC-33	The user can provide information about new technologies and systems (standards) for the platform's upgrade	CLEO	The EPCs need to be up to date with regards to new technologies currently on the market. There is a need to extend the input values of such technologies in EPCs. This requirement increases the accuracy of the EPC results	D1.2	Compare the input values for technologies of selected EPC software against the results produced by the D^2EPC solution	-	-	Nice to have
DEPC-34	The user can provide information for new standards/methodologies	FRC	The development of the set of values and input required for the issuance of operational EPCs should be identified	DoA	End-users should be able to provide feedback through a contact form to the D^2EPC Web Platform	-	-	Nice to have

ID	Description	Partner	Rationale	Origin/ Source	Fit Criterion	CS	CD	Priority
	related to operational EPC's for the platform's upgrade							

5.1.6 Other Requirements not categorised

ID	Description	Partner	Rationale	Origin/ Source	Fit Criterion	CS	CD	Priority
DEPC-45	The platform should be able to issue asset and operational rating certificates following EU standards	CERTH	A joint platform for EU MS for both rating systems doesn't exist but is required by the EC	DoA	Delivery of both asset and operation rating	5	5	Critical
DEPC-46	The platform should issue an SRI certificate based on methods A and B as defined by the EU in December 2020	CERTH	There aren't any calculation engines for delivering SRI certificates	DoA	Delivery of SRI certificates	4	4	Critical
DEPC-38	Quality Control for meter readings	SEC	If the meter readings are wrong, then no correct operational EPC may be compiled	DoA	The meter readings must be of high quality in terms of correctness and timely delivery of the readings. No outliers shall be allowed.	4	3	Critical
DEPC-47	Alerts based on predefined configuration	HYP	The users are able to select predefined rules in relation to specific information elements.	DoA	Data values and patterns complying to the predefined rules fully captured.	3	3	Major
DEPC-35	The data quality check must decide if a new operational EPC is presented	SEC	As in some regions or countries extended periods have similar data, the issuance of a new operational EPC may not be justified. On the contrary, if there are significant deviations	Market Needs	The data storage shall comply with GDPR, storing only tokens, no addresses nor names. Dubious data is to be flagged. Changes of meters must be handled, so the meter ID must be transmitted together with	-	-	Major

ID	Description	Partner	Rationale	Origin/ Source	Fit Criterion	CS	CD	Priority
			the EPC should be issued earlier. This may automate even more the dynamic EPC issuance.		the unit and a timestamp of the meter reading (metrological class of the meter shall be known but must not) The data storage interval for the meter readings shall not be longer than the EPC update interval. Data shall be dumped to have a back-up regularly. Monitoring of Operational Data from the building and deviations from the most recent Operational EPC might trigger or halt the issuance of an operational EPC			
DEPC-51	Users shall be able to give feed-back based on manual check of data, procedures, etc.	SEC	The users should be able to manually check the operational data and verify their quality. If not met with standards they should be able to configure the system or make other changes	Market Needs	The user is able to assess through graphical representation the data from the building used for the rating and request manually an extra check of the data credibility.	-	-	Nice to have
DEPC-36	Unification of end energy data into primary energy	SEC	The end energy demand is converted into primary energy demand to allow fair comparison of CO2 The heating demand of the building is an important indicator, to allow to rank the CO2 the used end energy is to be accounted for.	Market Need	The conversion factors shall take into consideration local cogeneration practice on a monthly basis.	-	-	Major
DEPC-39	Main climate correction data for the EPC production layer	SEC	The operational EPC is based on standard climates. Thus, degree days are necessary to calculate operational EPC. Degree days to	Market Need (German Legislatio	Degree days must be available for measured periods. (January 1st – February 1st, etc.) or might be calculated from weather data. This	-	-	

ID	Description	Partner	Rationale	Origin/ Source	Fit Criterion	CS	CD	Priority
			be used shall take into account the actual room temperatures and the cut of temperature theoretically, but we see that in Germany official correction data is taken for each postal code only, based on measured weather data. For our project, this data is not sufficient, since we need monthly data to be able to provide operational EPC each month during the heating period. It must be achieved for all pilots that heating degree days shall be available for each month and better may be calculated for a chosen time span.	n example)	weather data shall be marked as validated. Format shall be JSON			
DEPC-40	Operational Energy Inefficiency Correction (A correction algorithm is used to deduct parallel internal cooling demand from the heating demand)	SEC	Energy demand for Operational EPC is related to heating only	Market Need	For warmer climates and commercial buildings, the problem of parallel cooling and heating shall be tackled – deducting additionally to DHW – eventually, we need a correction algorithm, if this is a problem with some of the pilots	-	-	Nice to have
DEPC-41	Reference value for calculating operational EPC (The reference inhabited floor area is used to calculate the operational EPC)	SEC	Energy demand for Operational EPC is only correct if the heated area is correct.	Market Need	Reference inhabited (heated) floor areas must reflect the actual shape of the flats on each floor and exclude walls. Data shall be anonymous and related to the building.	-	-	Major

ID	Description	Partner	Rationale	Origin/ Source	Fit Criterion	CS	CD	Priority
DEPC-42	Allocation of consumed energy to heating	SEC	Domestic Hot Water demand is to be subtracted if the energy source is used for both and no metering of the DHW takes place.	Market Need	The domestic hot water correction must take into consideration the actual energy source for each of the floors (electric decentral heating, decentral solar, etc., or included in the meter readings), in the best case the occupancy and the difference between douche and bath shall be considered, as well as DHW circulation. Data shall be anonymous			Major
DEPC-43	Rerolling possibility for the operational EPC, if historical data is corrected and indication for changes (Data quality update allows to compile operational EPC with historical data)	SEC	-	Market Need	Rerolling shall create a new operational EPC result allowing to compare details with the old. Data about weather and DHW correction as well as heated floor area must be stored for every month (meter reading interval) to have documentation and basis for a new (revised) calculation. The old and the new rating is compared throughout the past periods.	-	-	Nice to have
DEPC-44	Test Data availability for testing the operative EPC tool (calculation and presentation)	SEC	Data shall be available for testing the operational EPC tool	Testing & Demonstration Purposes	Data must be provided for testing meter changes, changing heated floor areas, and the influence of the weather on the postal code. Data shall be available for up to three heating seasons and must be anonymous, data shall be in JSON, or CSV	-	-	Major
DEPC-49	The platform should support the possibility for the user to create	CERTH	It is already a core functionality of existing tools and should be	DoA / Market products	The end-user should be able to alter building parameters and issue a new certificate	3	5	Major

ID	Description	Partner	Rationale	Origin/ Source	Fit Criterion	CS	CD	Priority
	renovation scenarios and evaluate the performance		supported for the new KPIs and features of the D^2EPC platform					

5.2 Non-functional

ID	Description	Requirement Type	Partner	Rationale	Origin /Source	Fit Criterion	CS	CD	Priority
DEPC-6	The language used on the EPC must be simplified for easier understanding by an ordinary user	Usability	KTU	Need to simplify the language used in EPCs to understand by non-technical people. This requirement increases the usability of the EPC	D1.2	Validation of D^2EPC solution based on previous EPCs through a questionnaire of engaged stakeholders who provide their emails	1	4	Critical
DEPC-7	Valuable guidance for energy renovation measures is needed	Usability	KTU	Current EPCs do not explain the **importance of** energy renovation suggestions either **the benefits** of adopting such measures in the building level. This requirement increases the usability of the EPC	D1.2	Validation of D^2EPC solution based on previous EPCs through a questionnaire of engaged stakeholders who provide their emails	1	3	Major
DEPC-8	Authorization of further processing of user-owned consumption data	Usability	CLEO	Need to further process EPC data which gives valuable insights to energy related policies	D1.2	The data should be available to third parties in an agnostic and privacy-secured way.	-	-	Major
DEPC-9	The use of a combination of graphical and text representation of information	Usability	KTU	Need to present the results of the EPC in the most user-friendly manner using different means of presentation. This requirement increases the usability of the EPC	D1.2	Validation of D^2EPC solution based on previous EPCs through a questionnaire of engaged stakeholders who provide their emails	1	4	Major
DEPC-10	Polluter pay penalties for both user and the building designer after verification using a comparison tool to assess real consumption against the EPC	Usability	CLEO	Need to enable polluter pay penalties for the inconsistency of EPC with the allowable energy consumption of the buildings	D1.2	Comparison of the design-based EPC to the real-time operational EPC offered by the D^2EPC solution	2	4	Major

ID	Description	Requirement Type	Partner	Rationale	Origin /Source	Fit Criterion	CS	CD	Priority
DEPC-11	Data extracted from the building should be based on secure channels and protocols, starting from the use of IoT devices, sensors and building management systems	Security	KTU	The adoption of smart building technologies is hindered due to the user's concerns of data protection. This requirement increases the security related to data protection	D1.2	All IoT devices to be used are based on standardised communication protocols ensuring the data collection security	1	4	Major
DEPC-12	Protection of sensitive data when sharing energy-related data with third parties	Security	KTU	The adoption of smart building technologies is hindered due to the user's concerns of data protection. This requirement increases the security related to data protection	D1.2	All data are anonymized before shared with third parties, respecting GDPR regulations and without compromising the end-users' privacy.	1	4	Major
DEPC-13	Exclusion of exact building location, i.e., only postcode, and personal data in a public database	Security	KTU	The adoption of smart building technologies is hindered due to the user's concerns about data protection. This requirement increases the security related to data protection	D1.2	All data are anonymized before being shared with third parties, respecting GDPR regulations and without compromising the end-users' privacy.	1	4	Major
DEPC-14	The user shall be able to select between different basemaps for the 2D map	Look&Feel	GSH	Need to offer the possibility to the user to navigate and visualize basemaps in an effective manner	D1.2	Provision of tool for selecting the tile basemap of the WebGIS map	1	4	Medium
DEPC-50	The operational EPC shall consist of at least one figure for energy and one for CO2	Look&Feel	SEC	Need to offer to the user to understand the energy demand and CO2-**emission** impact of the building	D1.2	Proper visualization of energy demand and CO2 emissions	-	-	Major

6 Functional View

6.1 Context Diagram

Figure 10 presents the D^2EPC context diagram. A Context Diagram shows the system under consideration as a single high-level process and then shows the relationship that the system has with other external entities (systems, organizational groups, external data stores, etc.).

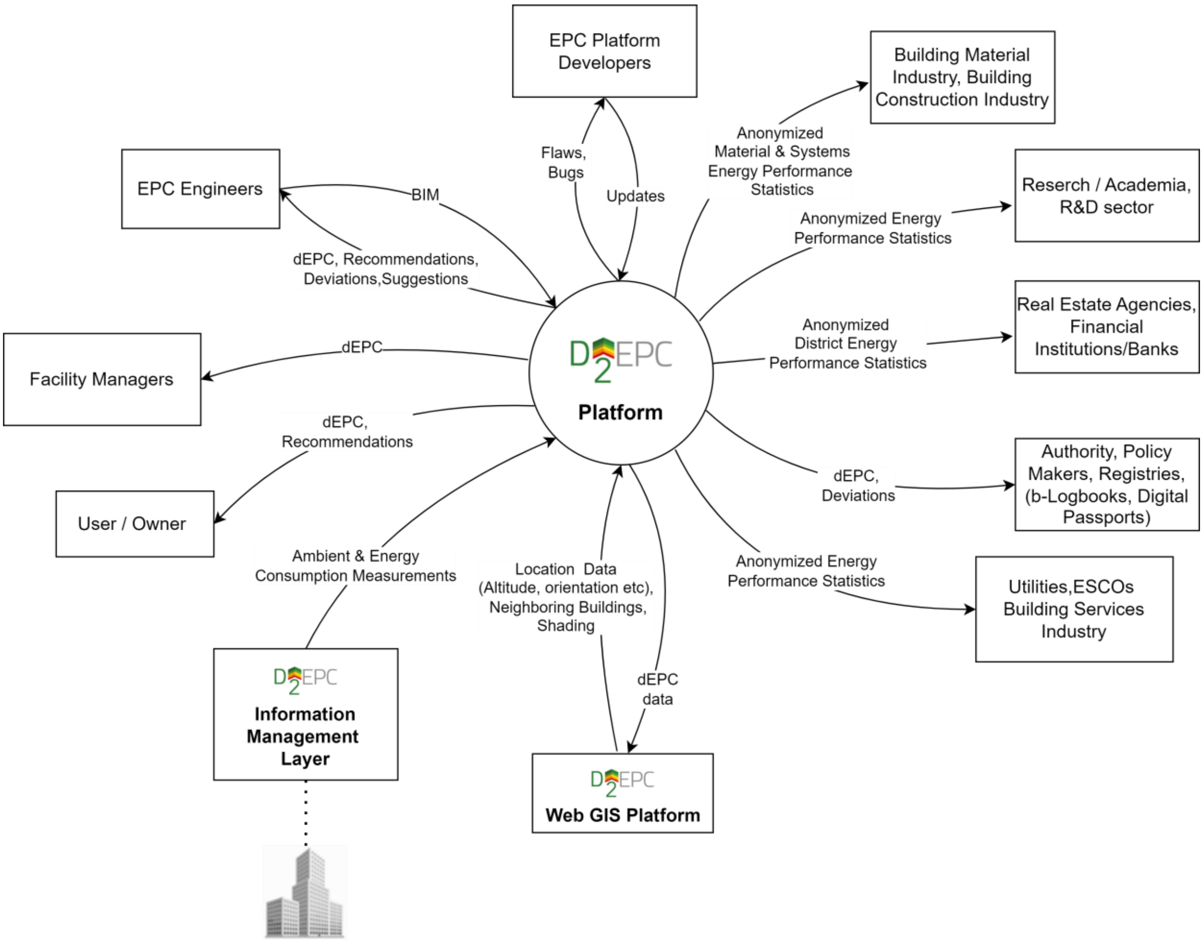

Figure 10. D^2EPC Context Diagram

Following, every core component or module (in terms of distinct) functionality is briefly explained, as more details are provided in the deliverables of WP3 and WP4.

6.2 D^2EPC Information Management Layer

The Information Management Layer (IML), as shown in Figure 11, is a cloud-based component to collect energy consumption and ambient conditions data strongly related to the building operation the IoT equipment including the Gateway and the off-the-shelf sensing equipment installed locally or by interfacing with open BMS available on site at the D^2EPC pilots. The IML component provides a secure environment for data collection and processing, and for communication and data exchange with other clouds. The IML component stores no data within D^2EPC, but streams all information collected to the common project repository.

The D^2EPC Information Management Layer consists of 3 sub-components as listed below.

6.2.1 Sub-components

6.2.1.1 IoT Interfaces

This subcomponent acts as an intermediary for communicating with the locally installed Gateways (if present). It is responsible for collecting all data streams through the reliable and secure communication framework established.

6.2.1.2 Application Layer

The application layer is the component responsible for the data processing. The term data processing within the context of the IML component refers to all procedures conducted under the established algorithmic framework, related to data cleansing, normalisation and transformation, to ensure the high quality of the collected data sets. It must be noted that the application layer is also the subcomponent responsible for transforming data into the appropriate format before further transmitting it to other D^2EPC components.

6.2.1.3 Common Information Interfaces

This subcomponent is responsible for establishing communication channels between the IML and other components or cloud-based services, enabling uninterrupted data exchange.

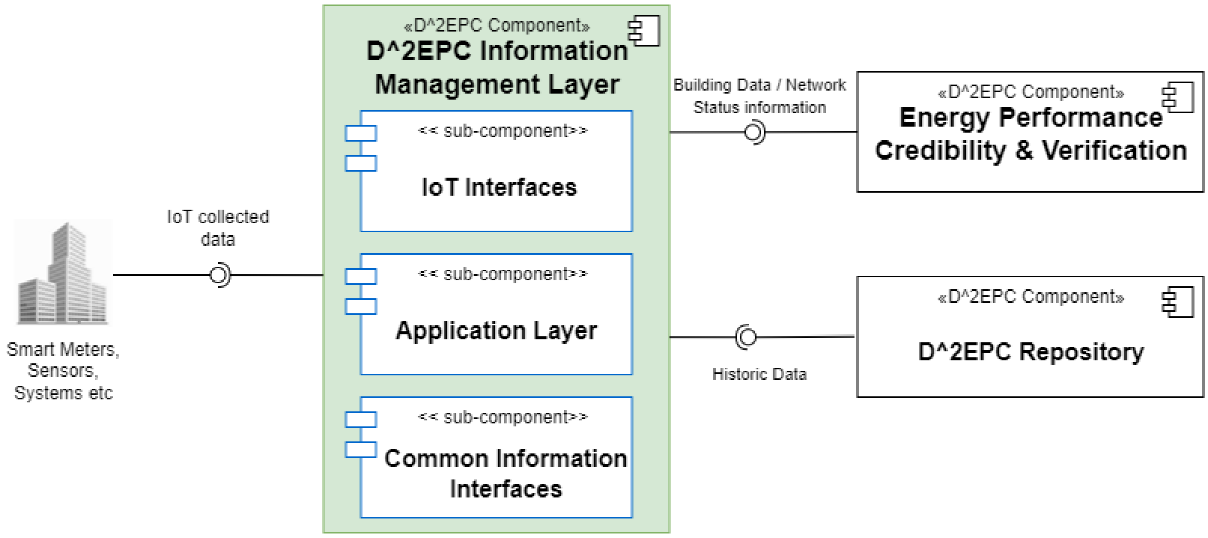

Figure 11. D^2EPC Information Management Layer Functional Diagram

Interface	R/W	Description (including preliminary format and context)
BMS & IoT	R	Collect data from the building infrastructure in real-time operation through open standards/communication protocols.
D^2EPC Repository	R	A separate communication channel is established with the D^2EPC repository in order the IML component to gain access in historic data (provided that it won't store any data).
Energy Performance Verification & Credibility	W	A separate communication channel is established with the D^2EPC repository in order the IML

		component to gain access in historic data (provided that it won't store any data).
Weather API (if needed)	R	Establishes an interface for data collection from a weather API in case a local weather station is not available.

6.3 Energy Performance Verification & Credibility

The Energy Performance Verification & Credibility (EPVC), as shown in Figure 12, is a cloud-based tool that aims to facilitate the verification process concerning the credibility of collected data streams through the locally installed IoT infrastructure/ equipment towards ensuring the reliability of the collected data. It introduces an automatic and continuous checking process of specific features related to data quality, availability etc.

With regards to the sensing network and the deployed hardware (gateway, sensors, metering equipment etc.) health, a particular user-friendly remote monitoring tool has been developed and integrated to the data validation and verification tool with physical representation of the network and ability to report any equipment malfunctions (communication interruptions, power failures, etc.).

6.3.1 Sub-components

6.3.1.1 Network monitoring tool

The Network monitoring tool is the subcomponent responsible for receiving and analysing the operational status of the IoT devices installed locally at the pilot sites. Upon detection of connection loss or malfunction of a device, the monitoring tool generates alerts for the end user presented by the Verification & Credibility UI.

6.3.1.2 Data quality tool

The Data quality tool is the subcomponent of the Energy Performance & Credibility component responsible for verifying the qualitative and quantitative reliability of the collected data defining their suitability to be used by other project components. The related factors considered are the credibility of the collected data based on whether the values remain within acceptable boundaries, their accuracy on reflecting the true state of the measured system and their completeness.

6.3.1.3 Verification & Credibility UI

The Verification & Credibility UI is a user-friendly interface responsible for reporting equipment malfunction and communication disruptions at the IoT devices network installed at the D^2EPC pilot sites. Additionally, notifications are provided to the end-users in case of problems identified in the collected data through the Data quality tool.

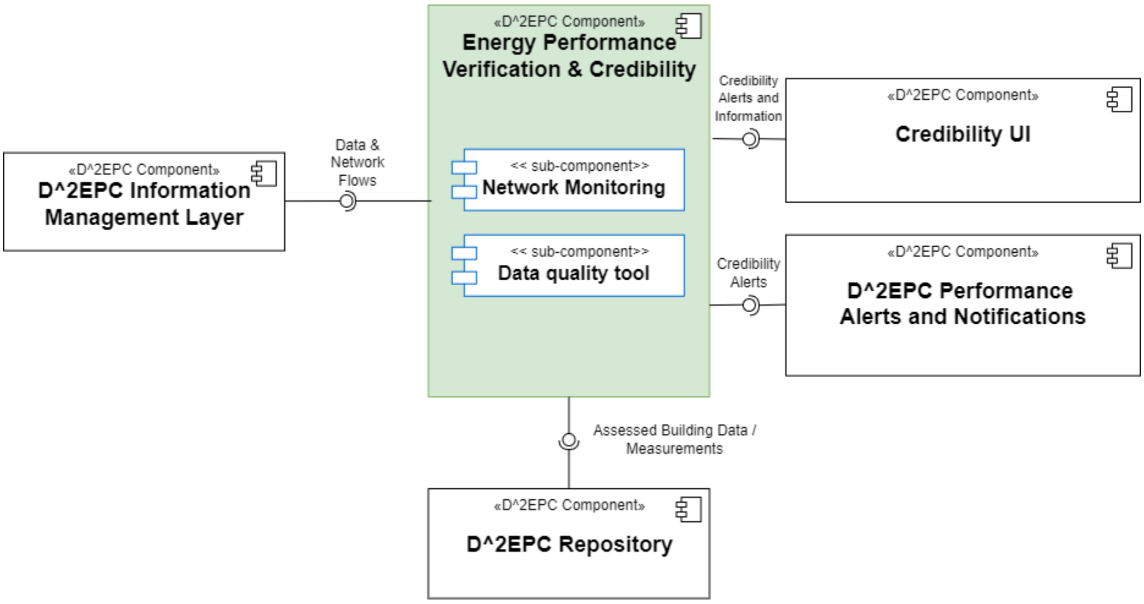

Figure 12. Energy Performance Verification & Credibility Functional Diagram.

