D2.1 User Needs and Requirements for the EU Kernel EPC Engine

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ABREVIATIONS

A/C	Air Conditioning
AI	Artificial Intelligence
API	Application Programming Interface
BEP	Building Energy Performance
BIM	Building Information Modelling
BPMN	Business Process Management Notation
CEN	European Committee for Standardization
CINEA	Climate, Infrastructure and Environment Executive Agency
EC	European Commission
EPB	Energy Performance of Building(s)
EPBD	Energy Performance of Building Directive
EPC	Energy Performance Certificate
ESCO	Energy Service Company
ETL	Extract, Transform, Load
EU	European Union
GDPR	General Data Protection Regulation
GIS	Geographic Information System
HVAC	Heat Ventilation and Air conditioning
IEC	International Electrotechnical Commission
IFC	Industry Foundation Classes
KPI	Key Performance Indicator
NZEB	Near Zero Energy Building
RTM	Requirement Traceability Matrix
SOTA	State of the Art

SRI	Smart Readiness Indicator
UAT	User Acceptance Testing
UC	Use Case
UML	Unified Modeling Language
WP	Work Package

PARTNERS SHORT NAMES

Partner No.	Short Name	Full Name
1	**ED**	European Dynamics
2	**QUE**	QUE TECHNOLOGIES
3	**EUP**	EUPHYIA-TECH
4	**SBC**	SBCGR (Sustainable Buildings Council Greece)
5	**EPBC**	EPB CENTER
6	**ENERSAVE**	EnerSave Solutions
7	**EU.BAC**	EU Building Automation Controls Association
8	**EGC**	European Green Cities
9	**EFIEES**	European Federation of Intelligent Energy Efficiency Services

About openBEP4EU

*The **openBEP4EU** project is co-funded by the European Union under Grant Agreement No. 101167613 (Life Programme). The project started as of September 1st 2024 and is anticipated to conclude in March 2027 (30 months duration).*

The building sector is recognised as one of the pillars for achieving the target of European climate neutrality by 2050. The EU is undergoing a twin transition, a digital and green transition as outlined in recent European directives. Buildings are a significant contributor of emissions, and they consume a sizeable portion of EU's energy consumption. Towards EU's direction of improving the performance of its building stock, Energy Performance Certificates (EPCs) have, among other initiatives and actions, been instrumental in achieving the set targets. EPCs have become a powerful tool for the end-users, such as service providers who can identify business opportunities, or policymakers who are empowered with better data on the building stock, enabling them to oversee the effects of policies and financial schemes.

A more harmonised European calculation methodology for the EPCs could, among others, increase comparability between regions, trust, and market uptake for features related to smart readiness, comfort, real energy consumption and district energy. To this end, OpenBEP4EU aims to deliver an open-source, universal software implementation of the CEN/ISO 52000 EPB standards family, namely the EU Kernel EPB Engine, to facilitate simultaneous and coordinated adoption of an innovative EPC calculation approach among all the Member States. This initiative aims to make building performance data easily accessible to various stakeholders like financial institutions, energy service providers, and building owners, fostering the development of financial products supporting sustainable renovation projects.

Core elements of openBEP4EU's activities also include the creation of an EPC Support Team to drive market adoption as well as a Sustainable Design Data Hub, aligned with the overarching goals of the European Bauhaus initiative, that not only serves as a data repository but also promotes collaboration and research for sustainable architecture and design. These activities will facilitate stakeholder engagement, contribute to improved EPC reliability, accuracy, accessibility, while paving the way for EPC market uptake across the EU Member States though well promotion strategies. All data sharing within this framework adheres to the principles of the Common European Energy Data Space, prioritizing sovereign data sharing and respecting data ownership among the involved stakeholders.

Executive summary

D2.1 – "User Needs and Requirements Report for the EU Kernel EPC Engine" aims to comprehensively identify the user requirements and needs of the OpenBEP4EU Digital Toolbox and to present the efforts carried out in the scope of T2.1 – "User Needs and requirements Assessment". It includes the description and outcomes of a thorough, comprehensive needs analysis conducted through a structured methodology that includes the identification of needs stemming from stakeholder expectations, business objectives, literature and state of the art analysis and use case analysis. The stakeholder needs are then aligned with the main functionalities planned to be included in the OpenBEP4EU Digital Toolbox (Figure 1) and are documented into a standardised catalogue of requirements. This approach ensures that the toolbox's development remains tightly coupled with actual stakeholder demands and good practices identified in recent EU funded projects (Next Gen EPC cluster's sister projects).