Interface	R/W	Description (including preliminary format and context)
D^2EPC Information Management Layer	R	Collects data and network flows directly from the IML. as well
BIM based Digital Twin	W	Send verified building IoT data
Performance Alerts & Notifications	W	This interface is meant to receive signals (alerts) in the case of equipment malfunction and communication disruptions or in the case of problems identified in the collected data through the Data quality tool

6.4 BIM-based Digital Twin

As already covered in D1.2 and D1.3, current methodologies for EPC do not employ the information-rich BIM files. Within D^2EPC, BIM-based performance assessment is considered, towards minimizing the effort and complexity of the overall process. Level 3 BIM practices enable dynamic energy (re-)assessment, allowing (near) real-time (re-)evaluation of asset EPC. The already existing methodology for representing a building with the BIM model is further enriched with real-life building data, resulting in the Building Digital twin (BDT). The calculation tool of D^2EPC retrieves all required information available concerning the building envelope, the design and materials, as well as the building systems through the BDT. The digital model also helps adding various behavioural characteristics to the BIM, while its dynamic nature (thanks to the continuous collection of operational data) allows regular adaptation of the digital model to reflect more accurately the buildings' reality. Also, a set of novel smartness, holistic, human-centric and sustainability indicators envisioned by the D^2EPC are calculated on the digital twin level, while simulation and forecasting capabilities enable proactive or early-stage response to identified deviations. By properly identifying the correlation between static and dynamic information originating from the various systems, an alive digital ecosystem becomes available for delivering the necessary level of information for dynamically extracting the building's performance. Furthermore, by identifying the building energy behavior patterns, the opportunity for near future energy performance predictions is given. The outcoming results feed modules that indicate recommendations to improve and optimize the buildings' energy design and construction (asset level), as well as operation and management (operational level), aiming towards improving the building's energy performance while potentially minimizing related costs and their environmental impact. The functional diagram of the Building Digital Twin is shown in Figure 13.

6.4.1 Sub-components

6.4.1.1 BIM Parser

The first step for the development of the digital twin is the creation of a parametric data model that contains all the necessary information for the building's elements (geometry, materials, constructive systems, technical system, sensing/metering devices etc.) and the way they interact with the surrounding elements and the environment (i.e., the BIM). It is now clear that quite a lot of information required, mainly for asset rating, but for operational as well, can be extracted by BIM files. The information derived from the building's BIM is used to estimate the overall energy performance in a detailed way including innovative features that can affect drastically the certification process. These features are related with the building smart readiness (SRI), human-comfort and wellbeing, energy performance and LCA analysis as well as analysis of cost and economic indicators. The BIM Parser subcomponent performs an in-depth analysis of BIM files in .ifc format, extracting and organizing information, in order to create a well-structured, json-based building data model. The latter constitutes the foundation towards effectively forming the BDT.

6.4.1.2 Input Data Validator

Considering the large amount of complex data retrieved from the BIM, there is an obvious need for proper data validation in order to handle missing or incorrect information. This process is carried out by the Input Data Validator, which is responsible for confirming the correctness and quality of the information extracted by the BIM Parser. Several forms of verification checks are performed, in terms of data type, range, uniqueness, consistency and code, leading to the generation of a report that identifies all the fields that do not meet the set requirements or are simply missing. The result is then communicated to the user through the Web Platform to perform the necessary corrective actions. The operation of this subcomponent is focused but not limited to the BIM data handling; any user-inserted information is similarly validated to ensure proper storage of information to create the building's digital twin. Additionally, real-time data from the EPVC tool are also channeled through the validator, to ensure proper correspondence between IDs of real data and static information from the BIM.

6.4.1.3 Building Behaviour Profiling

Combining the BIM model with real-time data gives the opportunity to describe various behaviours of the building (e.g., state transition, performance degradation) and the way that its systems react against changes in the external environment or user preferences. Several aspects of the building behaviour have to be examined in this process and thus multiple models are used to describe them. The Building Behaviour Profiling is responsible for mapping the entire building digital entity, including the nested interrelations, to a class object that can serve as a copied instance of the original building. Moreover, it provides necessary functions that can be used to access any level of information, modify different parameters and perform the required calculations, allowing the accessing service/tool to examine the building's behavioural response to potential changes.

A more detailed description of the Building Digital Twin aspects has been elaborated within T3.3 activities and documented in D3.5.

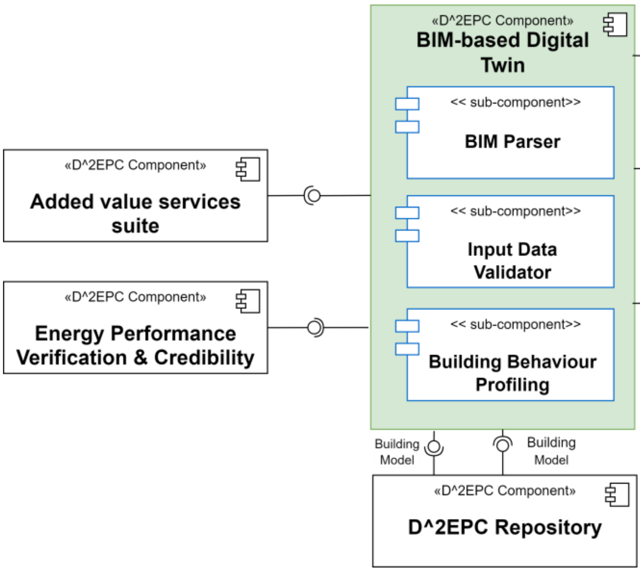

Figure 13. Building Digital Twin Functional Diagram

Interface	R/W	Description (including preliminary format and context)
Repository	R/W	This interface exposes building information (BIM, user info, etc.) and historical (near) real-time data from building measurements. Certain changes / configurations are stored back to the repository.
D^2EPC Web Platform	R/W	This interface is meant to receive static and dynamic building information, as well as to update modify the building stored information
AI Performance Forecast	R	This interface regards operational measurements for both models' training and execution
Calculation Engine	W	This interface is meant to receive static and dynamic building information.
Performance Alerts & Notifications	W	This interface concerns building-related notifications.
Energy Performance Verification & Credibility	R	This interface regards actual building measurements.

6.5 Calculation Engine

The Calculation engine (Figure 14) is one of the fundamental components of D^2EPC. This component is responsible for performing all the necessary calculations for accurately assessing both asset-related and operation-related performance. Three main modules are implemented to deliver the whole spectrum of KPIs included in the D^2EPC scheme. The Asset Rating module is related with the calculation of the building's as-designed energy performance, while the operational energy performance of the building is examined by the dedicated Operational Rating module. The extended set of KPIs regarding the building's financial and environmental status, human-comfort conditions as well as smart-readiness are calculated by the Building Performance Module. Each one of the three modules utilizes the BIM based Digital Twin documentation to access different sets of information, according to its respective calculation methodology.

6.5.1 Building Performance Module (BPM)

This module is responsible for calculating the enriched set of D^2EPC KPIs, including the ones that are already included in current EPC practices. The BPM is further divided into 4 dedicated submodules. Firstly, the SRI and LCA modules receive static information from the BIM-based DT to calculate the smart-readiness and life-cycle sets of KPIs, respectively. The Cost & Economic (C&E) indicators submodule utilizes both static and dynamic data to calculate the financial KPIs at the various operational stages of a building's life span. Lastly, the Human Comfort and Wellbeing (HC&W) submodule receives the indoor environment measurements to evaluate the occupant's well-being. The co-existence of the above modules in a common environment enhances the interoperability of the produced information and paves the way for further enrichment of the performance indicator's set though the combinations that can be generated.

6.5.2 Asset Rating Module

The role of this module is to evaluate the energy performance of the building's structure, *as-designed*. The development of this module is based on two main pillars; the automation of the EPC issuance procedure and the development of a common AR tool for the energy performance assessment of any building type throughout the EU MS included in the D^2EPC project. The collaboration of the module with the BIM-based Digital Twin enables the utilization of the already existing building documentation, thus minimizing the required human effort and the cost of the EPC issuance. Despite the highly automated asset rating procedure, the role of the EPC assessor remains major throughout the EPC issuance. Assessors are responsible for the intermediate evaluation of the inserted information from the BIM file, as well as the addition of any critical information missing from the BIM file. This is realized through the process carried out by the aforementioned Input Data Validator, which based on the requirements set by the asset rating module, may request additional information from the EPC assessor towards performing the asset-based assessment. The assessors also evaluate the results generated from the energy calculation and the classification of the examined building.

D^2EPC introduces a common EU-based Asset Rating methodology that enables the evaluation of the building stock under a common set of parameters and limits the discrepancies in the energy certification, introduced so far by the various national EPC schemes. For this purpose, D^2EPC adopted the EN ISO 52000 [9] series of standards as the foundation for the development of the Asset Rating Core Engine calculation module. Even though the standard provides the main set of equations for the calculation of the energy performance, the AR methodology has also utilized certain sets of information from the national EPC regulation frameworks, from the countries involved in the project (e.g., climate conditions, energy carrier data, boundary conditions and operation schedules of thermal zones).

The AR module provides both the classification of the building, as well as an extended set of the building's theoretical energy consumption results, under the pre-defined and standardized consumption profiles. The latter set of results includes information about the energy consumption per energy service (e.g., heating, cooling) or any possible on-site energy production (e.g., solar thermal collectors, PV), as well as per energy carrier. The calculations are presented per the three stages of energy conversion; energy demand, final and primary energy. The calculations for CO_2 emission and annual energy consumption cost are also included in the final results.

6.5.3 Operational Rating Module

In contrast to the Asset Rating, the Operational Rating (OR) module evaluates the *as-operated* energy performance of the examined building taking as a main input the measurements of energy consumption. The module utilizes the static and dynamic information, derived from the BIM-based Digital Twin, to evaluate the operational performance of the building in daily, monthly and yearly horizon. The EU-based calculation methodology for the Operational Rating has been developed within the D^2EPC project and aims to bridge the gap created from the variety of existing national methodologies.

According to the requirements of the proposed methodology, the tool facilitates the dynamic and automated issuance of the Operational rating Report. The issuance frequency is six months. Each Operational Rating report will be delivered to the Digital Twin module and stored at the D^2EPC Repository.

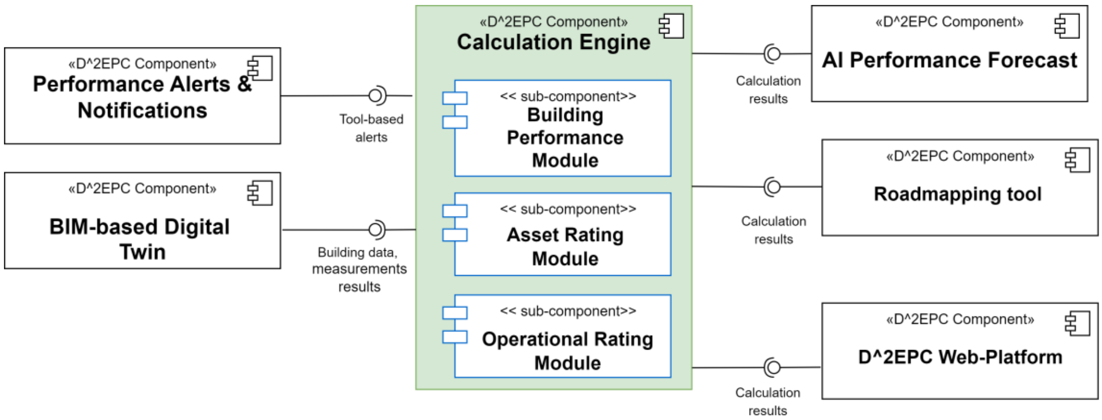

Figure 14. Calculation Engine Functional Diagram

Interface	R/W	Description (including preliminary format and context)
Performance Alerts & Notifications	W	This interfaces notifications and alerts generated by the tools.
BIM-based Digital Twin	R	This interface is meant to send static and dynamic building information
D^2EPC Web-Platform	W	This interface regards the tools parametrization and the visualization of the calculation results.
Roadmapping Tool	R/W	This interface concerns the different renovation scenarios for calculating the energy performance and assessing the scenario's viability.
AI-driven Performance Forecast	R/W	This interface concerns the predicted energy performance scenarios for calculating the Operational EPC rating results.

6.6 Roadmapping tool for performance upgrade

The main goal of this tool (Figure 15) is to provide the end-user with a complete roadmap with indicative renovation actions that intend to boost the building's energy performance. The development of this module has considered national renovation guidelines.

The Roadmapping Tool receives all the required information regarding the building's current state and exploits multiple strategic scenarios generation and novel decision support algorithms to explore from a large pool of potential solutions and identifies optimal scenarios based on the individual characteristics of each case.

The operation of this tool relies on the BIM-based DT and the Calculation Engine. The first is used to retrieve all the required information regarding the building's infrastructure and operational characteristics. The Calculation Engine (Asset Rating module) is used to evaluate the impact of each renovation scenario in terms of energy performance improvement.

The end-result is the generation of a solid and efficient renovation roadmap to guide both the EPC assessor and inform the building owner about the impact that a potential renovation could have to the building's overall performance.

6.6.1 Sub-components

6.6.1.1 Asset Management Scenario Generator

This component focuses on the generation of multiple renovation scenarios based on a predetermined list of renovation actions. Initially, the tool preforms a diagnosis of the building's current state and examines its compliance with the minimum requirements, derived from the national standards/ building codes or with the requirements defined by the energy assessor. The next step is to generate a variety of renovation scenarios aiming not only to just minimize its energy consumption, but also to improve the building operation in a holistic way, as described above. Each renovation scenario is provided to the Calculation Engine module to calculate the required list of KPIs and evaluate its overall performance.

6.6.1.2 Decision Support System

The resulted KPIs from each scenario are inserted into the Decision Support System (DSS) in order to perform a multi-criterion selection algorithm for the identification of the optimal renovation solutions and their prioritization in an ordered renovation activities list. According to the results, the tool generates a prioritized list with renovation actions, starting from the steps with a higher impact to the building's overall performance. The resulting renovation steps comprise the roadmap that the owner should follow to improve the building's energy performance.

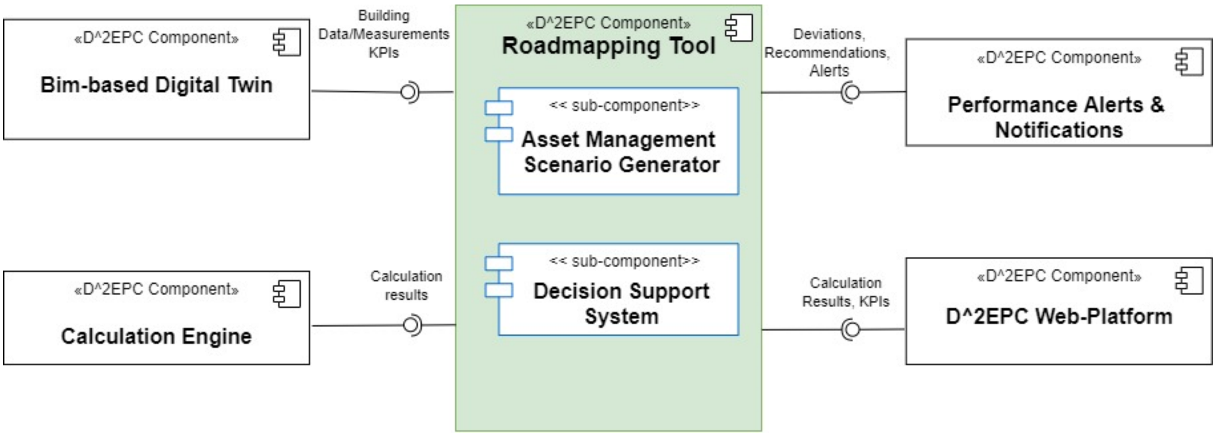

Figure 15 Roadmapping tool for performance upgrade

Interface	R/W	Description (including preliminary format and context)
Calculation Engine	R/W	Delivers different scenarios for calculating the energy performance and assessing the scenario's viability.
Performance Alerts & Notifications	W	Generates the recommendation context to be delivered as a notification for the end-user.
D^2EPC Web-Platform	W	Delivers building specific recommendations and user- centered suggestions

6.7 AI-driven Performance Forecasts

This component (Figure 16) acts complementary to the Roadmapping Tool by analysing in detail operational information extracted from the building. State-of-the-art AI algorithms (e.g., gradient boosting trees, recurrent neural networks, etc.) are employed to train dedicated models and forecast building operating conditions and their impact in building's energy efficiency/performance. The goal is to coordinate operation of building's assets in the optimal comfort and energy efficient manner and proactively indicate any patterns that if not pointed out and modified, might affect negatively the energy performance certification class of the building.

This tool feeds information into the Performance Notifications and Alerts component, to inform the user both during the EPC issuance (for operational rating), but most importantly during the actual operation of the building in (near) real-time.

This component consists of two modules, one for adaptively and regular training the models required, using a lightweight approach to avoid stressing the system, whereas the second performs the actual forecasting when needed.

6.7.1 Sub-components

6.7.1.1 Adaptive Lightweight Training

Given the frequent changes identified in user's behavior and building's use, this component is re-trained regularly based on new measurements provided from the building. This submodule is responsible for executing a lightweight process for re-training the AI-driven forecasting models, towards more easily adapting to the building's actual operational characteristics.

6.7.1.2 Performance Forecasting

By employing machine learning techniques to achieve dynamic, long-term building energy consumption forecasting, this submodule utilizes the Operational Rating module of the Calculation Engine in order to predict potential changes in the building's energy classification, notifying the user accordingly in case of an identified possible performance downgrade.

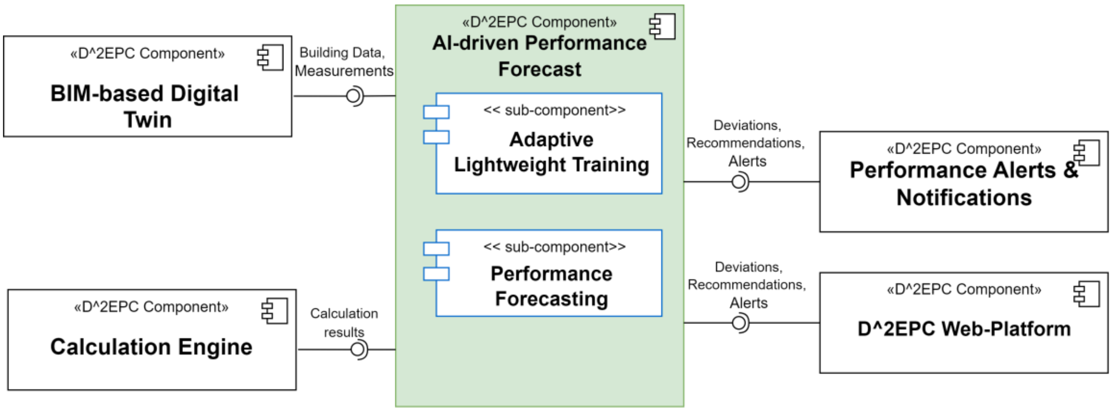

Figure 16. AI-driven Performance Forecasts Functional Diagram

Interface	R/W	Description (including preliminary format and context)
BIM-based Digital Twin	R	Retrieves building information and operational measurements for both models' training and execution.
Calculation Engine	R/W	Provides new scenarios for calculating Operational EPC rating results
Performance Alerts & Notifications	W	Generates the recommendation context to be delivered as a notification for the end-user.
D^2EPC Web Platform	W	Visualizes the results and sends further information about the proposed recommendations to be delivered to the end-user.

6.8 Performance Alerts & Notifications

The Performance Alerts & Notifications component is responsible for delivering not only the recommendations during the process of issuing an EPC (as notifications), but also during the actual operation of the building. The users can setup custom alerts against data sources, to notify them under certain conditions that may affect building energy performance and eventually might result in performance downgrade. Moreover, the tool provides specific notifications related to the execution of other tools, in order to provide guidelines during the EPC assessment process.

According to Article 11 of the EPBD, recommendations to users are mandatory in EPCs. To this end, this tool (Figure 17) is able to cover a wider range of recommendations during the EPC issuance and the (near)real time building's operation. Additional functionalities include the support provided to property owners with acurate and customised recommendations for daily operations, maintenance, and even renovations.

The notifications provided are semantically enriched based on information dynamically extracted by the various D^2EPC components, to optimally pinpoint the challenging issue and the appropriate user-response.

6.8.1 Sub-components

6.8.1.1 Notification Engine

This submodule is the backbone of the component, able to also provide for personalized context based on specific user profiles. The engine is configurable through the D^2EPC Web Platform, allowing for the creation of custom alerts that each tool produces. In addition, this submodule translates the recommendations provided by the AI-driven performance forecast and the EPC Roadmapping Upgrade tools into user-aware notifications that support the feedback towards the user.

6.8.1.2 Communication Client

This is the necessary submodule for connecting and pushing notifications to the Web Platform and the D^2EPC Repository.

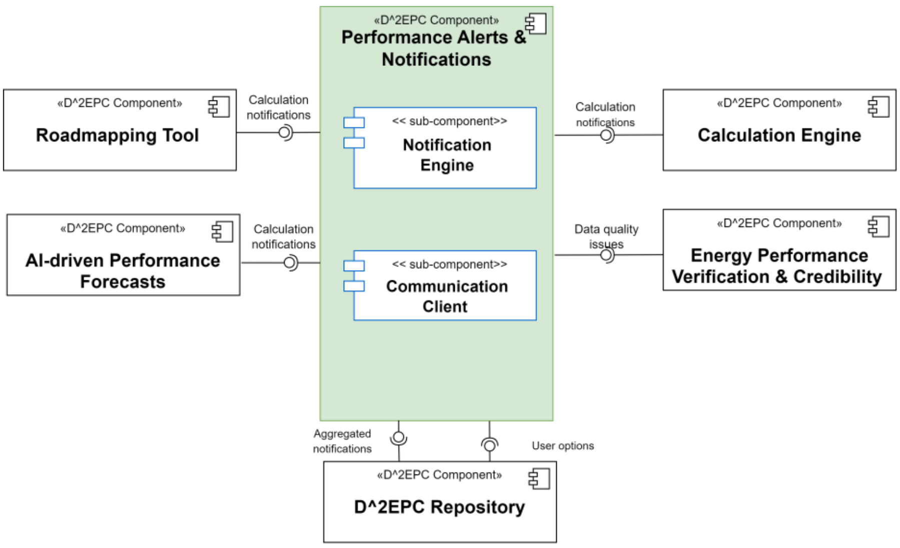

Figure 17 Performance Alerts & Notifications Functional Diagram

Interface	R/W	Description (including preliminary format and context)
AI-driven Performance Forecasts	R	Receives operational recommendations to create user-oriented notifications.
Roadmapping tool	R	Receives asset recommendations to create user-oriented notifications.
BIM-based Digital Twin	R	Receives building related information

Energy Performance Verification & Credibility Tool	R	Receives measurements that are not in the expected range, or signals in the case of equipment malfunction and communication disruptions.
D^2EPC Repository	R/W	Stores and receives older Alerts & Notifications
Calculation Engine	R	Receives operational and asset rating calculations to create user-oriented notifications
D^2EPC Web Platform	R/W	Provides for configuration capabilities for creating custom alerts and personalised notifications. Receives recommendations.

6.9 Building Energy Performance Benchmarking

This component (Figure 18) is responsible for the Classification / Comparison of buildings with reference to certain metrics, such as the as-designed and the as-operated performance, the smart readiness etc. Through the detailed analysis of the information deriving from the issuing process, this tool acts as a classification engine. This classification indicates the potential paths for performance improvements and can provide valuable insight to the Roadmapping tool and building renovation passports.

6.9.1 Sub-components

6.9.1.1 Classification Tool

The first step of this component is to properly classify buildings based on various traits, regarding both infrastructure and energy-related performance characteristics. These include, but not limited to, the residing European region and the building primary usage, as well as the asset and operational based EPC results and the smart readiness scores.

6.9.1.2 Benchmarking Tool

Building on the above classes, D^2EPC provides for an automated benchmarking service that invests on normalized metrics towards evaluating the performance of different buildings from different perspectives. The outcome of this benchmarking provides valuable information in terms of single building comparison to the building stock as well as overall statistics for the building stock.

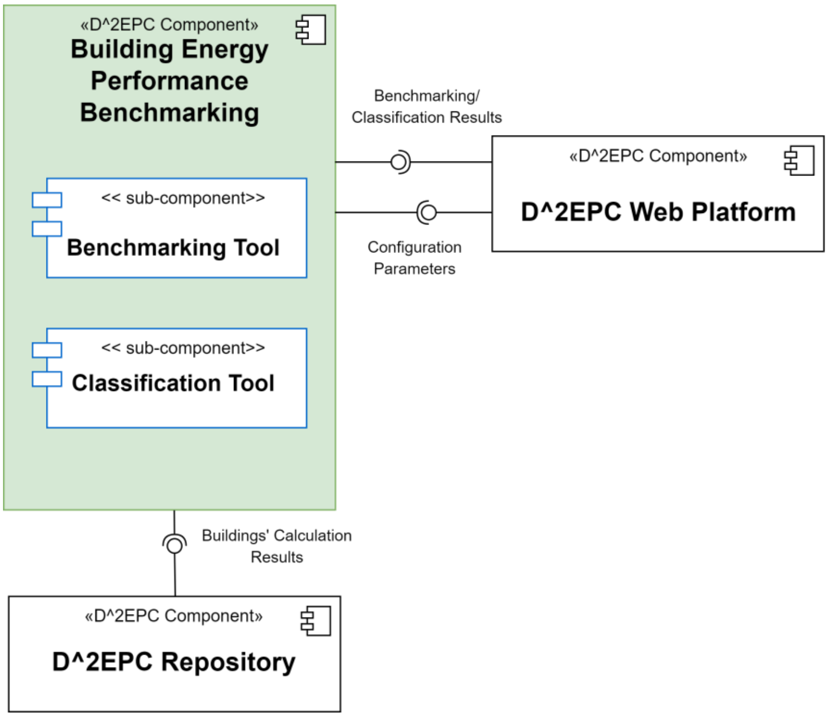

Figure 18 Building Energy Performance Benchmarking Functional Diagram

Interface	R/W	Description (including preliminary format and context)
D^2EPC Web Platform	W	Receives the benchmarking results to be delivered to the end user and provides configuration options for the tool.
D^2EPC Repository	R	Building performance results.

6.10 D^2EPC Web GIS Tool

A geographic information system (GIS) is a framework for gathering, managing, and analyzing data. Rooted in the science of geography, GIS integrates many types of data and information. It analyzes spatial location and organizes layers of information into visualizations using maps and 3D scenes. With this unique capability, GIS reveals deeper insights into data, such as patterns, relationships, and situations—supporting experts, practitioners and authorities in order to make smarter decisions, while helping users in general to understand complex spatial phenomena.

The D^2EPC GIS Tool, as shown in Figure 19, is an additional system on top of which energy quality data and dEPC information can be viewed in a GIS environment. The D^2EPC GIS tool is enhanced by adding multiple dimensions, regarding time (4^{th} Dimension) and level of details (5^{th} Dimension).

The creation of an open source database is suggested. Database creation and configuration is conducted through the latest database management tool, pgAdmin. The PostgreSQL database is an open source database management system (DBMS) that emphasizes the scalability of its applications and the compliance with the most technical standards. The PostgreSQL source code is available for free. By using the appropriate extensions (e.g., PostGIS) it is possible to extract GIS information to the D^2EPC databases, also ensuring interoperability with most OpenGIS Consortium (OGC) mapping standards such as: Web Map Service (WMS), Web Feature Service (WFS), etc. With the successful creation of the system database, through the online platform, the user is able to implement queries through a search form that leads to the execution of SQL queries and visualization of the results on a map but is also able to find polygonal entities on the map. It is also able to generate new queries by using combinational descriptive information (queries).

6.10.1 Sub-components

6.10.1.1 Spatial Database

As the sources of the data to be visualized are many and varied, there is the need for a database management system, in order to better organize, retrieve and interconnect the whole set of datasets. In the case of the Web GIS tool, a spatial database system is necessary, as the geometry and location of each element are crucial factors for the visualization and further analysis. As a result, a PostgreSQL database system is suggested. PostgreSQL is a free and open-source object relational database management system (DBMS) emphasizing extensibility and SQL compliance. This DBMS has powerful add-ons, including the PostGIS geospatial database extender, which is essential for the management of spatial datasets. By creating the D^2EPC system spatial database, the user of the tool is able to request complex calculations and SQL queries and receive fast answers through various ways of visualization depending on the query. The crucial part of a spatial database is the fact that the calculations consider the spatial dimension of the data and provide new spatial results, and also can be filtered through spatial restrictions, such as the vicinity, the distance, etc.

6.10.1.2 Open Source Web Mapping Server

In order to publish spatial data on the Internet, a web mapping server and geospatial internet services (WMS, WFS, etc.) are needed. A web mapping server is designed to be interoperable, which means that it allows the publishing of maps and spatial data from a variety of templates to client software, such as web browsers and Geographic Information Systems software. Geoserver and MapServer are two popular open source mapservers, whose goal is to make geospatial information as accessible as possible, by using specialized protocols such as Web Map Service (WMS), Web Feature Service (WFS), etc. that are designed to transfer the geospatial information to and from the server, according to the OGC (Open Geospatial Consortium) protocols. The In D^2EPC platform, the web mapping server links the spatial database with the tool, by being the organizer and the publisher of the datasets.

6.10.1.3 Open source JavaScript libraries

Open source client-side JavaScript libraries are utilized in order to publish the final results on the platform. Specifically, open-source client-side JavaScript libraries and HTML and CSS scripts are needed for embedding dynamic and interactive maps in web browsers. These libraries, such as OpenLayers and Leaflet, provide the technology for building web–based geographic applications, through tools that allow the configuration of their environment, such as zoom, pan, navigation map functions and many plugins for extending the web map's functionality with drawing tools, interfaces, pop-up windows etc.

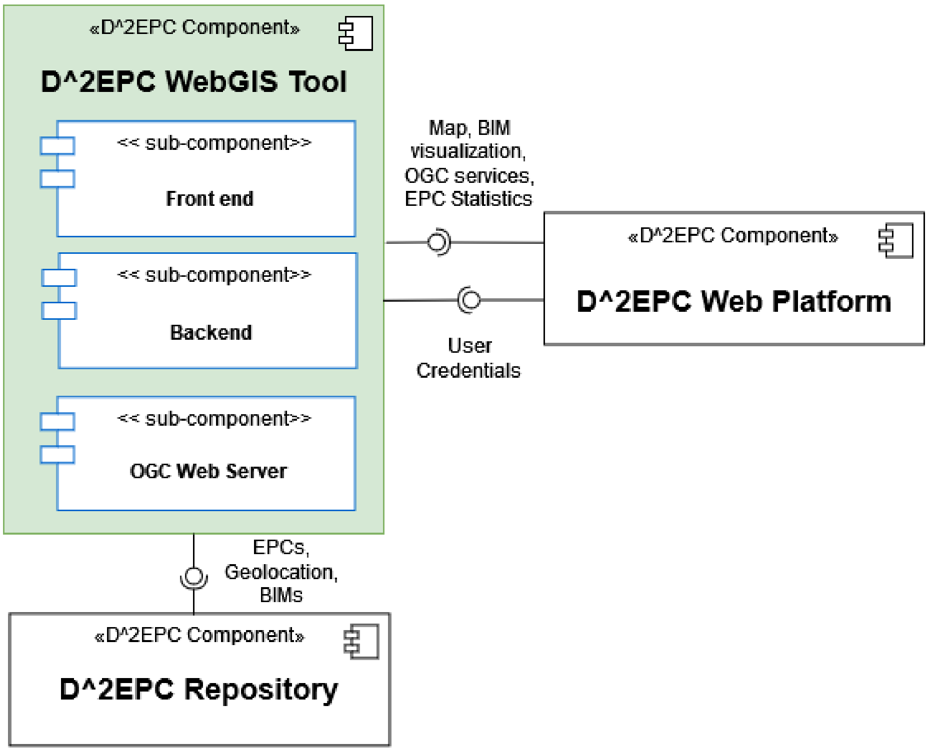

Figure 19. D^2EPC Web GIS Tool Functional Diagram

Interface	R/W	Description (including preliminary format and context)
Building model	R	Asset Rating EPC grade text
		IFC BIM Model
		JSON (geoJSON) or text for building location or postal code or approximate location
Querying tool	R	Query in PostgreSQL database with PostGIS extension
Web GIS	W	SW tool (web mapping server) with custom javascript code
D^2EPC Web Platform	W	Provide results visualizations to be delivered to the end user
	R	Logged in user credentials

6.11 D^2EPC Web Platform

The Web Platform (Figure 20) hosts the parametrization of the processes as well as the presentation of all the results from the various components and sub-components, such as the EPCs, the KPIs, recommendations and notifications, etc. The D^2EPC platform, as part of the presentation layer, queries information from the D^2EPC Repository. Employing visual analytics, the platform delivers a user-friendly and information reach environment for the D^2EPC end-users to interact with.

Given the dynamic aspects introduced by the D^2EPC, through the Web Platform the user is able not only to adjust and configure certain components, but also to request directly the execution of certain processes ad-hoc, for updating the EPC results.

According to the end-user the Web Platform provides a personalized environment to facilitate the interaction with the D^2EPC ecosystems. Firstly, the EPC assessor has extended access to the provided functionalities, as they can insert information required by the assessment process and authorize the various calculations. As a typical building BIM file usually lacks all the documentation required to perform the whole spectrum of the D^2EPC calculations, the Web Platform provides the necessary interfaces that show the missing information and to enable the assessor to easily add them. Furthermore, they allow to check the building's existing documentation in the BIM file and make modifications to correct any inconsistencies or update the building information in the case of a renovation action. At the building owner level, the Web Platform offers a demonstration of the results from all the performance assessment calculations, as well as, of all the high-level (non-technical) information that assist them to reduce their energy consumption and improve the overall rating. Finally, access to a third-party user (authorities, market, or research/academia) is also considered, providing aggregated EPC results and KPIs to gain a clear picture of the building stock's energy performance.

6.11.1 Sub-components

As the main integrator of all the D^2EPC components, the Web Platform includes various functionalities to arrange the provision of input data, the execution of the tools, the post-processing/storage of the results and finally the visualization of input forms, notifications, calculation results etc.

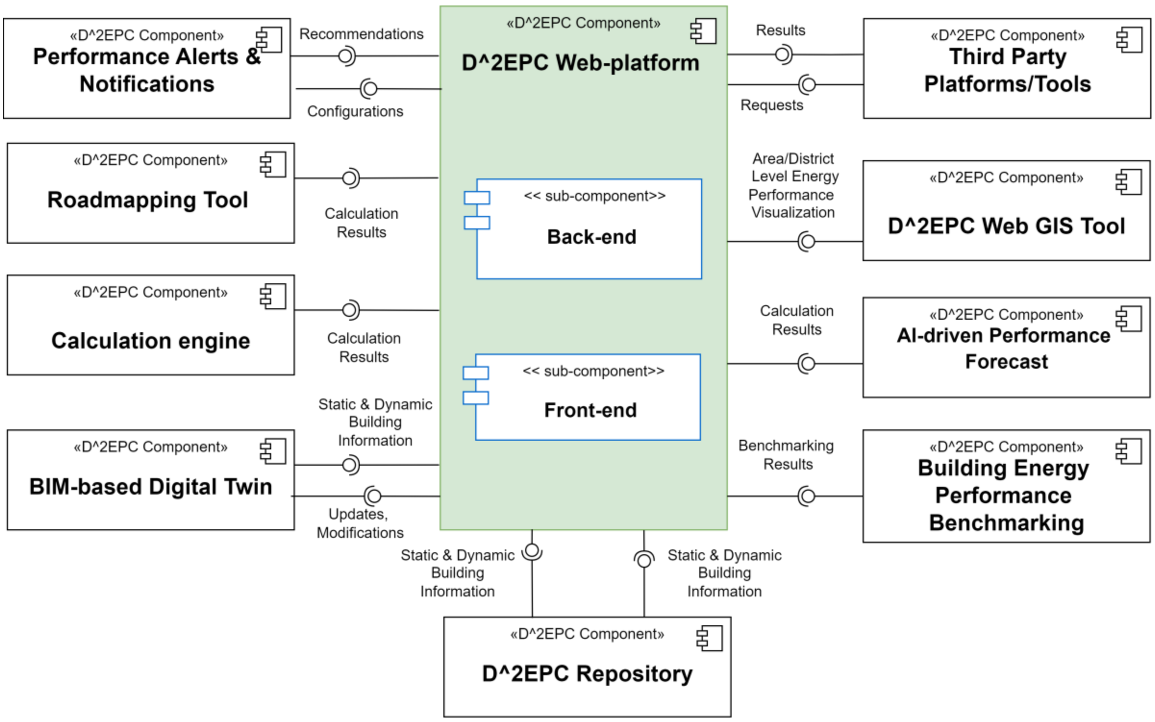

Figure 20. D^2EPC Web Platform Functional Diagram

Interface	R/W	Description (including preliminary format and context)
Performance Alerts & Notifications	R/W	Provides operational recommendations to the building user and receive configuration capabilities for creating custom alerts and personalised notifications.
Roadmapping tool	R	Receives building suggested renovation actions.
Calculation Engine	R	Receives EPC assessment and KPIs calculation results.
BIM-based Digital Twin	R/W	This interface is meant to send static and dynamic building information, as well as to update the building's stored information.
D^2EPC Repository	R/W	Receives and stores static and dynamic building information.
Building Energy Performance Benchmarking	R	Receives benchmarking results to be delivered to the end user.
AI-driven Performance Forecast	R	Receives the predicted operational-based EPC results.
D^2EPC Web GIS	R	Links the Web Platform to the WebGIS platform via common authentication.
Third Party Platforms/ Tools	R/W	Receives requests and sends results.

7 Information View

The final version of the information that is exchanged among the D^2EPC components is depicted in Figure 21, in the form of information flows. The D^2EPC Web Platform provides data to the Digital Twin using BIM files uploaded in IFC format (Figure 22). Real-time data that are collected from actual building sensors and meters by the Information Management Layer are forwarded to the Building Digital Twin through the Energy Performance Verification & Credibility tool. The Building Digital Twin communicates with the D^2EPC Repository to read/store the aforementioned data. Furthermore, it provides static building data or/and actual measurements to the Calculation Engine, the Roadmapping tool and the AI Performance Forecasts tool. The Building Energy Performance Benchmarking and the WebGIS tools access the D^2EPC Repository to retrieve static building data. All the aforementioned data flows follow the D^2EPC data model described in D3.5. The model schema is shown in Figure 23.

The D^2EPC Web Platform can be accessed directly by end users through the dedicated visual interfaces or by third-party services through the provided API interfaces.

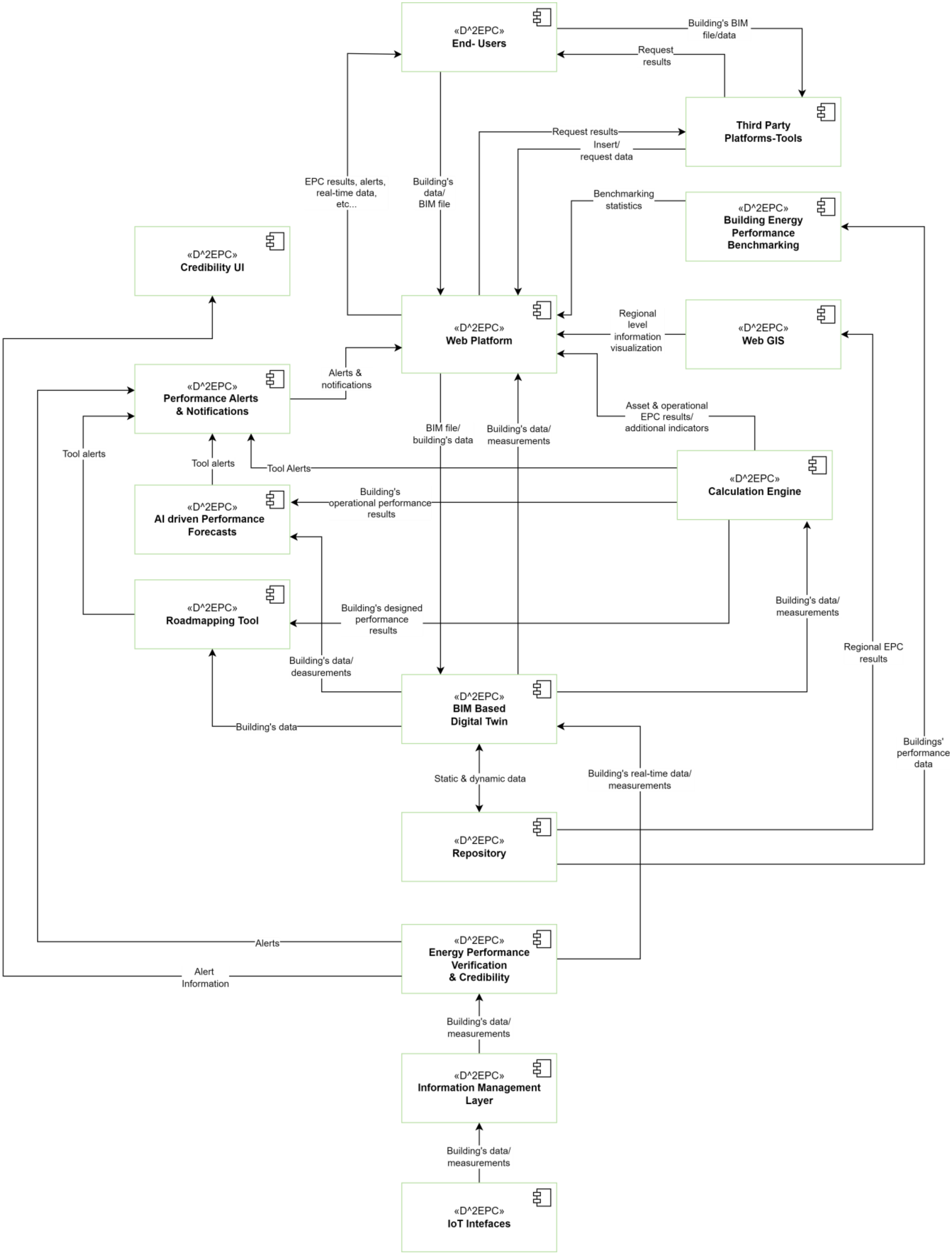

Figure 21. D^2EPC Information Flow Diagram

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ISO-10303-21;
HEADER;