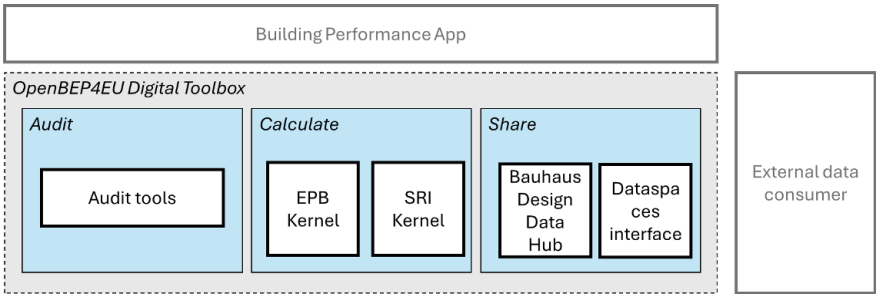

Figure 1: Functional blocks of the OpenBEP4EU Digital Toolbox

The requirements are addressed by the following OpenBEP4EU Digital Toolbox functions:

- **FUN1 – Audit** (collecting, recording and storing the building data needed for EPC and SRI assessment, including importing digital building models (BIM))
  - ***FUN1.1 - Import building model***: Enables the importing and processing of digital building models, extracting relevant data needed for energy performance and SRI audit.
  - ***FUN1.2 - Input additional data***: Enables the user to provide additional data that is not available in the digital building model and is required for energy performance and SRI audit.
- **FUN2 – Calculate** (calculation of EPB and SRI indicators in alignment with the CEN/ISO set of EPB standards and the EU SRI methodology)
  - ***FUN2.1 - Calculate energy performance KPIs***: Enables the calculation of energy performance KPIs of a building, based on the audit data (e.g. primary energy, CO_2 emissions).
  - ***FUN2.2 - Calculate SRI***: Enables the calculation of the SRI of a building, based on the audit data, reflecting the building's smart technology capabilities.
  - ***FUN2.3 - Generate report***: Generates different kinds of tailored reports (e.g. for end-users and authorities).
- **FUN3 – Share** (sharing data, EPB and SRI parameters, and good practices across platforms)
  - ***FUN3.1 - Dataspaces share***: Enables the secure sharing of persistent data with external entities (adhering to Common European Energy Data Space principles).
  - ***FUN3.2 - Browse data hub***: Enables browsing the information that is available in the Bauhaus Design Data Hub
  - ***FUN3.3 - Add in data hub***: Enables the addition of information in the Bauhaus Design Data Hub to build a growing repository of EPC and SRI related data and good practices.

Moreover, the purpose of the document has been extended to include a first design of the OpenBEP4EU Digital Toolbox architecture to facilitate the effective implementation and development of the EU Kernel EPC Engine. This initial architecture aligns the tool with the CEN/ISO 52000 family of EPB standards and an open source approach, ensuring uniform adoption of the common calculation framework across EU Member States.

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1. Introduction

1.1. Purpose of the document

D2.1 – "User Needs and Requirements Report for the EU Kernel EPC Engine" aims to identify the user requirements and needs of the OpenBEP4EU Digital Toolbox and presents the efforts carried out in the scope of T2.1 – "User Needs and requirements Assessment". D2.1 outlines a clear methodology for requirements elicitation and management, ensuring that the OpenBEP4EU Digital Toolbox development aligns with stakeholder expectations, thus establishing a shared understanding of the project scope and objectives. Effective requirements elicitation is an important activity in the process of system and project implementation, as it ensures the alignment of the outcomes with the stakeholder expectations by [1] [2] [3] [4] [5], thereby avoiding misunderstandings, prioritising key features, and improving communication among all stakeholders:

- Establishing a shared understanding of the scope, thus avoiding misunderstandings and conflicts,
- Enabling prioritisation and focus on the most important features,
- Improving communication across all stakeholders,
- Maintaining alignment with business objectives,
- Supporting effective and efficient project management and planning,

On top of the above, the technical partners identified that the architecture design included in the project Description of Work is a mere high-level representation that served the purposes of proposal evaluation, not a representation according to software design methodologies that can guide the development and facilitate the OpenBEP4EU Digital Toolbox implementation. For that reason, the purpose of the document has been extended to include the more elaborated Digital Toolbox architecture design, ensuring that the architecture follows software design good practices and can guide development, which is crucial for a complex, open source system intended for EU-wide adoption. By including the first version of the Digital Toolbox architecture, D2.1 bridges the gap between abstract requirements and a tangible design blueprint, facilitating implementation with long term oriented perspective.

More specifically the purpose of this document is:

- To define the methodology for requirements elicitation and management,
- To identify stakeholders and their main expectations from the OpenBEP4EU Digital Toolbox,
- To set the business objectives of the OpenBEP4EU Digital Toolbox in line with the stakeholder expectations,
- To identify needs stemming from both literature and UCs, and
- To elicit specific requirements for the OpenBEP4EU Digital Toolbox based on the analysis of the above.
- To design the first version of the architecture of the OpenBEP4EU Digital Toolbox.

This document is intended to support OpenBEP4EU partners in aligning their efforts to define, document, and validate user requirements for the project. By leveraging on standardised specification and documentation methodologies, the deliverable ensures a structured approach to capturing stakeholder needs, detailing use cases, and translating them into actionable user requirements. It provides clarity and traceability, enabling the validation and alignment with strategic goals, while offering developers, designers, and quality assurance teams precise specifications for implementation and testing. Furthermore, it fosters collaboration among all stakeholders, ensuring compliance with industry standards and delivering solutions that meet user expectations effectively.