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* Module:                          EDMstepFileFactory/EDMstandAlone
* Creation date:                   Mon Dec 06 13:43:47 2021
* Host:                            ITI-717
* Database:                        C:\Users\AGOUNA~1\AppData\Local\Temp\9060dfb6-bb29-476d-b2bd-223099c2e1c2\5a728e2d-6010-4bd5-a8b6-eb1bc6ac7fc5\ifc
* Database version:                5507
* Database creation date:          Mon Dec 06 13:43:37 2021
* Schema:                          IFC4
* Model:                           DataRepository.ifc
* Model creation date:             Mon Dec 06 13:43:37 2021
* Header model:                    DataRepository.ifc_HeaderModel
* Header model creation date:      Mon Dec 06 13:43:37 2021
* EDMuser:                         sdai-user
* EDMgroup:                        sdai-group
* License ID and type:             5605 : Permanent license. Expiry date:
* EDMstepFileFactory options:      020000
******************************************************************************************/
FILE_DESCRIPTION(('ViewDefinition [DesignTransferView_V1.0]'),'2;1');
FILE_NAME('0001','2021-12-06T13:43:47',(''),(''),'The EXPRESS Data Manager Version 5.02.0100.07 : 28 Aug 2013','21.1.11.27 - Exporter 21.1.11.27 - Alternate UI 21.1.11.27','');
FILE_SCHEMA(('IFC4'));
ENDSEC;

DATA;
#1= IFCORGANIZATION($,'Autodesk Revit 2021 (ENU)',$,$,$);
#5= IFCAPPLICATION(#1,'2021','Autodesk Revit 2021 (ENU)','Revit');
#6= IFCCARTESIANPOINT((0.,0.,0.));
#10= IFCCARTESIANPOINT((0.,0.));
#12= IFCDIRECTION((1.,0.,0.));
#14= IFCDIRECTION((-1.,0.,0.));
#16= IFCDIRECTION((0.,1.,0.));
#18= IFCDIRECTION((0.,-1.,0.));
#20= IFCDIRECTION((0.,0.,1.));
#22= IFCDIRECTION((0.,0.,-1.));
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#26= IFCDIRECTION((-1.,0.));
#28= IFCDIRECTION((0.,1.));
#30= IFCDIRECTION((0.,-1.));
#32= IFCAXIS2PLACEMENT3D(#6,$,$);
#33= IFCLOCALPLACEMENT(#167,#32);
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Figure 22. BIM file (.ifc) payload example

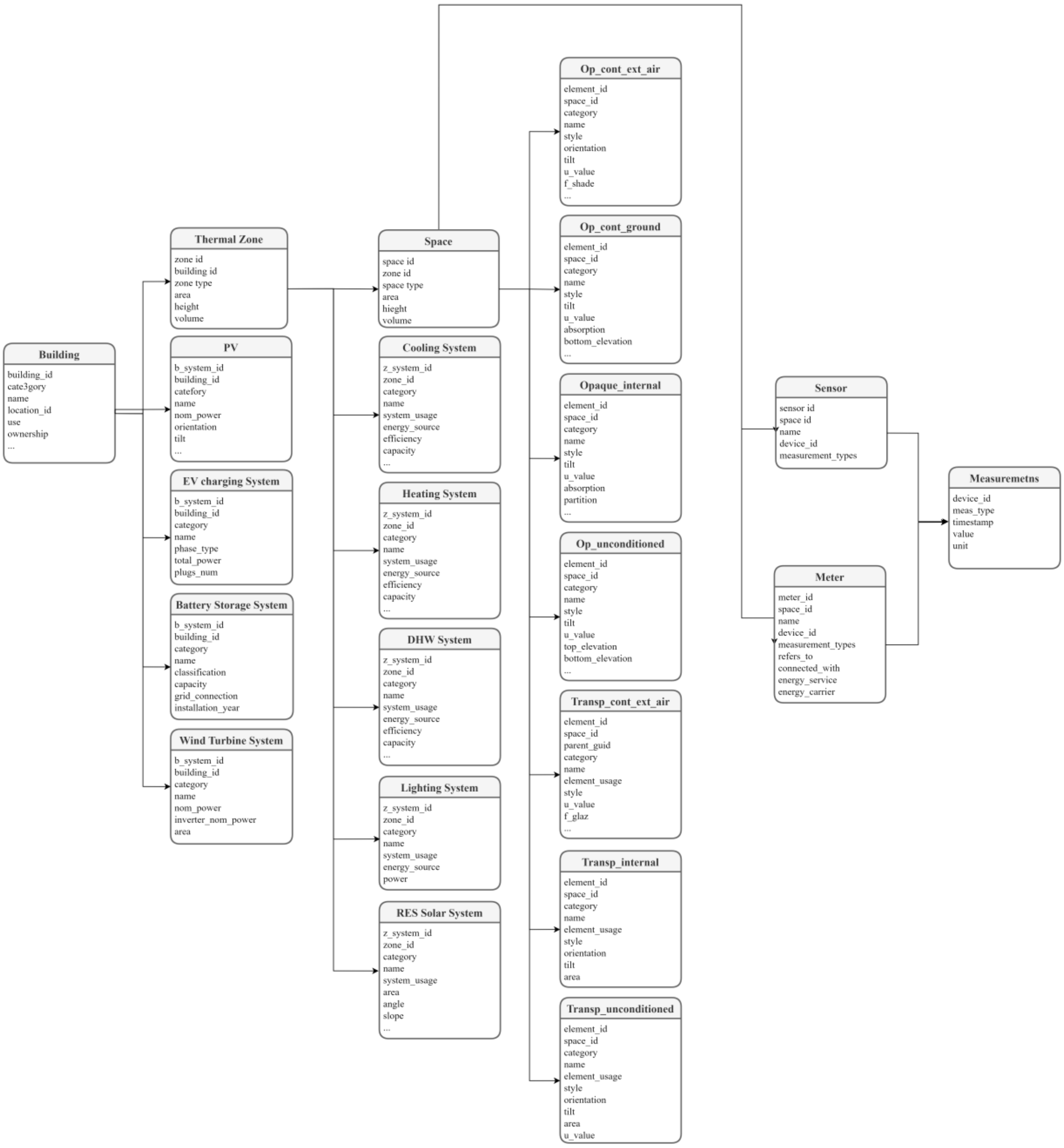

Figure 23. D^2EPC data model including basic elements information

8 Deployment View

The D^2EPC solution has both local and cloud-based deployment aspects, as presented in Figure 24. The *Main D^2EPC Cloud Server* has been set up by CERTH and hosts the majority of the developed tools and services, including the D^2EPC Web Platform. All services deployed within this server have been developed as Python software packages, in a way that they can be easily imported by any relevant application. Additionally, through the developed API interface, all services are accessible by authenticated third party tools without the need of using the user interfaces. Finally, both the Web Platform front-end and the back-end are deployed as Docker images, facilitating the installation of the solution in any server.

The WebGIS Tool is deployed on a separate cloud server, managed by Geosystems Hellas. The D^2EPC IML, the EPVC and the VCUI is hosted in a dedicated server, managed by Hypertech. The communication between the three servers is based on the HTTPs protocol. A redirection route for both tools is provided through the Web Platform.

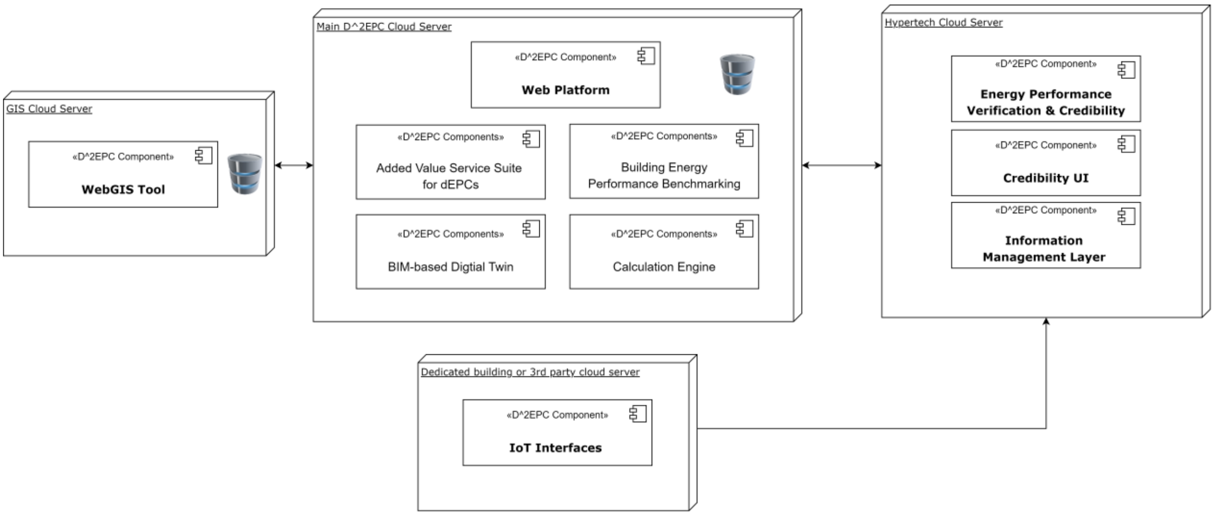

Figure 24. D^2EPC High-Level Deployment Diagram

To better describe the deployment needs for each of the above components, sub-components and modules, the required resources, as used for the current deployment of the components, are presented in the table below.

Table 5. Hardware requirements considered for the Deployment of the D^2EPC tools

Component	Owner	Support	Associated Task(s)	Hardware/Software object	Hardware/ Software requirements	Interaction
IoT Interfaces	HYP, pilot-site responsibles	-	T3.1	Raspberry Pi 4 (if newly installed) or any other pre-installed gateway/already set-up interface supporting common communication protocols	Raspberry Pi 4: Single-core CPU, 2GB RAM	Information Management Layer
Information Management Layer	HYP	-	T3.1	Linux	8-core CPU, 32 GB RAM, 1TB J2EE application running on Web Application Container (Tomcat 8)	IoT Gateway, D^2EPC Repository, Energy Performance Verification & Credibility component
Energy Performance Verification & Credibility			T4.3			Information Management Layer, D^2EPC BIM-based Digital Twin
D^2EPC Web Platform	CERTH	SEC, HYP, DMO	T4.4	Linux based PC with administrator right and credentials Windows/Linux-based PC with administrator right and credentials,	10-core CPU, 64GB RAM, 2TB storage Python 3 with necessary libraries (pandas, numpy, matplotlib, sklearn, etc.)	Calculation Engine, D^2EPC Web GIS, Performance Alerts & Notifications, Building Energy Performance Benchmarking, Credibility UI, Third Party Platforms/ Tools

Component	Owner	Support	Associated Task(s)	Hardware/Software object	Hardware/ Software requirements	Interaction
BIM-based Digital Twin			T3.3	SW: TBD, IONIC		Calculation Engine, Building Energy Performance Benchmarking, Roadmapping Tool, AI-Driven Performance Forecasts
Calculation Engine			T4.1			Building Energy Performance Benchmarking, D^2EPC Web Platform, AI-Driven Performance Forecasts, Roadmapping Tool, BIM-based Digital Twin
Building Energy Performance Benchmarking			T4.3			Calculation Engine, Roadmapping Tool, D^2EPC Web Platform
Roadmapping Tool			T4.2			Calculation engine, Performance Alerts & Notifications, AI-driven Performance Forecasts, Building Energy Performance Benchmarking
AI-Driven Performance Forecasts			T4.2			Calculation Engine, Roadmapping Tool, Performance Alerts & Notifications

Component	Owner	Support	Associated Task(s)	Hardware/Software object	Hardware/ Software requirements	Interaction
Performance Alerts & Notifications			T4.2			D^2EPC Mobile App, D^2EPC Web Platform, Roadmapping Tool, AI-driven Performance Forecasts
D^2EPC Web GIS	GSH	CERTH, KTU	T3.2	A Windows/Linux-based server with administrator right and credentials, Geoserver or Mapserver, PostgreSQL with PostGIS extension	4-core CPU, >2.0 GHz , > 8 GB RAM Server Disk Space: 4 GB for application footprint Spatial Data Storage >7200 RPM speed disk storage| Recommended: High Speed Disk Storage, >15000 RPM, SSD, RAID Arrays, or External SAN/NAS	D^2EPC Web Platform

9 Technical Use Cases (Dynamic View)

The D^2EPC use cases were extracted during the architecture workshops and through bilateral communications between technical partners. Through these, all the dependencies between the key architectural components and the data exchanged during the system's functions or procedures have been identified. The logic of these complex operations is presented through Sequence Diagrams defining the functionalities of each of the key architectural components and the execution flows within each use case. Besides these sequence diagrams, the requirements for each use case have been defined following the template introduced in Section 2, and are presented as well.

9.1 BS1 Definition of buildings energy class and whether minimum requirements are met for Asset Rating

9.1.1 UC1.1 Extract and Verify Data from BIM

Table 6. UC1.1 Requirements

Use Case #	UC1.1
Use Case Name	Extract and Verify Data from BIM
Intent	To extract all required information for asset rating and relevant set of indicators available in a BIM file and ensure that it's in the correct data format and complete
Version/Action/Author	v3
Last Update	09.06.2023
Actors Involved	Main Actor: Engineers, Building designers (EPC designers) Other: Registries, Public Bodies, Researchers/ Academics, Tenants/Owners, Software tool Developers, ESCOs
Brief Description	The EPC Designer (user) requests from the building owner the BIM file and uploads it through the D^2EPC platform. In case the BIM is incomplete or wrong, the user is informed. Additional data can be provided through a simplified, well-guided process. The BIM file is then used to create the Building Digital Twin, while data are stored in the D^2EPC Repository.
Assumptions	The building owner has a BIM file
Pre-conditions	None
Trigger	-
Goal (Successful End Condition)	All data that are needed as input to the Asset Rating Engine or other tools, which can be extracted from the BIM file, are available.
Post-conditions	Building Data are available for other processes and operations
Related Use Cases	UC1.2, UC1.3, UC1.4, UC1.5, UC1.6, UC3.1, UC3.2, UC4.3, UC5.1, UC5.2

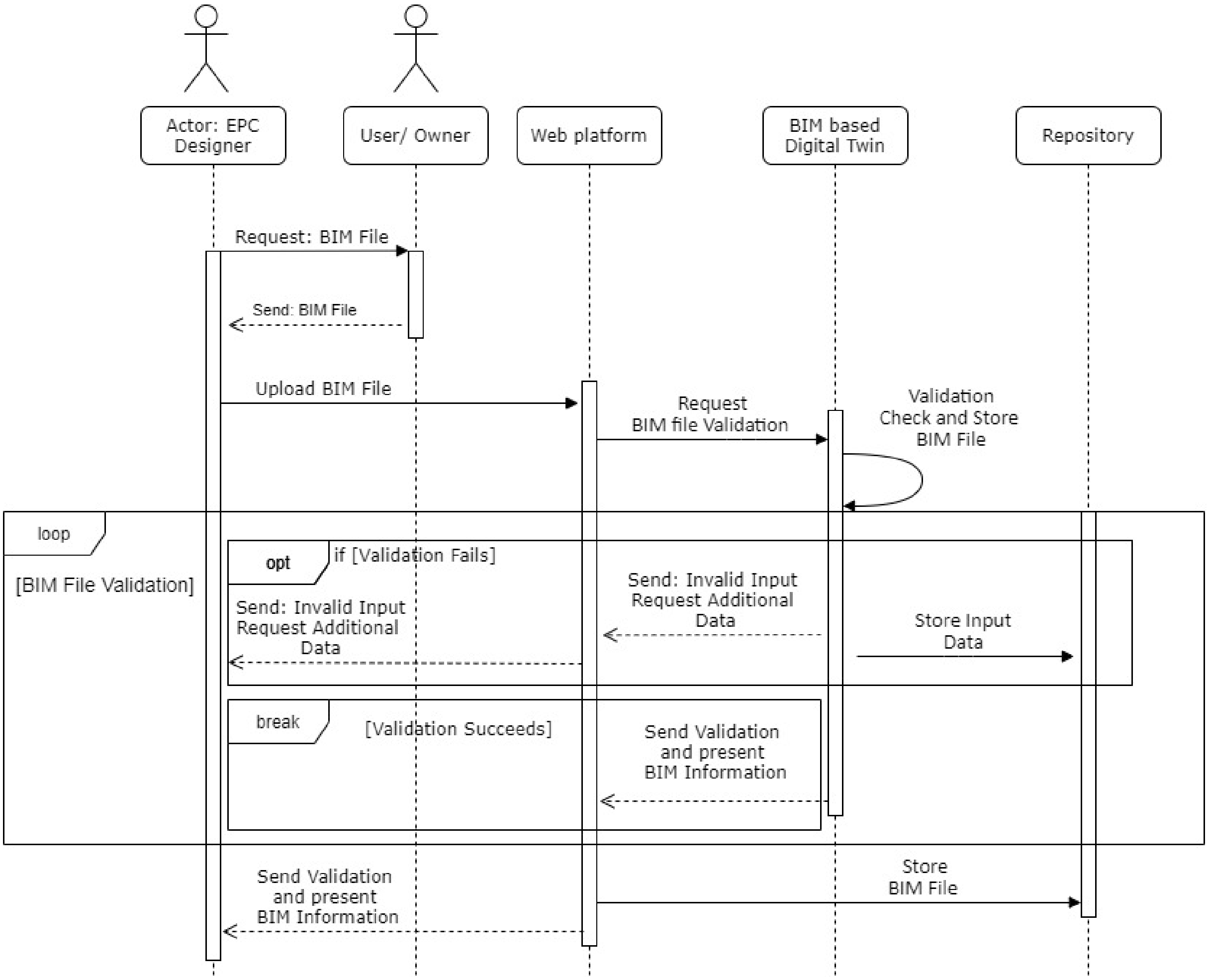

Figure 25. UC1.1 Sequence Diagram

9.1.2 UC1.2 Issue a D^2EPC asset EPC

Table 7. UC1.2 Requirements

Use Case #	UC1.2
Use Case Name	Issue a D^2EPC asset EPC
Intent	To issue a D^2EPC EPC based on asset rating
Version/Action/Author	v3
Last Update	09.06.2023
Actors Involved	Main Act or: Engineers, Building designers (EPC designers) Other: Registries, Public Bodies, Researchers/ Academics, Tenants/Owners, Software tool Developers, ESCOs
Brief Description	The EPC designer requests the issuance of an asset-based EPC from the D^2EPC Web Platform that sends the request to the Calculation Engine. The Calculation Engine requests the necessary data through the BIM-based Digital Twin and the Asset Rating module of the

	Calculation Engine performs the asset-based EPC calculation. The Calculation Engine sends the results to the Web Platform that delivers the EPC and stores selected results in the D^2EPC Repository.
Assumptions	Data from a BIM file and from user inputs, (as per UC1.1) are available in the Repository
Pre-conditions	UC1.1
Trigger	A request for a new asset-based EPC
Goal (Successful End Condition)	D^2EPC asset-based EPC issued
Post-conditions	Asset EPC data (energy class, asset rating-related indicators) are available for other processes and operations.
Related Use Cases	UC1.3, UC1.4, UC1.5, UC1.6,

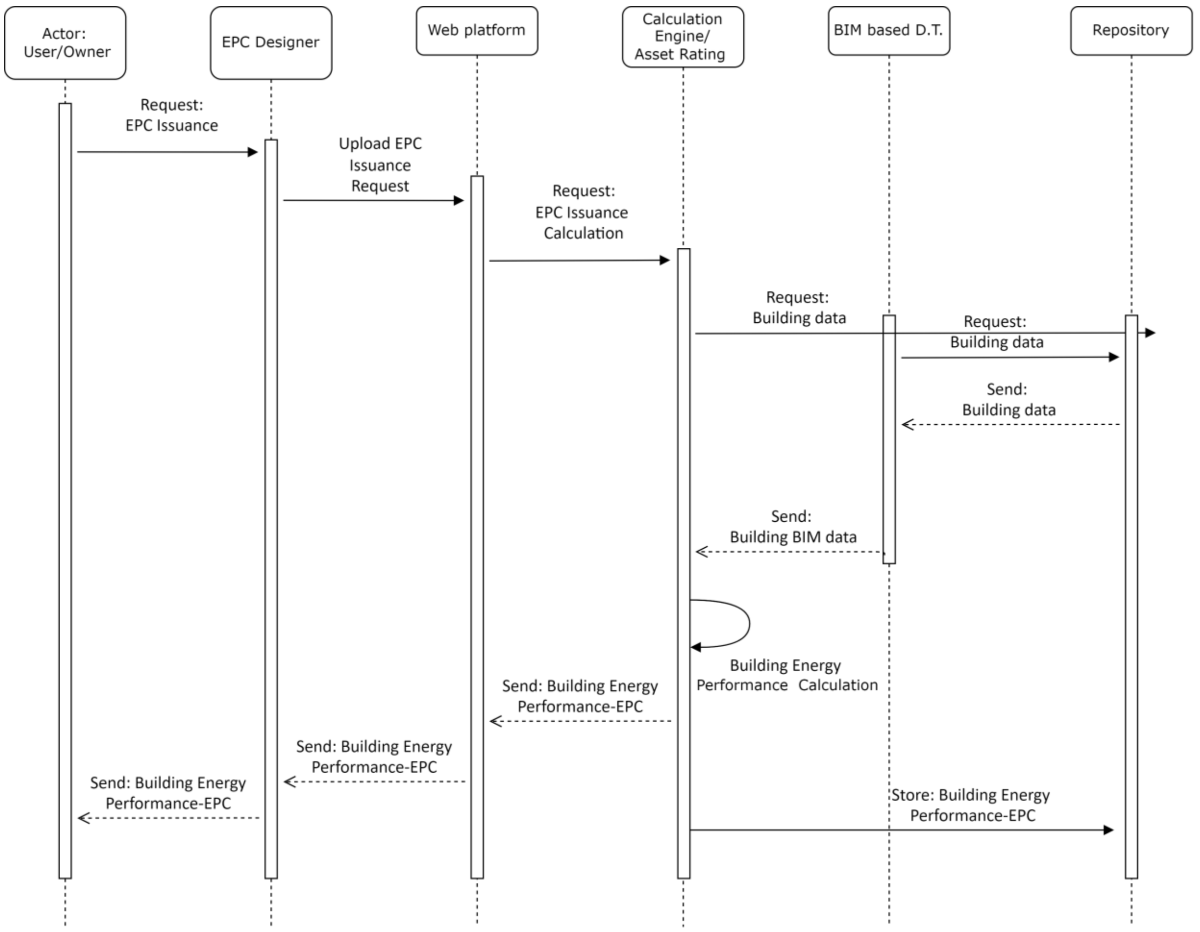

Figure 26. UC1.2 Sequence Diagram.