1.2. Relation to other tasks of WP2

The user requirement elicitation that is performed in the context of T2.1 is closely related to WP2 "Implementation, delivery and demonstration of the EU Kernel for EPC asset calculation". Specifically, T2.1 establishes the foundation by identifying stakeholders, collecting data, analysing needs, and validating requirements in alignment with industry standards and EU directives. These requirements then inform the design and development activities in subsequent tasks, creating a feedback loop that keeps the project aligned with it strategic goals and the EPBD regulatory framework. This holistic approach guarantees that as the project progresses, it remains grounded in validated user needs and complies with the broader objectives of WP2. The derived use cases and user requirements will be closely related and monitored in accordance with the following tasks:

- T2.1 - "User Needs and Requirements Assessment" is dedicated to developing a methodology and execution of stakeholder identification, data collection, needs analysis, prioritization, comprehensive documentation, validation with stakeholders, and alignment with industry standards. T2.1 will be responsible for monitoring the progress and evaluation of all user requirements during the project's life cycle.
- T2.2 - "Development of the backend of an EU Kernel EPC engine" is dedicated to the creation of a robust, compliant, and technologically advanced Energy Performance engine to support the creation of next-generation EPCs and which will adhere to the latest European Performance of Buildings EPB standards and regulations. T2.2 will be responsible for monitoring the user requirements related to the building's energy performance calculations using the EU kernel EPB engine.
- T2.3 - "Integration of Smart Readiness Indicator (SRI)" aims to integrate the Smart Readiness Indicator (SRI) in the EU Kernel EPB engine to elevate the quality of energy performance assessments. T2.3 will be responsible for monitoring the user needs related to the SRI standards.
- T2.4 - "EU Kernel data population using Data Space Principles" aims to ensure data secure communication and sovereignty among stakeholders. T2.4 will be responsible for monitoring the user requirements related to the secure communication of various stakeholders.
- T2.5 - "Open-Source Software Documentation and Training Material" ensures the accessibility, usability, and continuous improvement of the OpenBEP4EU Digital Toolbox and the integrated Smart Readiness Indicator (SRI). This task revolves around creating open-source software documentation and comprehensive training materials. T2.5 will be used for monitoring user needs related to the repository for sharing between stakeholders.

1.3. Structure of document

The structure of the document is the following:

Section 1: Introduces the document by defining its purpose and target audience,
Section 2: Describes the methodology followed for the requirements elicitation and documentation,
Section 3: Analyses the stakeholders of EU Kernel EPC engine and their expectations,
Section 4: Analyses the business objectives of the OpenBEP4EU Digital Toolbox,
Section 5: Overviews existing UCs of similar projects, identifies and analyses the openBEP4EU UCs, and summarises outcomes of literature analysis,
Section 6: Analyses the OpenBEP4EU Digital Toolbox user requirements,
Section 7: Describes the first version of the architecture of the OpenBEP4EU Digital Toolbox,
Section 8: Concludes the document with remarks and future outlook.

1.4. Target Audience

The requirements documented in this document aim to set the context and scope of the OpenBEP4EU Digital Toolbox features and provide a common understanding as to what the OpenBep4EU Digital Toolbox will offer. As such, it is addressed to different types of stakeholders:

- EC, as a funding agency during the duration of the project,
- Member States, as customers/adopters of the Digital Toolbox,
- Energy assessors (companies and individuals) as the end-users of the Digital Toolbox features,
- 3rd-party app developers, as customers/users of the Engine, who develop intermediary applications to be used by other end-users,
- Building owners and operators, also as the end-users of the Engine features,
- Any other organisation that wants insight to energy performance or data, like ESCOs, financial institutions, etc.
- Partners of the project, as the responsible for the implementation.

1.5. Disclaimer

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2. Methodology for the requirements elicitation and management

This section outlines the structured approach used to define the openBEP4EU UCs. Firstly, the methodology of eliciting user requirements is outlined and then the followed methodology is analysed for determining the openBEP4EU UCs.

2.1. Main activities

OpenBEP4EU employs a structured requirements elicitation and analysis process, ensuring comprehensive documentation of the critical system needs. This includes the following key activities [6] [7] [8] [9]:

1. **Set system boundaries**: The system's purpose and scope, in alignment with the business objectives are defined.
2. **Identification of stakeholders and expectations**: The most significant stakeholders of the system and their main expectations, in line with the system scope, are identified.
3. **Requirements gathering**: Requirements are collected by utilising various methods, such as literature analysis, UC analysis, state of the art assessment and technology push.
4. **Classification of requirements**: Collected requirements are further analysed and classified, identifying overlaps and conflicts, and documenting important requirements.
5. **Managing requirements**: Documented requirements are validated and managed through the project life, performing updates when needed.

As indicated by the 'Managing requirements' activity, the whole process is iterative. The above activities will be continuously performed during the implementation to validate and refine accordingly the requirements documented in this report.

2.2. Methods for gathering of requirements

As indicated above, various methods are utilised to gather the requirements. The gathering activity itself brings together two main approaches of elicitation, bottom-up and top-down requirements gathering (Figure 2) [10]:

- Bottom-up requirements gathering is related with technology push, state of the art features, whether explicitly needed or desired in order to innovate. These are then aligned with the stakeholder expectations and formalised into prioritised requirements.
- Top-down requirements gathering is related to needs derived from stakeholder expectations and system business goals. The goals and expectations are analysed into specific needs and then are decomposed into detailed requirements.

Figure 2: Bottom-up and top-down requirements gathering brought together

2.2.1. Literature and State of the Art analysis

A comprehensive literature and State of the Art analysis serves two main purposes [11] [12] [13]:

- **Understanding the landscape**: to gain a thorough understanding of the current state of EPC schemes across the EU, in order to identify strengths, weaknesses and opportunities for improvement. This involves the review of current EPB regulations, directives and standards, taking into account the objective of harmonising EPCs across Member States.
- **Identifying best practices and needs**: to identify best practices, as well as emerging trends and technologies in EPB calculation and reporting. This ensures that the OpenBEP4EU Digital Toolbox is aligned with the latest advancements and addresses currently identified needs for EPB and SRI calculations effectively.

The literature review encompasses different kinds of resources, such as:

- Official documents, directives and regulations, like the Energy Performance of Buildings Directive (EPBD) and other related guidelines, as well as national EPC schemes of EU member states. This ensures alignment with the overarching EU policy framework and enhances the feasibility of harmonisation.
- CEN/ISO 52000 EPB standards and other related EPB standards, analysing specific calculation methodologies, data requirements and reporting formats, as well as defining which are within the scope of the OpenBEP4EU Digital Toolbox.
- Scientific publications and reports, related to EPCs, EPB and related topics, in order to identify best practices and innovative approaches.
- Existing software and tools, to identify implementation approaches and discover potential synergies.

2.2.2. Use Case analysis

In order to document and validate use cases, the IEC 62559 standard use case template was utilised as a basis for the use case description. The methodology ensures that stakeholder inputs are systematically captured, enabling the identification and extraction of comprehensive user requirements. The IEC 62559 standard provides a universal template for documenting use cases in a consistent and comprehensive manner. It emphasizes the clear definition of system functionalities, stakeholder roles, and conditions for success, ensuring traceability and reusability of use case information across different phases of the project.

The detailed steps in the UCs development process are the following:

1. Stakeholder engagement and identification
2. Use Case scoping and prioritization
    a. Potential use cases are brainstormed and categorized based on their relevance, impact, and alignment with project objectives.
    b. A prioritization exercise is conducted to focus on high-value use cases that address critical functionalities and stakeholder concerns.
3. Use Case documentation
    a. Use Case Name and ID: A unique identifier and descriptive title.
    b. Scope: Describes the scope of the use case as a short description.
    c. Objectives: Describes what the main actor(s) want to achieve.
    d. Features: Main features expected from the system to implement the use case.
    e. Assets: Assets required from the actors to implement the use case.
    f. Actors: The individuals, systems, or components interacting with the use case.
    g. Assumptions: Assumptions considered for the successful execution of the use case.
    h. Preconditions: The conditions or states that must exist before the use case can be executed.
    i. Trigger: The event or action that initiates the use case.

j. Postconditions: The expected state or outcome after the successful execution of the use case.

4. Review and validation
   a. Drafted use cases are reviewed to ensure completeness and accuracy.
   b. Feedback is incorporated, and use cases are refined iteratively.
5. Linking to requirements
   a. Each use case is analysed to identify and extract specific user requirements.
   b. The use cases are later elaborated in specific scenarios as flows.

The procedure to be followed in illustrated in Figure 3:

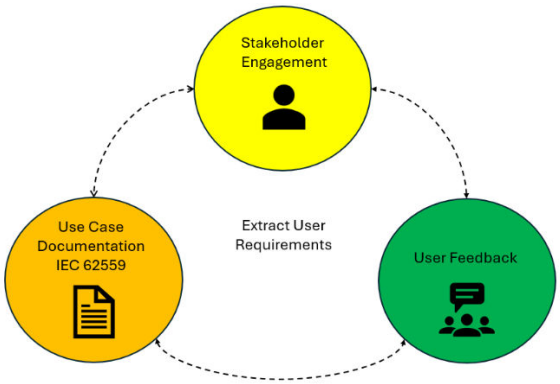

Figure 3: User Requirements extraction methodology

The benefits of the suggested methodology:

- Clarity: Ensures consistent and thorough documentation of use cases.
- Traceability: Facilitates seamless linking between stakeholder needs, use cases, and extracted requirements.
- Reusability: Documents can be adapted for future projects or extended functionalities.
- Collaboration: Enhances stakeholder engagement and alignment throughout the requirements gathering process.

2.3. Documentation of requirements

The requirements are documented according to the following format:

ID <ID>	**Function(s)** (ID(s) of related function(s))	**Source** (reference to stakeholder need ID(s), as in paragraph 5.5)
<Title> <Requirement description>		

The requirement description adheres to the following format:

(While <operational condition>), the <user role/system/module> <must/should/could/won't have> be able to <capability>.