9.1.3 UC1.3 Issue an SRI report

Table 8. UC1.3 Requirements

Use Case #	UC1.3
Use Case Name	Issue an SRI report
Intent	To perform an SRI assessment of the building and issue an SRI report
Version/Action/Author	v3
Last Update	09.06.2023
Actors Involved	Main Actor: Engineers, Building designers (EPC designers) Other: Registries, Public Bodies, Researchers/ Academics, Tenants/Owners, Software tool Developers, ESCOs
Brief Description	The EPC designer navigates to the SRI-dedicated page in the Web Platform. The BIM-based Digital Twin retrieves available required input parameters from the Repository and fills the input forms. The EPC designer edits/adds the respective parameters and requests the issuance of an SRI report from the D^2EPC Web Platform that sends the request to the Calculation Engine. The Building Performance module of the Calculation Engine performs the SRI calculation and the results report is sent to the Web Platform and stored in the Repository.
Assumptions	The building owner has a BIM file and a new calculation of the SRI parameters is needed.
Pre-conditions	UC1.1
Trigger	A request for a new SRI report
Goal (Successful End Condition)	SRI Report issued
Post-conditions	SRI-calculated results are available for other processes and operations
Related Use Cases	UC1.2, UC1.5, UC1.6

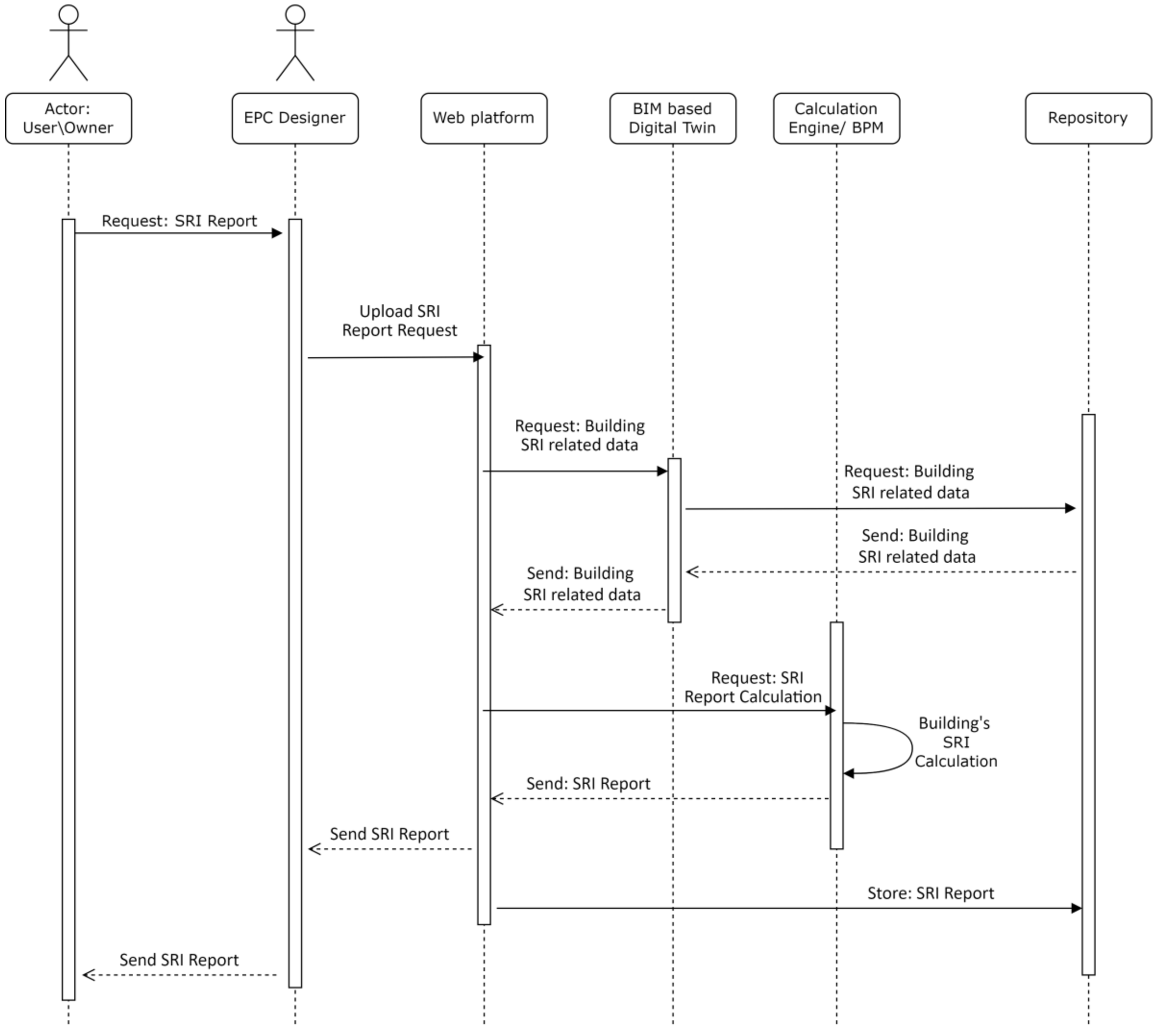

Figure 27. UC1.3 Sequence Diagram

9.1.4 UC1.4 Asset Rating Indicator Assessment Report (LCC, LCA)

Table 9. UC1.4 Requirements

Use Case #	UC1.4
Use Case Name	Asset Rating Indicator Assessment Report (LCC, LCA)
Intent	To extract all required data for the asset rating-related indicators assessment of the building
Version/Action/Author	v3
Last Update	09.06.2023
Actors Involved	Main Actor: Engineers, Building designers (EPC designers) Other: Registries, Public Bodies, Researchers/ Academics, Tenants/Owners, Software tool Developers, ESCOs
Brief Description	The EPC designer requests the issuance of an Asset Rating Indicator Assessment report, including the LCC and LCA set of indicators, from

	the D^2EPC Web Platform that sends the request to the Calculation Engine. The Calculation Engine requests building information and historical data that are imported through the BIM-based Digital Twin. The Building Performance Module of the Calculation Engine performs the calculation of the indicators and the report is sent to the Web Platform and stored in the Repository.
Assumptions	The building owner has a BIM file and a new calculation of the asset rating indicators is needed.
Pre-conditions	UC1.1
Trigger	A request for a new Asset Rating Indicator Assessment report
Goal (Successful End Condition)	Asset Rating Indicator Assessment Report (including selected LCC, LCA indicators) issued
Post-conditions	Asset Rating-related indicators are available for other processes and operations
Related Use Cases	UC1.2, UC1.5, UC1.6, UC3.2

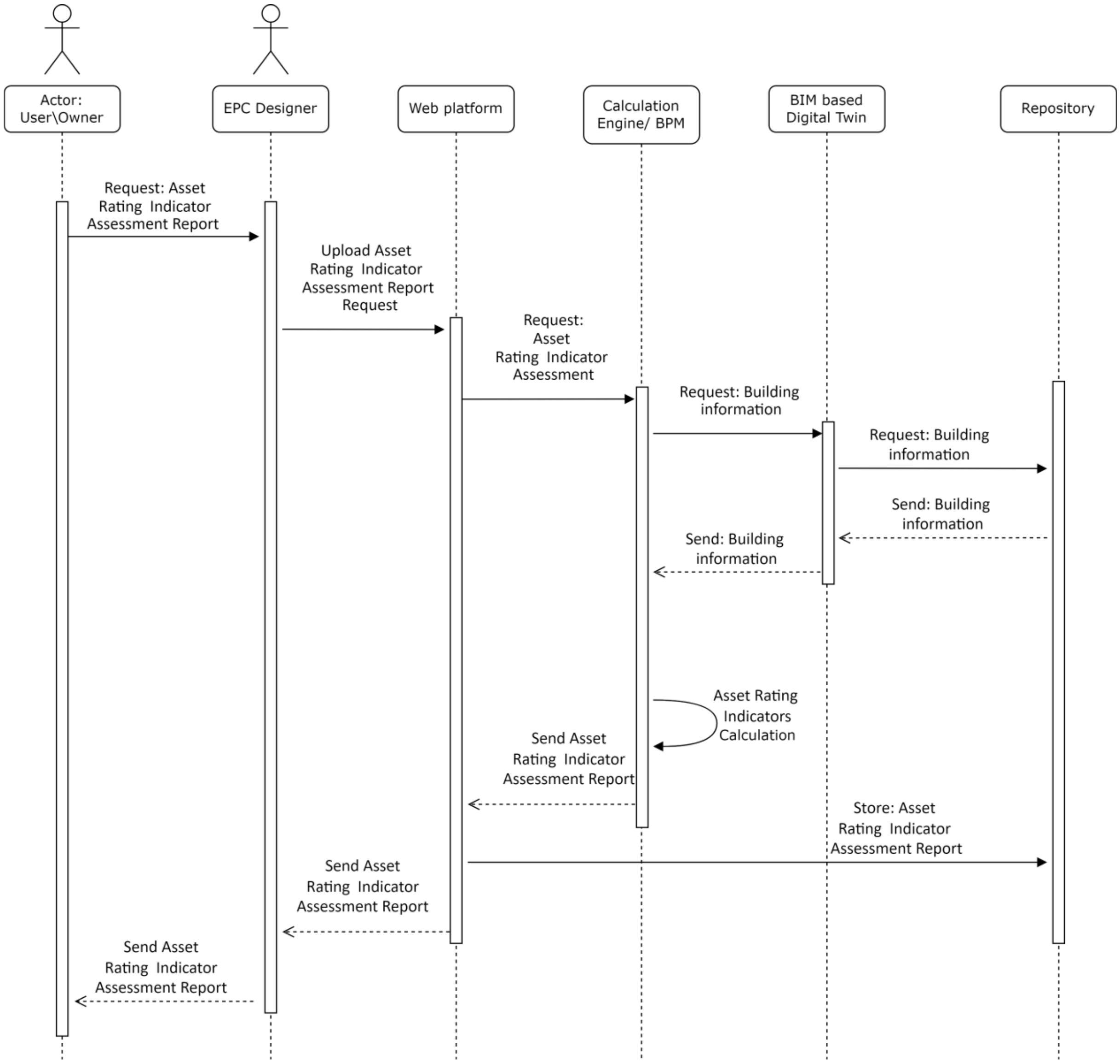

Figure 28. UC1.4 Sequence Diagram

9.1.5 UC1.5 Provide Design recommendations for performance improvements

Table 10. UC1.5 Requirements

Use Case #	UC1.5
Use Case Name	Provide Design recommendations for performance improvements
Intent	To identify optimal asset-based design recommendation scenarios and send recommendations for performance improvements
Version/Action/Author	v3
Last Update	12.06.2023
Actors Involved	Main Actor: Engineers, Building designers (EPC designers)

	Other: Registries, Public Bodies, Researchers/ Academics, Tenants/Owners, Software tool Developers, ESCOs
Brief Description	The EPC designer (user) requests optimal asset-based design recommendations from the D^2EPC Web Platform that sends the request to the Roadmapping Tool. The Roadmapping Tool requests building infrastructure information that is imported through the BIM-based Digital Twin and then performs internal processes to identify the optimal scenarios. Based on those scenarios, the Roadmapping Tool requests new EPC results that are calculated as in UC1.2 by the Asset Rating module of the Calculation Engine and stored in the Repository. Based on the asset-based results and the new EPC Indicators, the Roadmapping Tool identifies the optimal scenario and sends information to the Notification and Awhichs Tool that sends an alert for the availability of new optimal design recommendations to the Web Platform. The user is informed about the new recommendation and data are stored in the Repository.
Assumptions	The building owner has a BIM file.
Pre-conditions	UC1.1, UC1.2
Trigger	A request for performance improvements
Goal (Successful End Condition)	Deliver optimal design recommendations for performance improvements
Post-conditions	Energy performance upgrade potential based on optimal design recommendations is available for other processes and operations
Related Use Cases	UC3.3

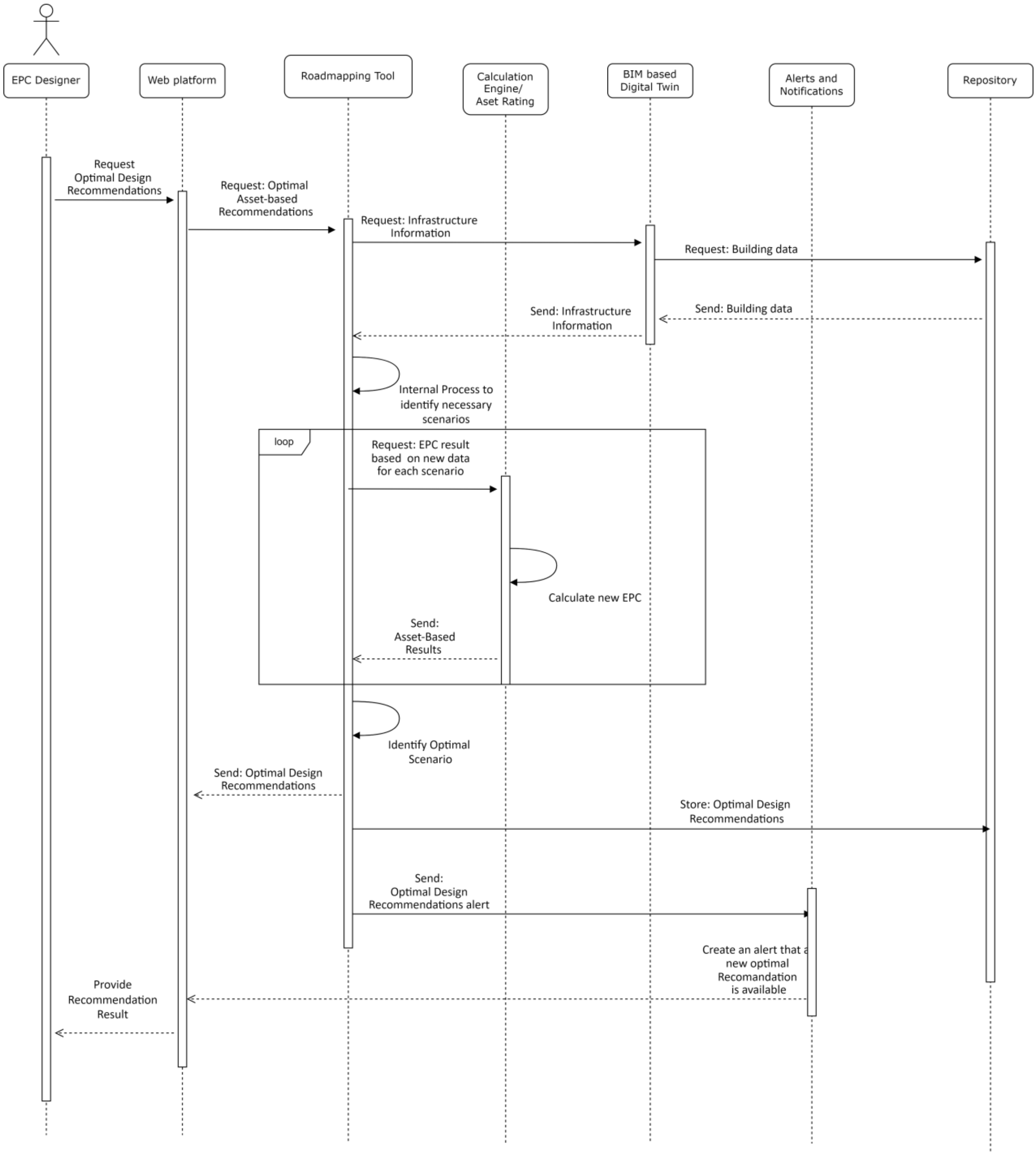

Figure 29. UC1.5 Sequence Diagram

9.1.6 UC 1.6 Asset Rating as a service

Table 11. UC1.6 Requirements

Use Case #	UC1.6
Use Case Name	Asset Rating as a service
Intent	To access the services of the D^2EPC Web Platform based on asset rating through third party tools
Version/Action/Author	v2

Last Update	12.06.2023
Actors Involved	Main Actor: Engineers, Building designers (BIM/EPC designers) Other: Registries, Public Bodies, Researchers/ Academics, Tenants/Owners, Software tool Developers, ESCOs
Brief Description	The BIM/ EPC designer using a third-party platform requests authorization from the D^2EPC Web Platform in order to log in. If authorized access, the BIM/ EPC designer sends a request for calculation of the asset-based EPC and/or additional indicators (SRI, LCC, LCA) to the Web Platform, which executes the request as in UC1.1-UC.1.5 and sends results to the third party platform.
Assumptions	BIM file available.
Pre-conditions	UC1.1
Trigger	Request from a third-party platform to use the asset-based EPC calculation service provided by the D^2EPC Web Platform
Goal (Successful End Condition)	Deliver results according to the performed request
Post-conditions	-
Related Use Cases	UC1.2, UC1.3, UC1.4, UC1.5

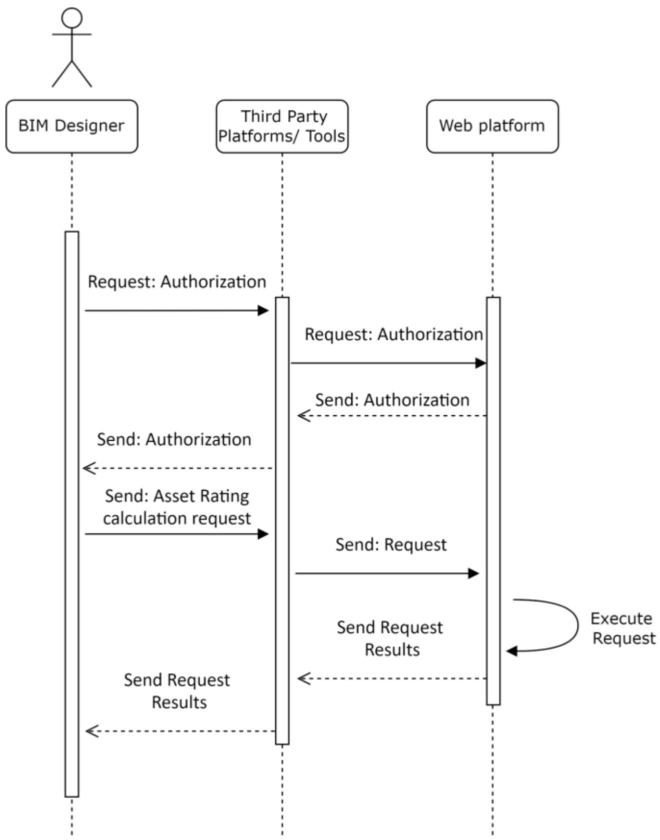

Figure 30. UC1.6 Sequence Diagram

9.2 BS2 Definition of buildings energy class and whether minimum requirements are met for Operational Rating

9.2.1 UC2.1 - Extract and Verify Data from Measurements for the Digital Twin

Table 12. UC2.1 Requirements

Use Case #	UC2.1
Use Case Name	Extract and Verify Data from Measurements for the Digital Twin
Intent	To collect, process and verify the validity of raw data collected from the IoT devices installed locally to be used in the Digital Twin
Version/Action/Author	v3
Last Update	12.06.2023
Actors Involved	Main Actor: Engineers, Building designers (EPC designers) Other: Registries, Public Bodies, Researchers/ Academics, Tenants/Owners, Software tool Developers, ESCOs
Brief Description	Building's data streams are transmitted from the building communication interfaces to the Information Management Layer and then sent to the Verification and Credibility tool for checking and to the D^2EPC Repository, through the Building Digital Twin, to be stored. If data quality is acceptable, then it can be retrieved by the BIM-based Digital Twin. If data quality is not acceptable, then the user receives an alert generated by the Notifications and Alerts tools and visualised in the Web Platform. More details on the data not being accepted are provided by the Credibility UI.
Assumptions	IoT devices are installed locally and/or interfaces between the locally available BMS and the IML have been established.
Pre-conditions	None
Trigger	Continuous process – no trigger required
Goal (Successful End Condition)	Verified, cleansed, near real-time data
Post-conditions	Available data to be further used by other data-driven components of D^2EPC.
Related Use Cases	UC2.2, UC2.4, UC2.5, UC3.1, UC3.2, UC4.2, UC4.3

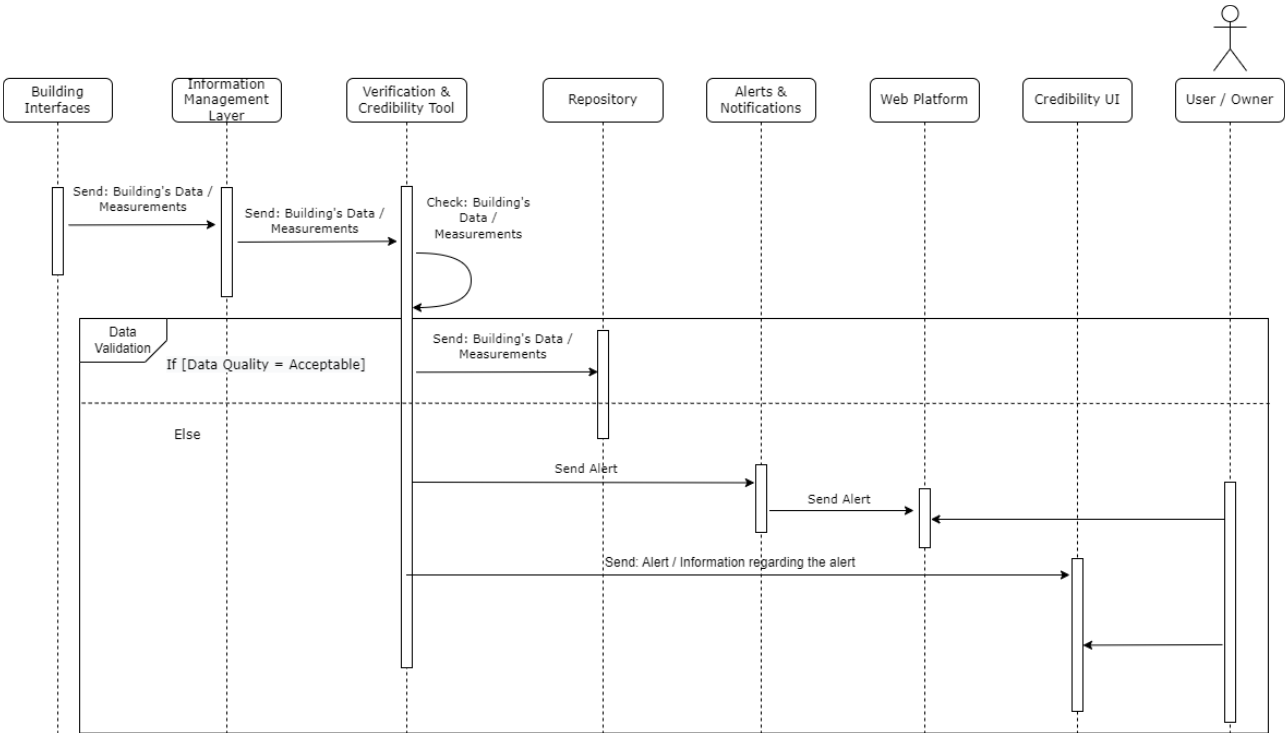

Figure 31. UC2.1 Sequence Diagram.