Where the priority is specified according to the MoSCoW method [14]:

- Must: Critical, part of the minimum usable product.
- Should: Important, but not necessary.
- Could: Desirable, mostly for enhancing user experience or customer satisfaction.
- Won't have: Least important, even though they could provide additional value, they are out of scope.

Additional statements may by appended to a requirement, in order to provide clarifications or implementation options. The format of the additional statements is *"<item> may <clarification>"*.

2.4. Traceability

This document includes different levels of analysis to ensure traceability between the final requirements for implementation and stakeholder expectations. Different levels of traceability are as follows and illustrated in Figure 4:

- Requirements (paragraphs 6.2) are traced to main functions (paragraph 6.1.2) and stakeholder needs (paragraph 5.5)
- Main functions (paragraph 6.1.2) are also traced to stakeholder needs (paragraph 5.5)
- Stakeholder needs (paragraph 5.5) are traced to specific analysis items (paragraphs 5.1, 5.2, 5.3, 5.4)
- Implementation elements (paragraph 7.3.3) are traced to main functions (paragraph 6.1.2) and requirements (paragraphs 6.2)

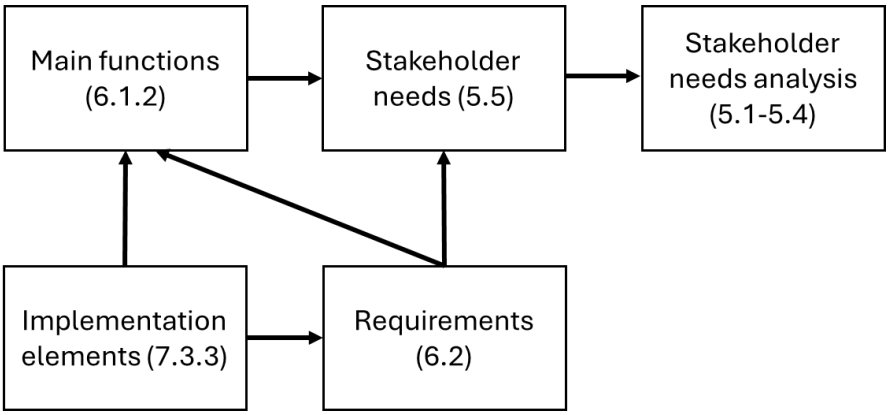

Figure 4: Illustration of traceability between the different analysis levels in this document

3. Stakeholder analysis

This section analyses the stakeholders of the EU Kernel EPC Engine and their expectations. By explicitly identifying each stakeholder category and their motivations, the project ensures that the toolbox features address real-world needs. For instance, energy assessors require a user-friendly auditing tool to improve EPC reliability and compliance, while building owners seek clear renovation guidance and trust in EPC recommendations, reflecting findings from Next Gen EPC cluster's projects. Third-party developers need open APIs and documentation to build custom apps, and policymakers expect harmonised calculations for comparability across the EU. Each stakeholder group's main expectations are captured to guide requirement formulation. For example, energy authorities expect the tool to support convergence with national EPC schemes and EU standards (to facilitate mutual recognition and easier implementation of the EPBD recast), whereas financial institutions and ESCOs anticipate access to reliable building performance data (to develop financing products for deep renovations). Building owners and tenants prioritize actionable and comprehensible outputs (like tailored renovation roadmaps and improved comfort indicators), and assessors look for reduced administrative burden (through automation and data import from BIM models). By gathering these expectations through surveys, interviews, and workshops, the project creates a stakeholder needs catalogue. This catalogue is then used to derive functional requirements, ensuring each feature of the OpenBEP4EU Toolbox (audit, calculation, data sharing) can be traced back to a specific stakeholder need or pain point. Such traceability not only enhances user acceptance but also aligns the project's outcomes with the broader push for user-centric EPC systems.

3.1. Classification

The table below summarizes the main stakeholder classes for openBEP4EU.

Table 1: openBEP4EU Stakeholders

Stakeholder	Description
Energy auditors	Professionals responsible for evaluating the performance, compliance, and quality of buildings or systems against predefined standards or benchmarks.
Building material manufacturers	Manufacturers of materials, which play a crucial role in the energy performance of buildings.
Building owner/managers	Individuals or entities overseeing the ownership, operation, and maintenance of buildings, ensuring functionality and efficiency.
Construction and development companies	Companies that are directly related with the construction and renovation of buildings
Energy Service Companies (ESCOs)	Businesses that provide energy solutions, including retrofitting and performance-based energy savings projects, to improve efficiency and reduce costs.
Financing Institutions	Banks, investment firms, or funding agencies that provide capital for building projects, energy performance upgrades, or renewable energy initiatives.
Insurance companies	They insure buildings and properties. Insurers are increasingly interested in the energy performance of buildings, as it affects risk assessment and property value.
Public Authorities	Governmental or regulatory bodies that enforce compliance with laws, policies, and standards related to building design, operation, and sustainability.
Researchers and developers	Experts in academia or industry focused on advancing innovative technologies, methodologies, and solutions for sustainable building design and operation.

Smart Home Technology developers	Developers of Smart Home and other related technologies. As buildings become increasingly connected with smart technologies, they are more interested in energy performance and SRIs.
Tenants	End-users of buildings, directly impacted by the energy performance of the properties in which they live or use.
Third-party app developers	They create applications, software or platforms that leverage the OpenBEP4EU Digital Toolbox functionalities, providing related services to end-users (e.g. assessors/energy auditors). Their products form the User Interface and experience in interacting with the engine.

The above stakeholders can be grouped into (Figure 5):

- Assessors, who are mainly concerned about the energy performance of buildings and are mostly interested in the audit and calculation functions.
- Building material manufacturers, who are mainly concerned about the accuracy of the calculations, and more specifically about the accurate representation of the impact of their products on energy performance.
- Public authorities, who are mainly concerned with the harmonisation and comparability of the results, and with the availability of tools for accurate building energy performance assessment that leads to fundamental data for evidence-based policy making regarding EU's building stock.
- 3rd-party developers, who develop their own applications and products and are interested in reusing, extending and integrating the calculation functions and data.

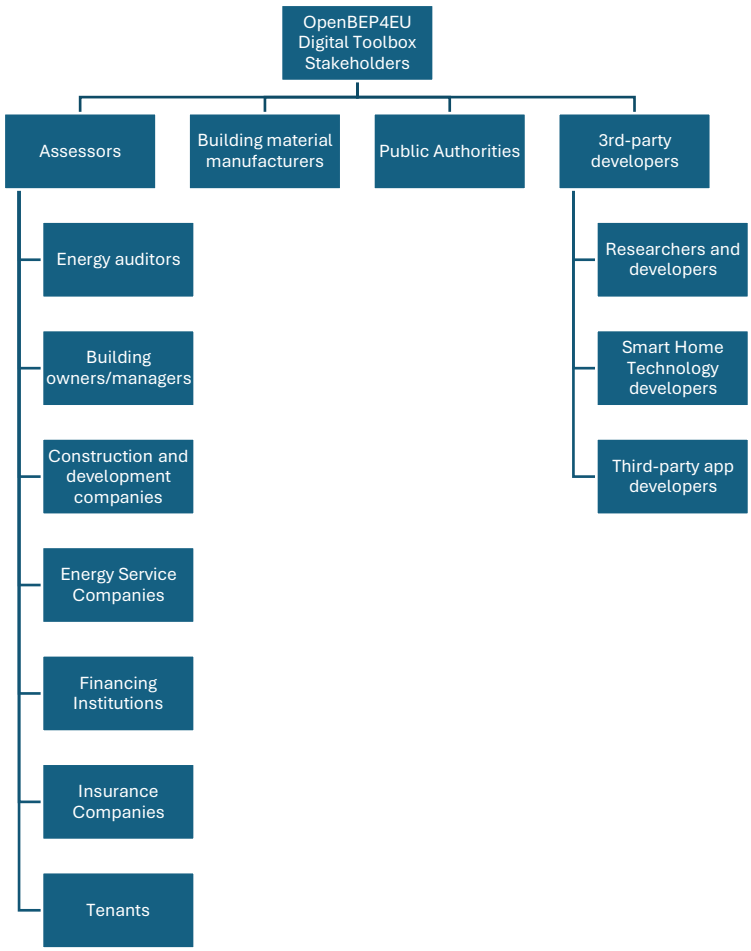

Figure 5: Groups of stakeholders

3.2. Main expectations

In the table below the main expectations for each type of stakeholder are identified in order to provide an understanding of the context and environment. While related with the purpose of the system, the stakeholder expectations in this section provide a holistic overview and may or may not be addressed by the developed system. The later will depend on the final system scope, business objectives and priorities.

Table 2: openBEP4EU stakeholder expectations

Stakeholder	Main expectation(s)
Assessors / Energy auditors	• Accurate and reliable energy performance calculations for EPBs. • Compliance with regulatory frameworks, certifications, national regulations and standards such as the CEN/ISO 52000 EPB series. • Easy to use and streamlined, with minimal training time.
Building material manufacturers	• Accurate integration of data related to thermal and energy properties of materials. • Objective, fair and transparent assessment of the impact of different building materials. • Recognition and reward of innovative and high-performance building materials that contribute to energy performance.
Building owner/managers	• Accurate and reliable energy performance calculations for EPBs and SRIs, utilising energy performance KPIs. • Receive EPB reports with clear, actionable information on how to improve building's energy performance. • Receive recommendations that balance energy savings and increased value with investment costs.
Construction and development companies	• Utilise EPCs, SRIs and EPB KPIs to optimise building design, construction and renovation. • Compliance with regulatory frameworks, certifications, national regulations and standards such as the CEN/ISO 52000 EPB series. • Fair and transparent EPB reports that enable trustworthy comparisons across different buildings and support green financing processes.
Energy Service Companies (ESCOs)	• Identify potential for energy savings and improvements across different buildings. • Monitor and assess accurately the energy savings from renovations. • Access reliable data for assessing risks and return on energy investments.
Financing Institutions	• Assess building's energy performance KPIs for green loans and financing schemes. • Provide incentives for energy-efficient building upgrades. • Compliance with regulatory frameworks, certifications, national regulations and standards such as the CEN/ISO 52000 EPB series.
Insurance companies	• Access information that help in evaluating risks for insured buildings considering factors like energy efficiency and resilience to climate change. • Develop insurance products that incentivize energy-efficient buildings. • Access information that contribute to more accurate assessment of property value.