9.2.2 UC2.2 Issue a D^2EPC operational EPC

Table 13. UC2.2 Requirements

Use Case #	UC2.2
Use Case Name	Issue a D^2EPC operational EPC
Intent	To issue a D^2EPC EPC based on operational rating
Version/Action/Author	v3
Last Update	12.06.2023
Actors Involved	Main Actor: Engineers, Building designers (EPC designers) Other: Registries, Public Bodies, Researchers/ Academics, Tenants/Owners, Software tool Developers, ESCOs
Brief Description	The EPC designer requests the issuance of an operational EPC from the D^2EPC Web Platform that sends the request to the Calculation Engine. The Operational Rating module of the Calculation Engine requests the building's data retrieved from a BIM file and operational data, which are imported through the BIM-based Digital Twin. Then, the Operational Rating module of the Calculation Engine performs the EPC calculation. The Calculation Engine sends the results to the Web Platform that delivers the EPC.
Assumptions	The building owner has a BIM file and building's historical data are available in the Repository.

Pre-conditions	UC1.1
Trigger	A request for a new operational EPC.
Goal (Successful End Condition)	D^2EPC operational EPC issued.
Post-conditions	KPIs and operational EPC are available for other processes and operations.
Related Use Cases	UC2.3, UC2.4, UC2.5, UC3.2

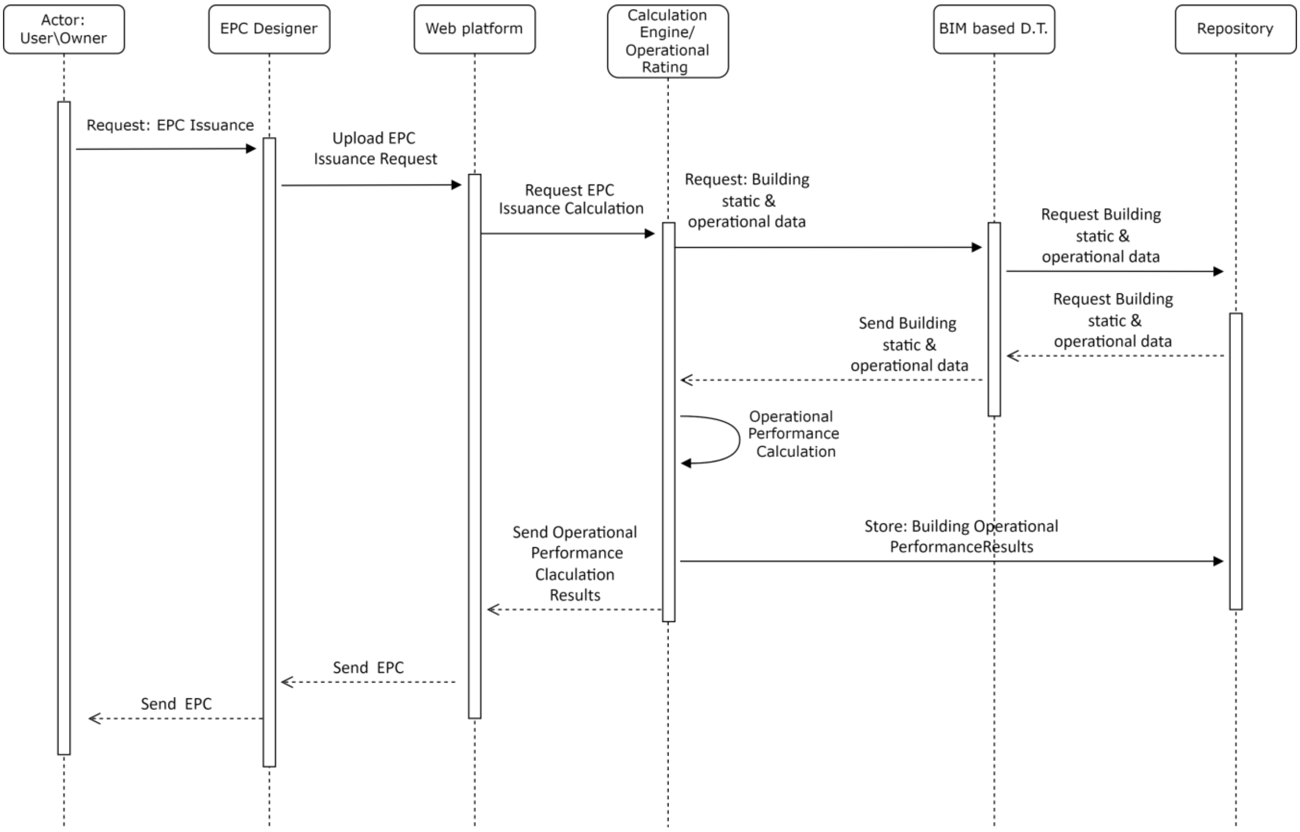

Figure 32. UC2.2 Sequence Diagram

9.2.3 UC2.3 Operational Rating Indicator Assessment Report (LCC, HC&W)

Table 14. UC2.3 Requirements

Use Case #	UC2.3
Use Case Name	Operational Rating Indicator Assessment Report (LCC, HC&W)
Intent	To extract all required data for the operational rating-related indicators assessment of the building
Version/Action/Author	v3
Last Update	12.06.2023

Actors Involved	Main Actor: Engineers, Building designers (EPC designers) Other: Registries, Public Bodies, Researchers/ Academics, Tenants/Owners, Software tool Developers, ESCOs
Brief Description	The EPC designer requests the issuance of an Operational Rating Indicator Assessment report from the D^2EPC Web Platform that sends the request to the Calculation Engine. The Calculation Engine requests buildings information, measurements and operational data that are imported through the BIM-based Digital Twin. The Building Performance module of the Calculation Engine performs the calculation of the indicators and the report is sent to the Web Platform and stored in the Repository.
Assumptions	The building owner has a BIM file and a new calculation of the operational rating-related indicators is needed.
Pre-conditions	UC2.1
Trigger	A request for a new Operational Rating Indicator Assessment report.
Goal (Successful End Condition)	Operational Rating Indicator Assessment Report (including selected LCC, HC&W indicators) issued.
Post-conditions	Operational Rating-related indicators are available for other processes and operations.
Related Use Cases	UC2.2, UC2.5, UC2.6, UC3.2

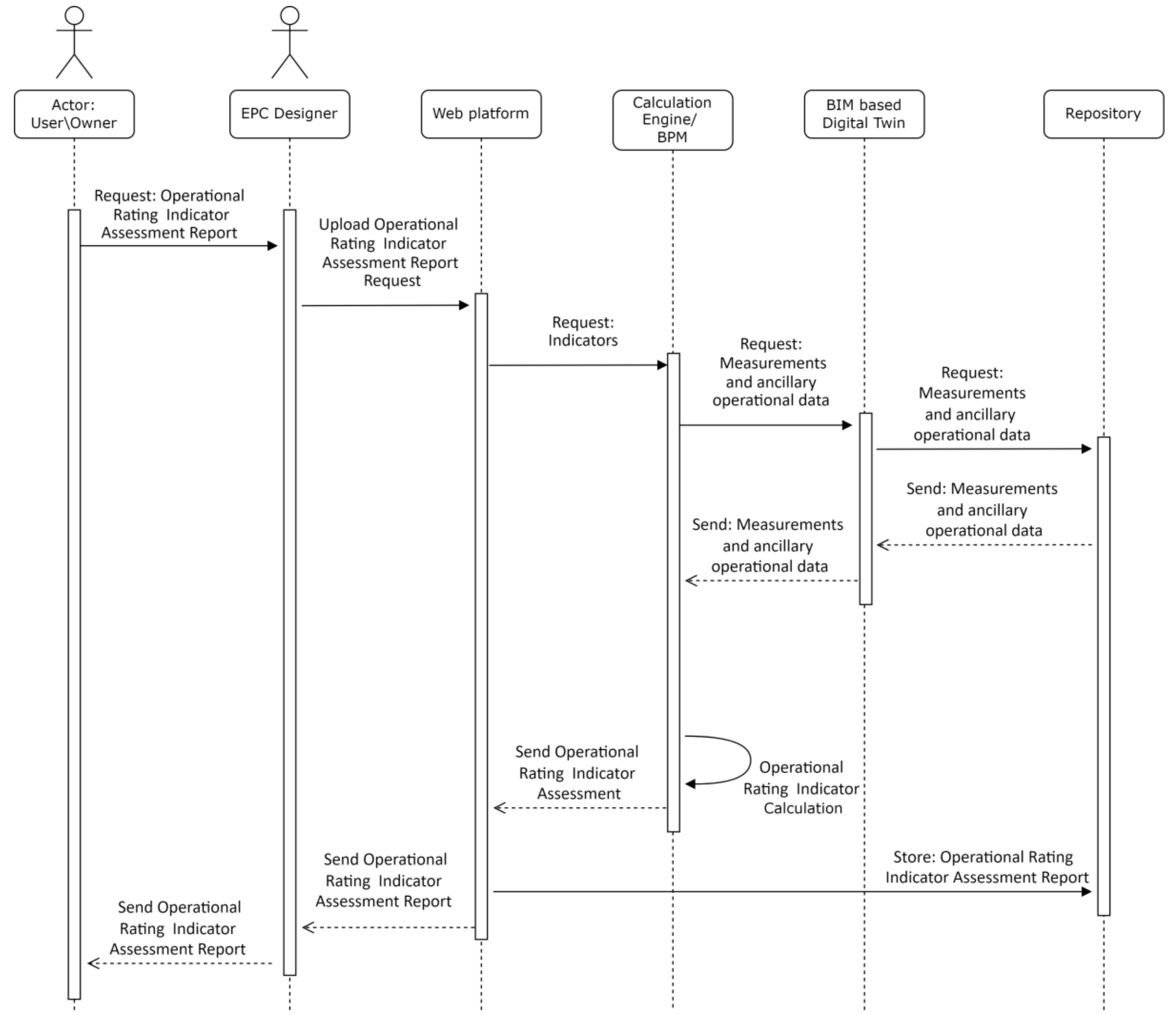

Figure 33. UC2.3 Sequence Diagram.

9.2.4 UC2.4 Provide Operational recommendations for performance improvements

Table 15. UC2.4 Requirements

Use Case #	UC2.4
Use Case Name	Provide operational recommendations for performance improvements
Intent	To identify any possible performance-degrading operational behaviours and send recommendations for performance improvements
Version/Action/Author	v3
Last Update	12.06.2023
Actors Involved	Main Actor: Engineers, Building designers (EPC designers) Other: Registries, Public Bodies, Researchers/ Academics, Tenants/Owners, Software tool Developers, ESCOs

Brief Description	The EPC designer (user) requests operational-based recommendations from the D^2EPC Web Platform (or it can be automatically generated as a request by the Web Platform) that sends the request to the AI-driven Performance Forecasts. The AI-driven Performance Forecasts requests building infrastructure information and measurements that are imported through the BIM-based Digital Twin and then performs internal processes to predict the long-term building operational behaviour. Based on the predictions, the AI-driven Performance Forecasts requests new EPC results that are calculated as in UC2.2 by the Operational Rating module of the Calculation Engine and stored in the Repository. Based on the operational based results and the new EPC Indicators, the AI-driven Performance Forecasts identifies any possible operational patterns that might affect the building's performance and sends information to the Notification and Alerts Tool that sends an alert for the availability of new performance recommendations to the Web Platform. The user is informed, and data are stored in the Repository.
Assumptions	The building owner has a BIM file. Historical data for predicting the long-term building energy consumption and the operational-based EPC are available in the Repository.
Pre-conditions	UC1.1, UC2.2
Trigger	A request for performance recommendations or self-triggered process.
Goal (Successful End Condition)	Deliver recommendations for performance improvements.
Post-conditions	-
Related Use Cases	UC3.3

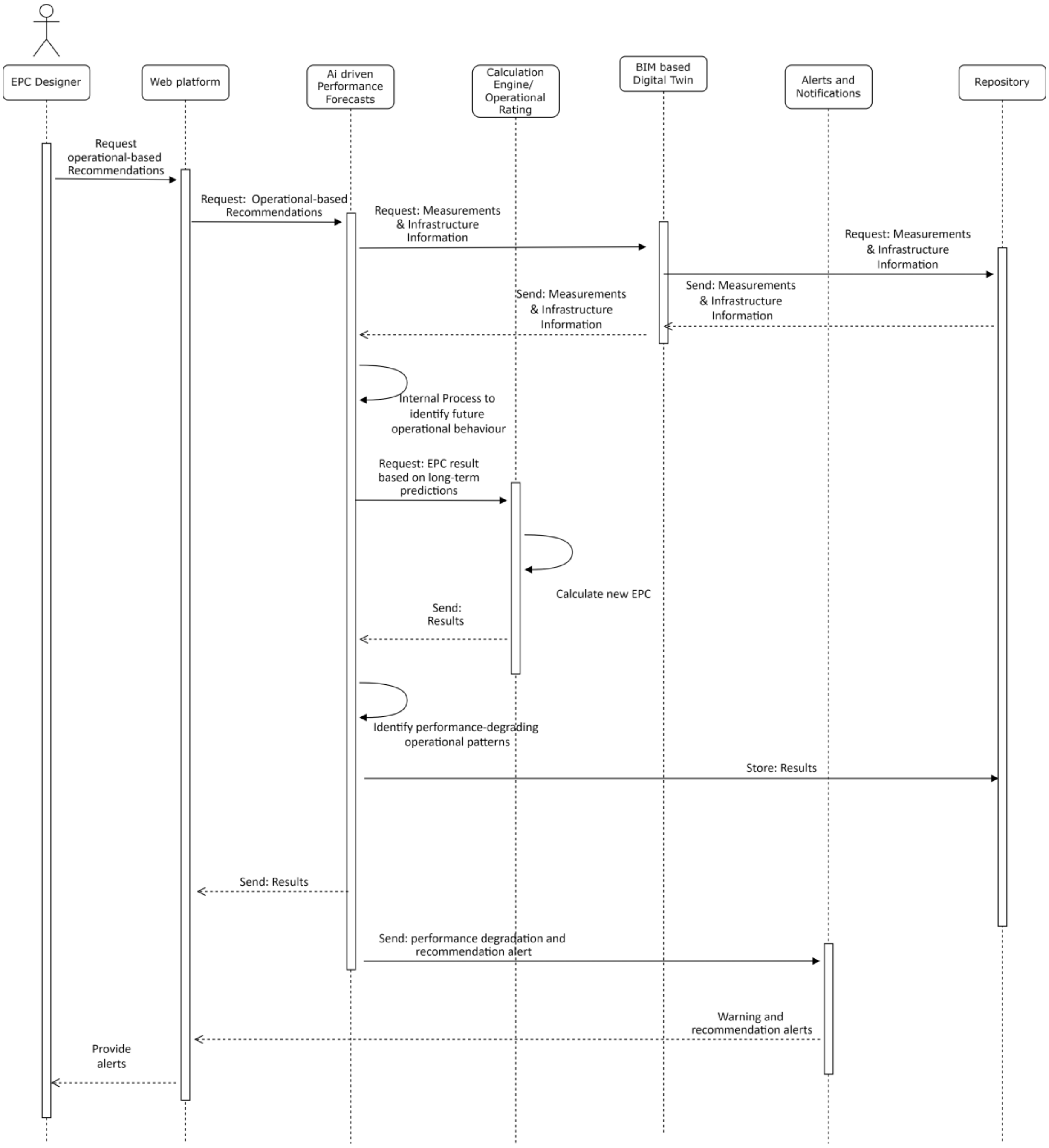

Figure 34. UC2.4 Sequence Diagram

9.2.5 UC2.5 Operational Rating as a service

Table 16. UC2.5 Requirements

Use Case #	UC2.5
Use Case Name	Operational Rating as a service
Intent	To access the services of the D^2EPC Web Platform related to operational rating through third party tools
Version/Action/Author	v3

Last Update	12.06.2023
Actors Involved	Main Actor: Engineers, Building designers (BIM/EPC designers) Other: Registries, Public Bodies, Researchers/ Academics, Tenants/Owners, Software tool Developers, ESCOs
Brief Description	The BIM/ EPC designer using a third-party platform requests authorization from the D^2EPC Web Platform in order to log in. When access has been authorized, the BIM/ EPC designer sends a specific request for calculation of the operational-based EPC and/or additional indicators (LCC, HC&W) to the Web Platform, which executes the request as in UC2.2-UC.2.4 and then sends results to the third party platform.
Assumptions	BIM file and actual data are available. Measurements provided by the user are valid.
Pre-conditions	UC1.1, UC2.1
Trigger	Request from a third-party platform to use the services related to operational rating provided by the D^2EPC Web Platform.
Goal (Successful End Condition)	Deliver results according to the performed request.
Post-conditions	-
Related Use Cases	UC2.2, UC2.3, UC2.4

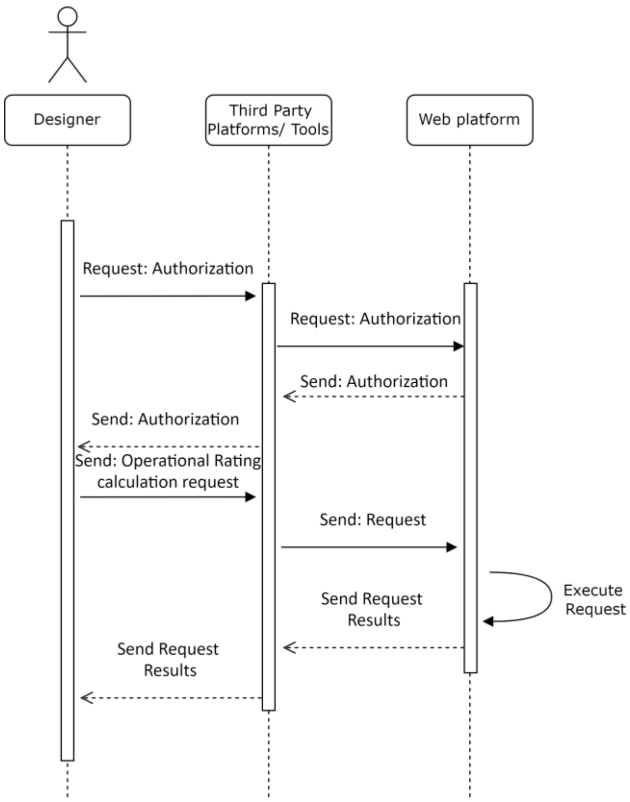

Figure 35. UC2.5 Sequence Diagram.

9.3 BS3 Provision of (near) real-time building information, deviations, and recommendations

9.3.1 UC3.1 Provide (near) real-time building's energy performance information

Table 17. UC3.1 Requirements

Use Case #	UC3.1
Use Case Name	Provide (near) real-time building energy performance information
Intent	To visualize real-time building energy performance information
Version/Action/Author	v2
Last Update	10.05.2022
Actors Involved	Main Actors: Public Bodies, Registries, Tenants/Owners, Software Tool Developers, ESCOs, Building services Industry Other: Standardization Bodies, Engineers, Researchers/Academia, Building services Industry, Professional Consultants, Environmental/ social campaigning organizations
Brief Description	The user/ owner requests (near) real-time building information from the Web Platform which request is transmitted to the BIM-based Digital Twin. Data available are retrieved from the Repository by the Digital Twin and then visualised to the user through the Web Platform.
Assumptions	IoT devices are installed locally and/or interfaces between the locally available BMS and the IML have been established.
Pre-conditions	UC1.1, UC2.1
Trigger	Request for representation of (near) real-time building information
Goal (Successful End Condition)	(Near) real-time Building Information Representation
Post-conditions	-
Related Use Cases	UC2.2-UC2.5

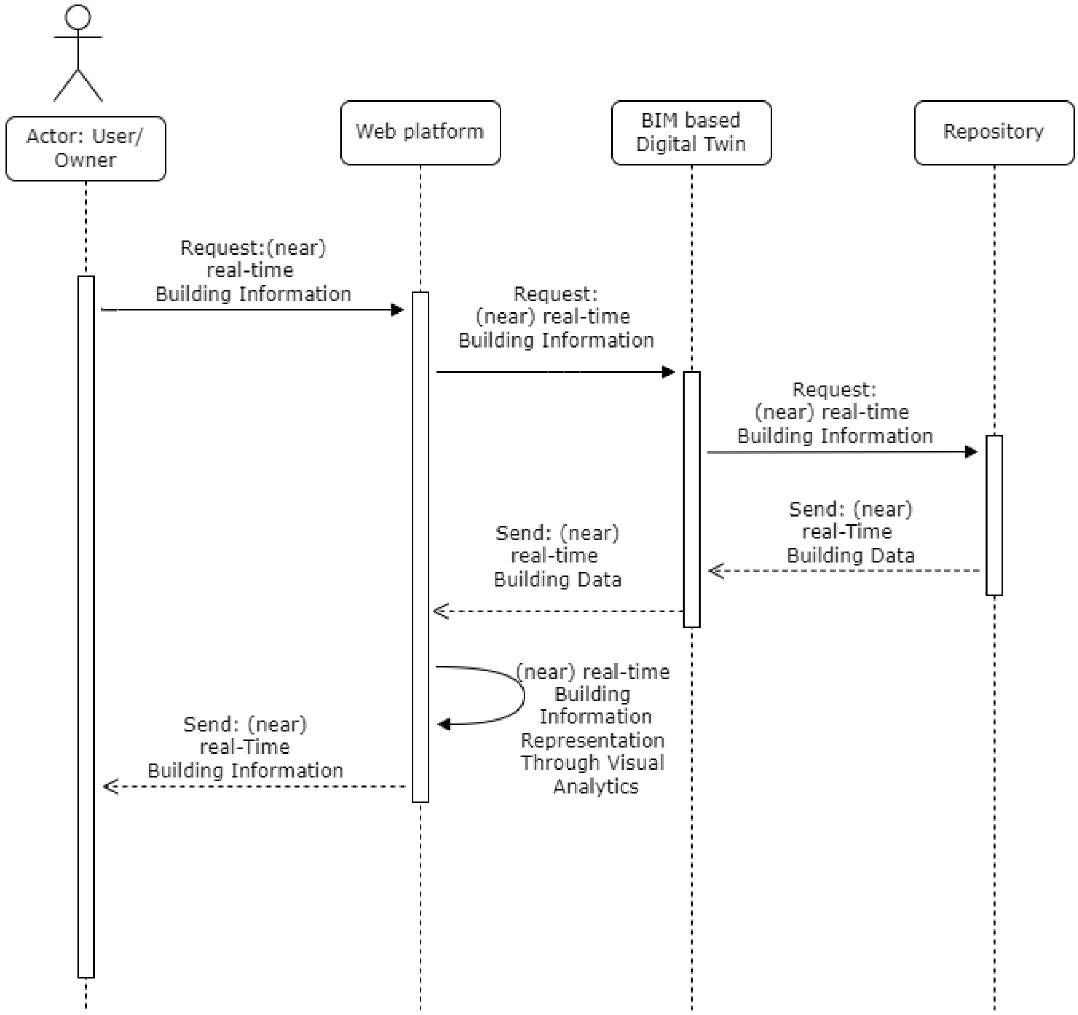

Figure 36. UC3.1 Sequence Diagram.

9.3.2 UC3.2 Provide information on as-designed/in-operation deviations

Table 18. UC3.2 Requirements

Use Case #	UC3.2
Use Case Name	Provide information on as-designed/in-operation deviations
Intent	To check the deviations between as-designed and in operation performance
Version/Action/Author	v3
Last Update	12.06.2023
Actors Involved	Main Actors: Public Bodies, Registries, Tenants/Owners, Software Tool Developers, ESCOs, Building services Industry Other: Standardization Bodies, Engineers, Researchers/Academia, Building services Industry, Professional Consultants, Environmental/ social campaigning organizations

Brief Description	The request is sent from the Web Platform (either triggered by the user or as a scheduled automated event) to the Calculation Engine that requires operational and asset rating data from the BIM-based Digital Twin, retrieved by the Repository. Based on these data, the Building Performance Module of the Calculation Engine calculates As designed and In operation Deviations, stores results in the Repository and provides them to the user through the Web Platform.
Assumptions	-
Pre-conditions	UC 1.2, UC2.2
Trigger	Request by the user or as a scheduled automated process
Goal (Successful End Condition)	To enhance situational awareness of the buildings performance and indicate deviations between as-designed and in operation
Post-conditions	-
Related Use Cases	UC1.3, UC1.4, UC2.3, UC2.4, UC2.5, UC3.1, UC3.3

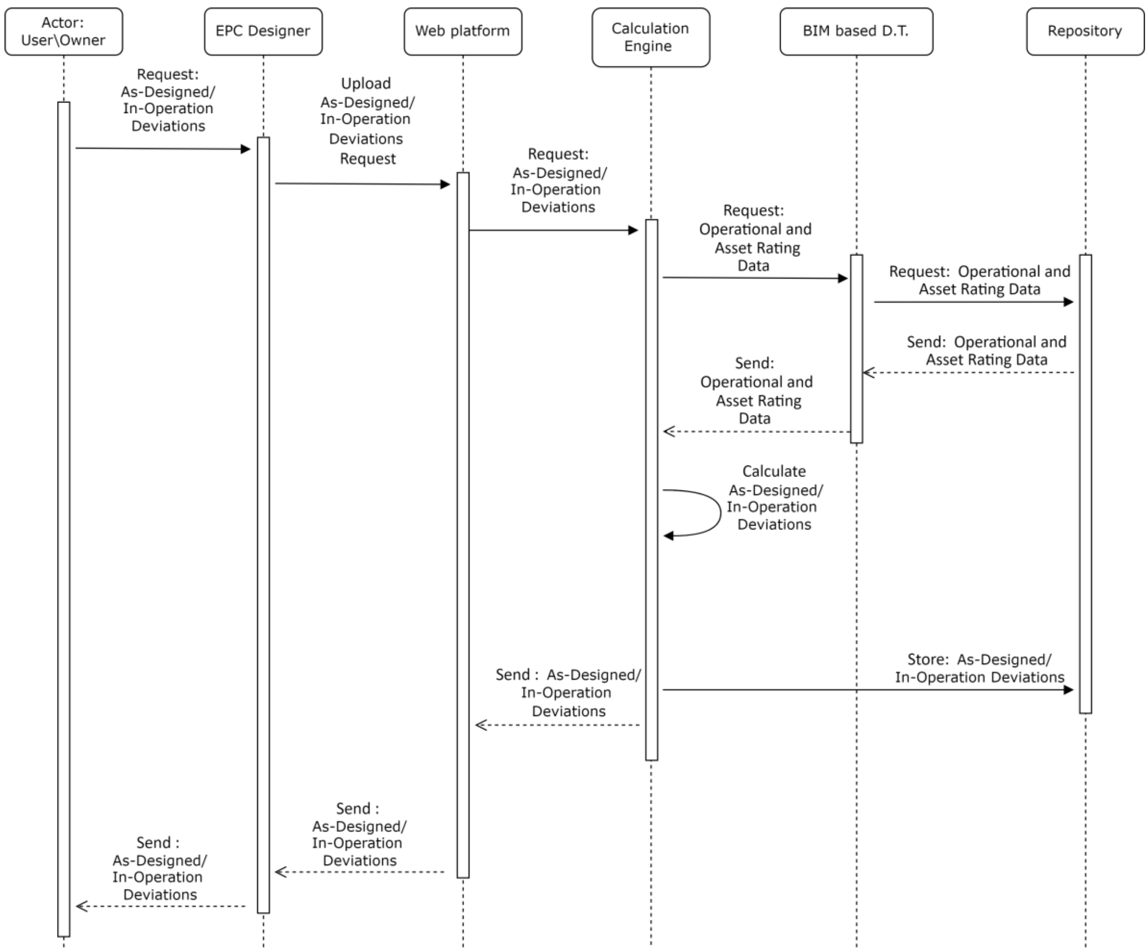

Figure 37. UC3.2 Sequence Diagram.

9.3.3 UC3.3 Provide regular recommendation for improving operational energy performance & conditions in terms of health and comfort

Table 19. UC3.3 Requirements

Use Case #	UC3.3
Use Case Name	Provide regular recommendations for improving operational energy performance & conditions in terms of health and comfort
Intent	To improve operational energy performance and indoor conditions (health, comfort)
Version/Action/Author	v3
Last Update	12.06.2023
Actors Involved	Main Actors: Public Bodies, Registries, Tenants/Owners, Software Tool Developers, ESCOs, Building services Industry Other: Standardization Bodies, Engineers, Researchers/Academia, Building services Industry, Professional Consultants, Environmental/ social campaigning organizations
Brief Description	The D^2EPC Web Platform sends a request for improvement recommendations to the AI-driven Performance Forecasts and the Building Performance Module. The AI-driven Performance Forecasts requests building infrastructure information and measurements that are imported through the BIM-based Digital Twin and then performs internal processes to predict the months-ahead building operational behavior. The BPM requests building infrastructure information and HC&W measurements that are imported through the BIM-based Digital Twin. Based on the predictions, the AI-driven Performance Forecasts requests new EPC results that are calculated as in UC2.2 by the Operational Rating module of the Calculation Engine and stored in the Repository, while the BPM calculates the new HC&W KPIs. Based on the operational based results, the AI-driven Performance Forecasts identify any possible operational patterns that might affect the building's performance, while the Building Performance Module identifies any unfavorable conditions in relation to human comfort. Both tools send information to the Notification and Alerts Tool that sends alerts for the availability of new performance/human comfort recommendations to the Web Platform.
Assumptions	-
Pre-conditions	UC1.2, UC2.2
Trigger	Request for improving operational energy performance & conditions in terms of health and comfort

Goal (Successful End Condition)	Recommendations for improving operational energy performance & conditions in terms of health and comfort
Post-conditions	-
Related Use Cases	UC1.2, UC1.3, UC2.3, UC2.4, UC2.5

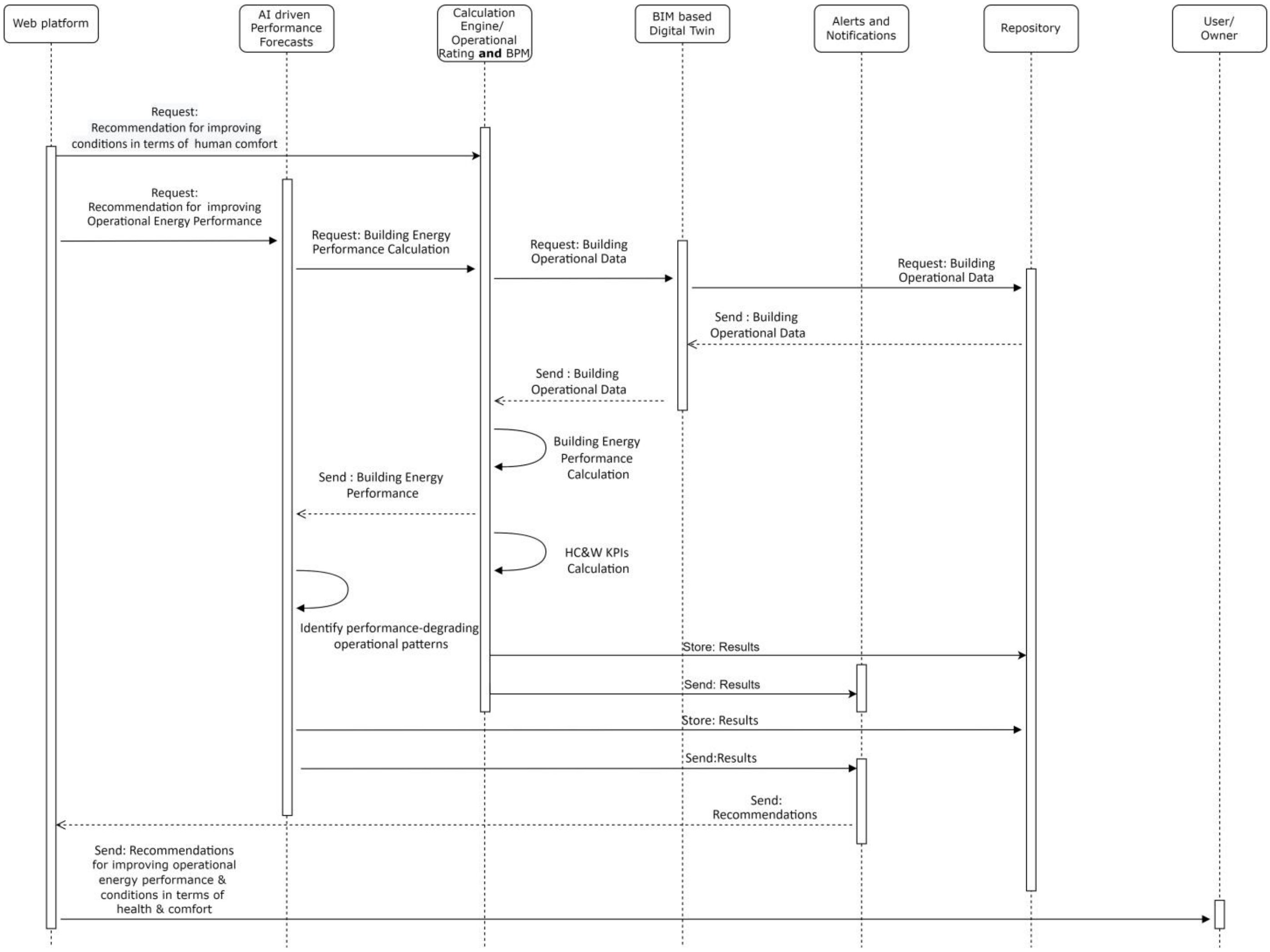

Figure 38. UC3.3 Sequence Diagram.

9.4 BS4 Provision of regional level of EPC statistics for third-party stakeholders

9.4.1 UC4.1 Regional Level Visualisation of dynamic (aspect of time) energy performance information for asset-based EPCs

Table 20. UC4.1 Requirements

Use Case #	UC4.1
Use Case Name	Regional Level Visualisation of dynamic (aspect of time) energy performance information for asset-based EPCs
Intent	Provision of regional (NUTS or administrative) visualisation tools for asset-based EPC ratings
Version/Action/Author	v2
Last Update	04.05.2022
Actors Involved	Main Actor: Authorities/ Registries/ Public Bodies, Software Tool Developers, ESCOs, Building services Industry Other: Researchers/ Academia, Real Estate Agents, Standardization Bodies, EU Commission, Environmental/ social campaigning organizations
Brief Description	Authorities/ Registries/ Public Bodies request from the WebGIS platform Regional Level Asset Ratings via selections on the map or via querying tools. The request is transmitted to the D^2EPC WebGIS backend which retrieves the data from the D^2EPC Geospatial Database, created explicitly for the D^2EPC WebGIS. The data in the DB are updated by the Calculation Engine upon EPC issuing requests. Results are sent to the WebGIS platform for visualisation through the Web Platform.
Assumptions	The building owner agrees to share the building’s asset rating. The building’s approximate location should be provided without any major distortions.
Pre-conditions	UC1.2
Trigger	The request for visualisation of asset rating performance of buildings in an area/region.
Goal (Successful End Condition)	Visualisation of Regional Level of dynamic (an aspect of time) energy performance information for asset-based EPC ratings.
Post-conditions	Building, region/area data are available for examination and evaluation from the stakeholders.
Related Use Cases	UC1.3, UC1.5, UC1.6, UC5.1, UC5.2

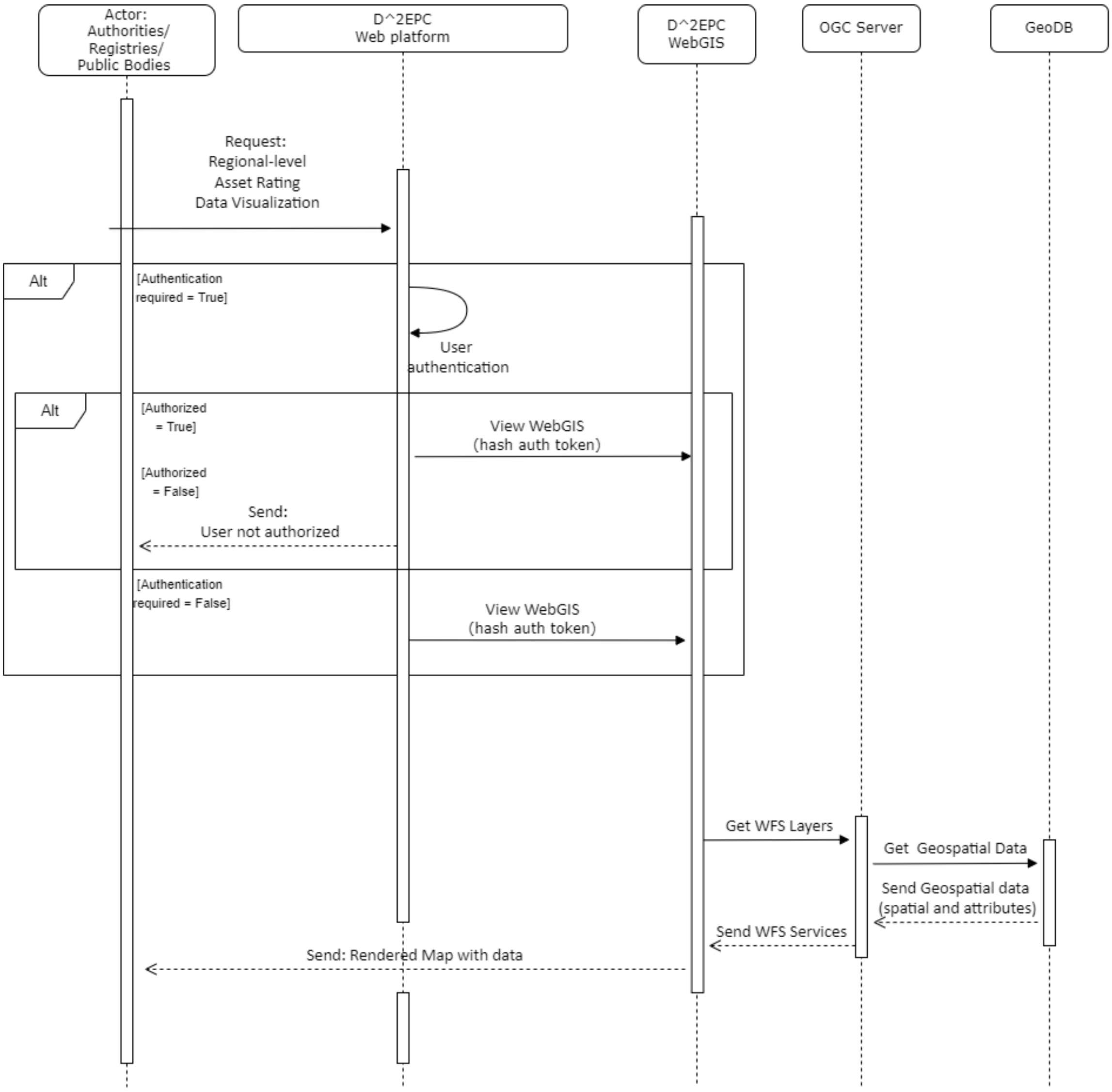

Figure 39. UC4.1 Sequence Diagram.