Public Authorities	• Compliance with regulatory frameworks, certifications, national regulations and standards such as the CEN/ISO 52000 EPB series. • Access reliable information that help in monitoring the effectiveness of energy efficiency policies and programs. • Access information that help in setting realistic and achievable targets regarding energy efficiency in the building sector.
Researchers and developers	• Collect energy performance results for developing novel AI algorithms for forecasting energy performance retrofitting actions. • Access transparent, clear and well-documented methodology of the energy performance calculations. • Easy integration, interfacing and customisation to incorporate new research results and new innovations.
Smart Home Technology developers	• Seamless interoperability with smart home devices to accurately assess their impact on energy performance and SRIs. • Adherence to data protection regulations when interoperating with smart devices
Tenants	• Receive clear and understandable information on building energy performance. • Receive information on adopting energy-saving behavior.
Third-party app developers	• Well-documented and easily accessible APIs to integrate their applications. • Stable and reliable backend service. • Reasonable licensing model that allows commercial use and access to technical support.

4. Business objectives

The OpenBEP4EU Digital Toolbox is designed with clear business objectives that align with both stakeholder needs and European policy goals. First, it aims to boost the quality and convergence of EPC assessments across the EU, providing a common engine that increases reliability and trust in EPC results. This objective supports Member States in meeting the EPBD mandate for more consistent calculation methodologies and addresses the market's call for more comparable and transparent EPCs. Second, the toolbox seeks to accelerate deep energy renovation by linking high-quality EPC outputs with actionable renovation recommendations, thus inciting building owners and investors to undertake upgrades. By improving the depth and rate of renovations (a key goal of the EU Renovation Wave), OpenBEP4EU contributes to climate targets like Fit for 55 (55% emissions reduction by 2030) and the long term decarbonisation of the building stock.

Another core objective is to facilitate innovation and new services in the building energy sector. By providing open access to the EPC calculation engine and data (within the bounds of privacy and security), the project enables third parties, startups, energy service companies, software developers, to build applications on top of the toolbox. This openness drives interoperability and competition, leading to new features like smart readiness evaluations or integration with digital building logbooks being more easily developed and adopted.

Finally, the toolbox aims for financial sustainability and uptake: it will support new business models (e.g., one-stop renovation services, "energy efficiency as a service" offerings) by supplying reliable data, and it will reduce implementation costs for Member States by offering a ready-made, standard solution. Overall, these business objectives ensure that OpenBEP4EU not only delivers a technical tool but also generates value and momentum towards the EU's energy efficiency and carbon neutrality goals.

4.1. Business environment

Energy Performance Certificates (EPCs) play an instrumental role towards EU's direction for improving the performance of the building stock. Despite their many advantages, EPC tools are based on older rudimentary calculation methods and remain rather fragmented across Member states with some of them developing their own national calculation methods and related calculation tools, while others took over partly or entirely the first version of the CEN/ISO EPB standards and developed the related tools. So, EPC tools fail to provide trust and reassurance in their results which is necessary to trigger investments thus achieving a lack of market uptake of Energy Performance Certificates. To increase the comparability between regions and market uptake, standardization efforts have been performed, like the CEN/ISO 52000 family of EPB standards, whose calculation methods overcome existing limitations by accounting existing technologies (building automation) and important metrics (thermal comfort, indoor quality, etc.). However, the problem persists since there is limited access to buildings data by multiple parties (policy makers, public authorities) thus making the need for a centralized data space for knowledge sharing compelling, that can inspire energy saving policies and retrofitting actions.

Other emerging technologies, like the Smart Readiness Indicators, are pushing the industry towards more comprehensive energy performance assessments for buildings. At the same time, Building Information Modeling is increasingly adopted in construction and renovation works with information on energy performance evaluations, presenting new opportunities for data-driven decision-making.

The OpenBEP4EU Digital Toolbox must adapt to the above regulations and market conditions, integrating technological innovations to remain relevant and competitive. It needs to be compatible with existing regulations and methodologies, while at the same time providing a harmonised, standardised and transparent solution that can be used across the EU.