9.4.2 UC4.2 Regional Level Benchmarking and statistics comparison between regions

Table 21. UC4.2 Requirements

Use Case #	UC4.2
Use Case Name	Regional Level benchmarking and statistics comparison between regions
Intent	Provision of comparison & visualisation tools for regional (NUTS or administrative) statistics of EPCs. Provision of querying tools based on spatial attributes or EPC statistics.
Version/Action/Author	v2
Last Update	04.05.2022

Actors Involved	Main Actor: Authorities/ Registries/ Public Bodies, Software Tool Developers, ESCOs, Building services Industry Other: Researchers/ Academia, Real Estate Agents, Standardization Bodies, EU Commission, Environmental/ social campaigning organizations
Brief Description	Authorities/ Registries/ Public Bodies have the ability to view the statistics for asset-based EPC ratings for a selected region on a map and compare them against a different region by also selecting it on the map. The comparison mode is activated by selecting it via a dedicated button on the D^2EPC WebGIS front-end Authorities/ Registries/ Public Bodies have the ability to view EPC statistics based on attribute or spatial queries
Assumptions	The building owner agrees to share the building's real-time measurements from the installed sensors. The building's exact location should be provided without any major distortions.
Pre-conditions	UC2.2
Trigger	The request for comparison of EPC statistics for asset-based EPC ratings between different regions on the map .
Goal (Successful End Condition)	Comparison of EPCs based on asset rating methodology between regions.
Post-conditions	Building, region/area data are available for examination and evaluation by the stakeholders.
Related Use Cases	UC2.3, UC2.5, UC3.1, UC3.2, , UC4.3, UC5.1, UC5.2

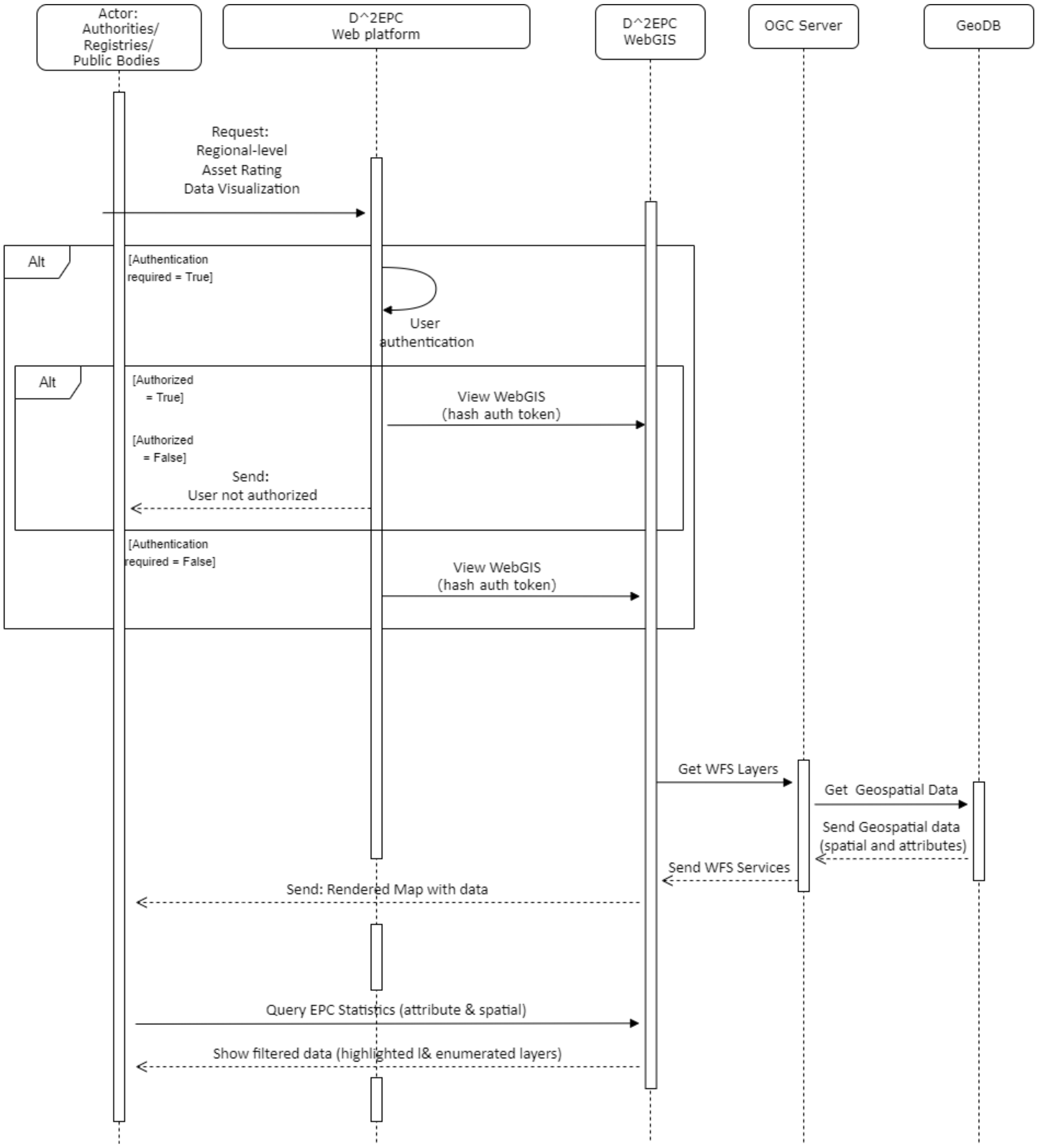

Figure 40. UC4.2 Sequence Diagram.

9.4.3 UC4.3 Building Performance Benchmarking statistics for Operational rating of pilot buildings and 3D Visualization

Table 22. UC4.3 Requirements

Use Case #	UC4.3
Use Case Name	Building performance statistics for operational rating of pilot buildings and 3D visualisation
Intent	Provision of enhanced visualisation of BIM models in the WebGIS environment coupled with (near) real time energy performance data
Version/Action/Author	v2

Last Update	04.05.2022
Actors Involved	Main Actor: Building Owners
Brief Description	Building Owners can visualise the 3D model of the building as well as all additional information provided through the BIM file such as individual components, construction materials etc.
Assumptions	Only authorized users can select this mode
Pre-conditions	UC1.1, UC2.1,
Trigger	3D Visualisation of pilot case buildings
Goal (Successful End Condition)	Provide an enhanced visualisation of the current building state in the WebGIS platform
Post-conditions	-
Related Use Cases	UC2.2, UC4.1, UC4.2, UC5.1, UC5.2

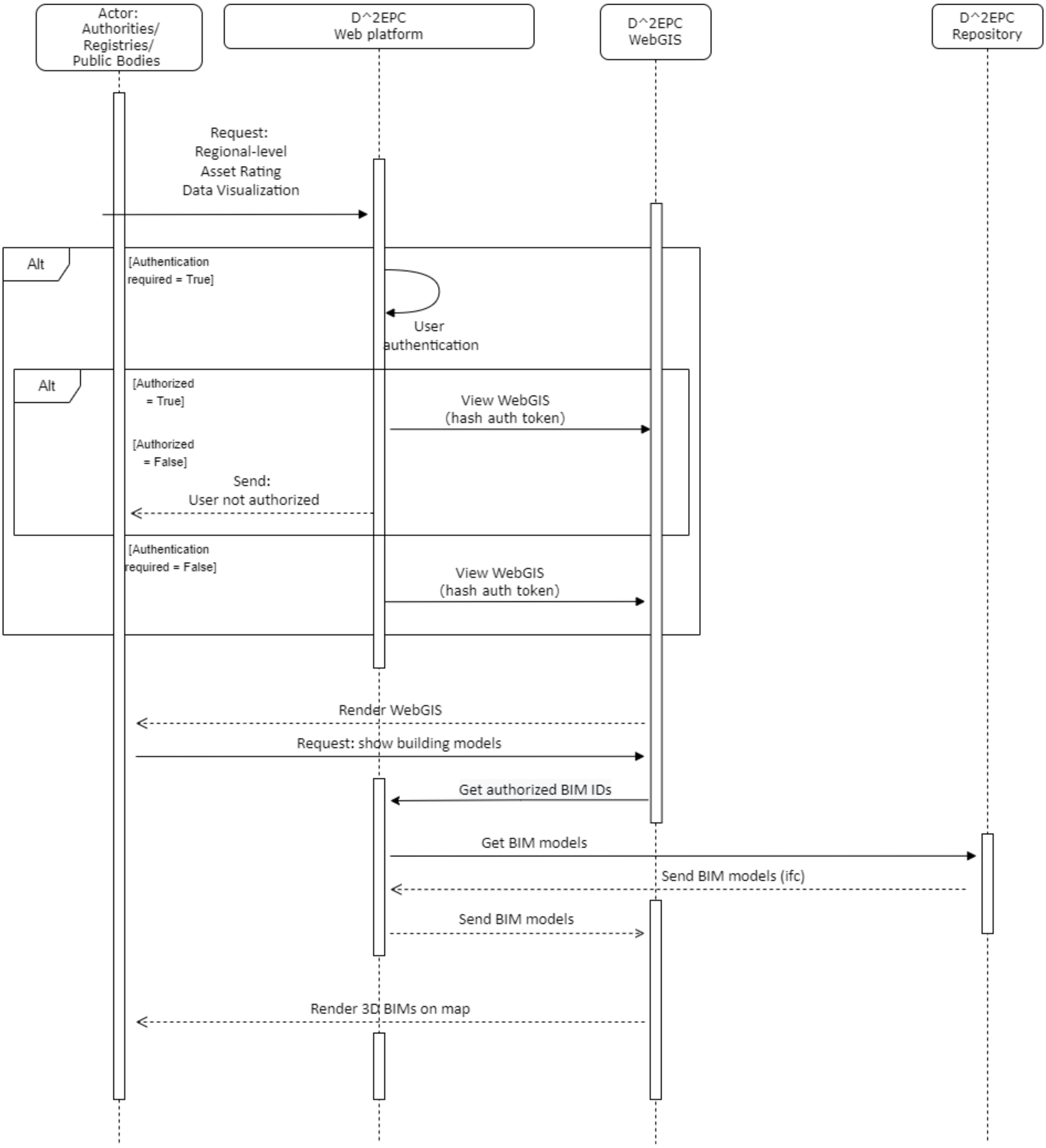

Figure 41. UC4.3 Sequence Diagram.

9.5 BS5 Provision of dEPC statistics related to materials, assets, etc. for promoting "greener" equipment campaigns

9.5.1 UC5.1 Provision and Visualisation of correlation of building materials and energy performance

Table 23. UC5.1 Requirements

Use Case #	UC5.1
Use Case Name	Provision and Visualisation of correlation of building materials and energy performance
Intent	To provide insights to the various stakeholders on how the used building's materials affect their energy performance
Version/Action/Author	v3
Last Update	12.06.2023
Actors Involved	Main Actor: Building Services/Material Industry, Suppliers, Engineers, Building designers, Facility Managers, ESCOs Other: Researchers/ Academia, Public Bodies, Environmental/social campaigning organizations, Standardization bodies, EU Commission
Brief Description	Building Services/Material Industry, Suppliers, Engineers, Building designers, Facility Managers and ESCOs request from the Web Platform Asset Rating Data benchmarked visualization and the request is transmitted to the Building Energy Performance Benchmarking Tool. The Building Energy Performance Benchmarking tool requests asset-based energy performance data from the D^2EPC Repository and performs the correlation between the building materials and the energy performance. The correlation result is sent for visualisation through the Web Platform.
Assumptions	Asset-based energy performance data are available in the Repository and the user role has appropriate access rights.
Pre-conditions	UC1.2, UC2.2, UC 2.3, UC 3.2
Trigger	The request for visualisation of the correlation of building materials and energy performance.
Goal (Successful End Condition)	Find the more appropriate materials for each case (location, use etc.) and establish best practices for the building construction industry.
Post-conditions	Building, region/area data are available for examination and evaluation from the stakeholders.
Related Use Cases	UC4.1, UC 4.2, UC4.3

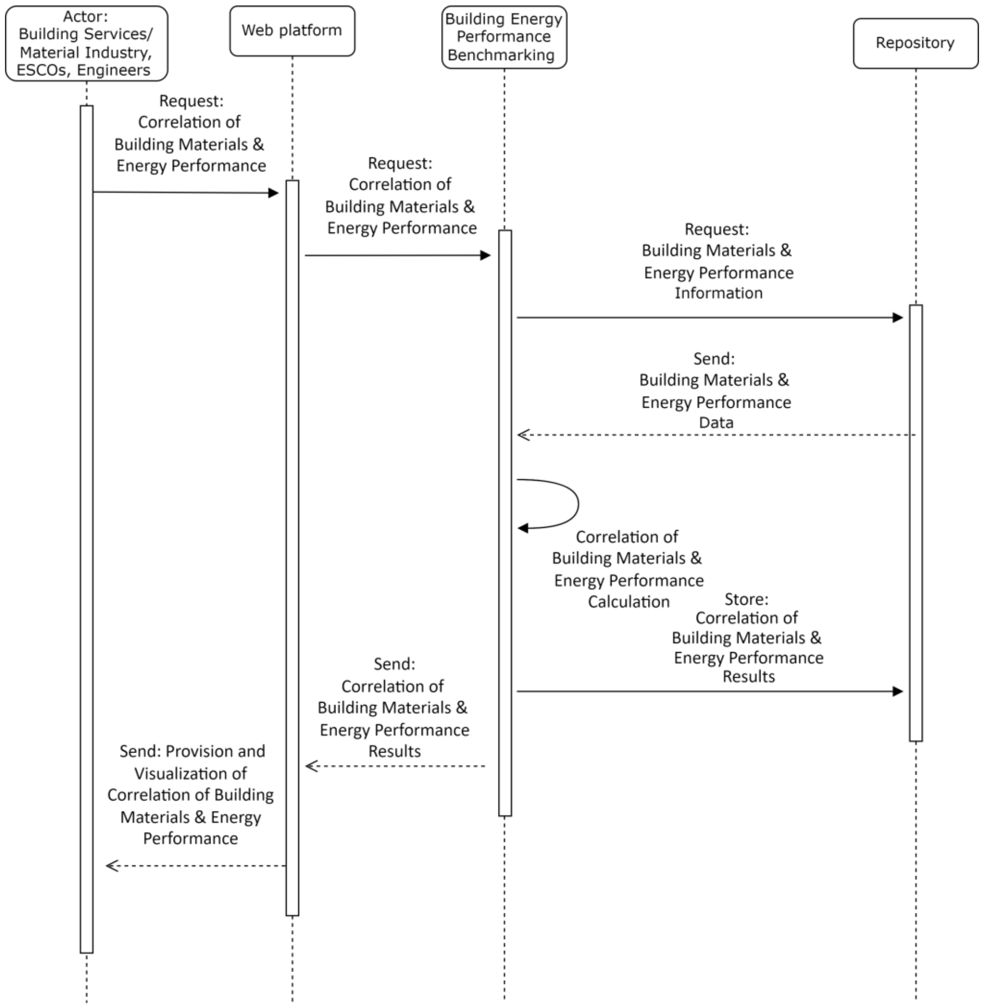

Figure 42. UC5.1 Sequence Diagram

9.5.2 UC5.2 Provision and Visualisation of correlation of building assets/systems and energy performance

Table 24. UC5.2 Requirements

Use Case #	UC5.2
Use Case Name	Provision and Visualisation of the correlation of building assets/systems and energy performance
Intent	To provide insights to the various stakeholders on how the used building infrastructure and the installed systems can affect their energy performance.
Version/Action/Author	v3
Last Update	12.06.2023

Actors Involved	Main Actor: Building Services/Material Industry, Suppliers, Engineers, Building designers, Facility Managers and ESCOs, Owner/ Tenant/ User, Other: Researchers/ Academia, Public Bodies, Environmental/social campaigning organizations, Standardization bodies, EU Commission
Brief Description	Building Services/Material Industry, Suppliers, Engineers, Building designers, Facility Managers, ESCOs request from the Web Platform Asset Rating Data benchmarked visualization and the request is transmitted to the Building Energy Performance Benchmarking Tool. The Building Energy Performance Benchmarking tool requests operational-based energy performance data from the D^2EPC Repository and performs the correlation between the assets/systems and the energy performance. The correlation result is sent for visualisation through the Web Platform.
Assumptions	Operation-based energy performance data are available in the Repository and the user role has appropriate access rights.
Pre-conditions	UC1.2, UC 1.3, UC2.2
Trigger	The request for visualisation of the correlation between building assets/systems and energy performance
Goal (Successful End Condition)	Find the more appropriate building systems and infrastructure for each building case (location, use etc.) and establish best practices for the building construction industry
Post-conditions	Building, region/area data are available for examination and evaluation from the stakeholders
Related Use Cases	UC4.1, UC 4.2, UC4.3

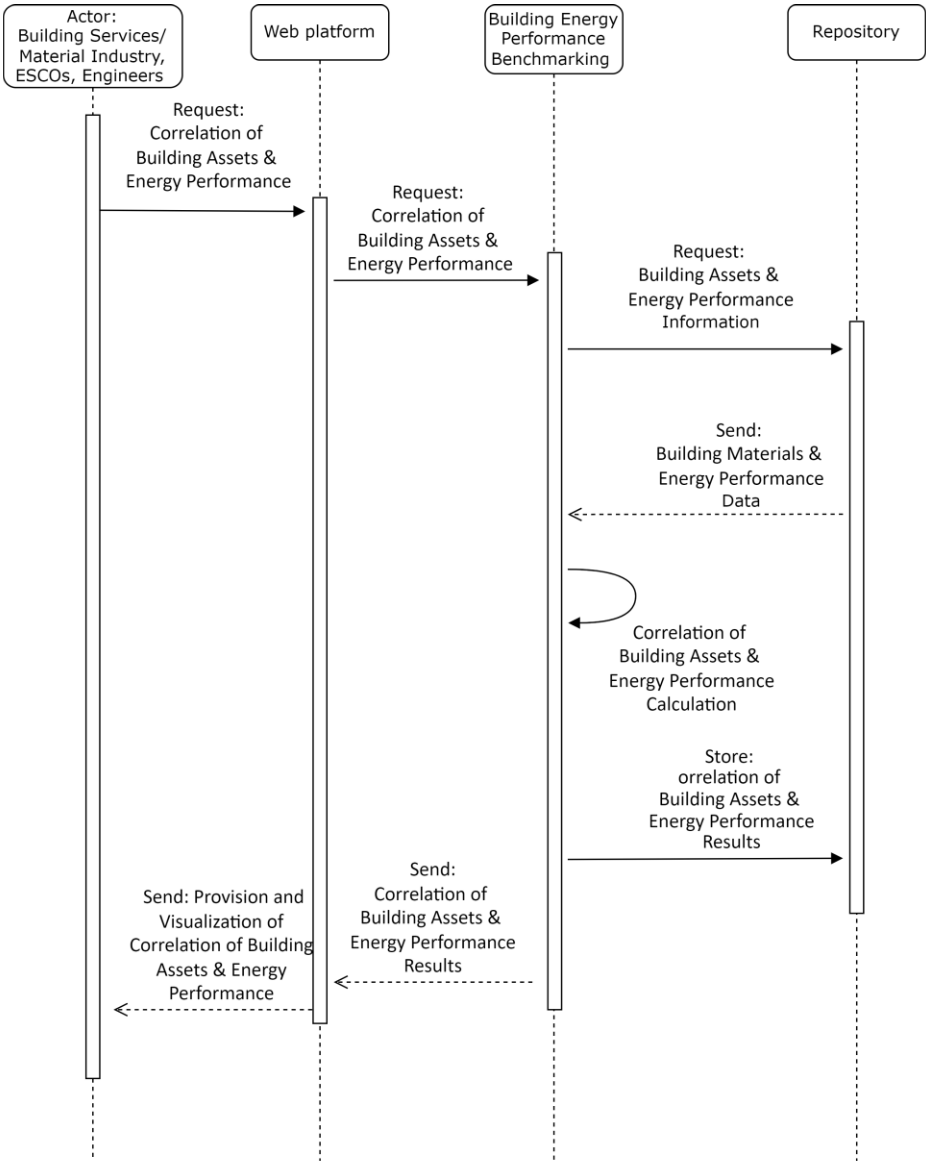

Figure 43. UC5.2 Sequence Diagram.

10 Conclusions

This report is the third and final report out of three deliverables for defining in detail the D^2EPC architecture, describing the system's main building blocks and giving a comprehensive overview of all components, their high-level functionality and interdependencies. The previous version has been updated with all the additional features and modifications, in alignment with the progress of the project within the final months of its implementation.

The system architecture design methodology that was applied has been described, following best practices introduced from various standards and frameworks in the literature. The methodology proposed and followed provides a well-defined process and structure for describing the D^2EPC architecture, presenting different viewpoints of the system architecture, including:

- The Functional View describing the system's functional elements, their responsibilities and primary interactions with other elements.
- The Information view, defining the data flow as well as data distribution.
- The Deployment View, describing the modules and existing software hardware requirements.
- The Dynamic View (Use Case Analyses) presents the operations of components, their functionalities and interactions in the runtime environment.

The system requirements that frame the architectural problem and explicitly represent the stakeholders' needs and desires have been described. This third deliverable version further updates the functional and non-functional requirements that were carefully selected and documented following the Volere methodology, in order to ensure that they make sense in the context of the outcome of the project and conveyed to all the team members working on it.

As a result of applying this methodology to the D^2EPC system architecture definition process, the main building blocks of the system were clearly identified and broken down into manageable modules, with clear responsibilities. The preliminary in-depth analysis in the first deliverable identified missing components/subcomponents and corresponding functionalities within the original conceptual architecture, leading to the refinement of the overall system architecture. The same process was repeated in the third iteration of the task, to contemplate the architecture with newly introduced subcomponents, modified/additional functionalities and updated component interaction, as a result of their further development in other tasks carried out by each responsible partner.

Finally, within this report, the original version of the D^2EPC Business Scenarios and Technical Use Cases has now been finalized, to better present the operational flows envisioned within the D^2EPC platform by the various stakeholders identified in previous WP1 activities.

Following the completion of the project's activities within technical work packages, the authors of this report are confident that all the technical aspects of the D^2EPC framework have been clarified and well-documented in this report, which now delivers the fully developed D^2EPC system architecture.

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