4.2. Goals of the OpenBEP4EU Digital Toolbox

The main goals of the OpenBEP4EU Digital Toolbox can be summarised as follows:

- **EU Market harmonisation**: To create a unified and transparent EU-market building energy performance assessment, by providing a standards-based engine for calculating energy performance of buildings, to be used for EPCs, and SRIs, fostering trust and comparability.
- **Driving innovation and investment**: To stimulate investment in building energy performance and smart technologies by providing reliable data on energy performance of buildings.
- **Supporting policy making**: To empower policy-makers with accurate and consistent data on building stock performance, thus enabling the informed decision-making towards achieving the EU's green goals and the effective monitoring of energy efficiency related programs.
- **Enhancing building value and tenant well-being**: To enable building owners and tenants to easily understand and improve their building's energy performance and smart readiness, reduce costs, and enhance comfort and well-being.
- **Development of 3rd-party apps**: To facilitate the development of diverse 3rd-party applications around energy performance, offering various kinds of services tailored to different uses, fostering innovation in construction and renovation, by providing standardised and reliable EPB and SRI calculations and indicators.

5. UCs and literature analysis

This section provides an overview of existing use cases from similar projects and derives the specific OpenBEP4EU use cases (UCs), along with a summary of literature and state-of-the-art analysis. Firstly, a review of next-generation EPC initiatives was conducted to gather good practices and innovative features. This review identified how cutting-edge concepts, like building logbooks, dynamic EPCs, comfort and indoor environment indicators, and integration of real time data, have been tested in practice. Lessons learned from these projects' UCs inform OpenBEP4EU's approach. For example, the need for a digital repository of building data (a "logbook") is incorporated via the Bauhaus Design Data Hub, and the inclusion of the SRI and comfort metrics in calculations addresses emerging user expectations for more holistic building performance information.

Building on the state-of-the-art, the team defined specific use cases for the Digital Toolbox. These UCs cover scenarios such as: an energy assessor conducting a building audit using BIM import and automated data checks, a building owner receiving an EPC report with a tailored renovation roadmap, a third-party developer invoking the Kernel Engine via an API to calculate KPIs for their own energy management app, and a national authority aggregating EPC data from the toolbox for policy analysis. Each use case is described with actors, preconditions, main flow, and outcomes. Notably, the openBEP4EU UCs stress interoperability and real world integration, for instance, using a BIM model as input aligns with the industry trend toward digital twins in energy assessment, and providing an API for external apps ensures the tool can plug into existing energy audit workflows. The literature analysis also highlighted gaps that our UCs address, such as the lack of standard methods for operational performance integration and data exchange between EPC software and databases . By explicitly designing UCs to cover these gaps (e.g. a UC for periodic operational data updates to the EPC), we ensure the requirements will support the evolution of current EPC practices.

5.1. UCs from literature

In the context of this deliverable, UCs from 2 projects related with EPCs and EPB calculations are reviewed, to find common needs for the OpenBEP4EU Digital Toolbox:

- D^2EPC (Horizon 2020)[1] aims to set the grounds for the next generation of dynamic Energy Performance Certificates (EPCs) for buildings. The proposed framework sets its foundations on the smart-readiness level of the buildings and the corresponding data collection infrastructure and management systems. It is fed by operational data and adopts the 'digital twin' concept to advance Building Information Modeling, calculate a novel set of energy, environmental, financial and human comfort/wellbeing indicators, and through them the EPC classification of the building in question.
- SmartLivingEPC (Horizon Europe)[2] project aims to deliver a certificate which will be issued with the use of digitised tools and retrieve the necessary assessment information for the building shell and building systems from BIM literacy, including enriched energy and sustainability related information for the as designed and the actual performance of the building. The new certification scheme will also expand its scope, covering aspects related to water consumption, as well as noise pollution and acoustics. SmartLivingEPC certificate will be fully compatible with digital logbooks, as well as with building renovation passports in order to allow the integration of the building energy performance

[1] https://www.d2epc.eu/en

[2] https://www.smartlivingepc.eu/en

information in digital databases. A special aspect of SmartLivingEPC will be its application in building complexes, with the aim of energy certification at the neighbourhood scale.

The use cases from the above projects [15] [16] that are relevant to openBEP4EU are the following:

- **(D^2EPC) Extract and Verify Data from BIM**: The objective is 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. The EPC Designer (user) requests from the building owner the BIM file and imports it through the D^2EPC platform. In case the BIM is incomplete or wrong, the user should be informed. It should also be possible to input (additional) data through a simplified UI. The BIM file is then used to create the building's Digital Twin, with data stored in the D^2EPC Repository.
- **(D^2EPC) Issue a D^2EPC asset EPC**: The objective is to issue a D^2EPC EPC based on asset rating. The EPC designer requests the issuance of an asset EPC from the D^2EPC Web platform that sends the request to the Calculation Engine. The D^2EPC Calculation Engine requests the necessary data through the BIM-based digital twin and the D^2EPC Asset Rating module of the Calculation Engine performs the asset-based EPC calculation. The Calculation Engine stores the issued EPC in the Repository and sends the results to the Web platform that delivers the EPC.
- **(D^2EPC) Issue an SRI report**: The objective is to perform an SRI assessment of the building and issue an SRI report. The EPC designer requests the issuance of an SRI report from the D^2EPC Web platform that sends the request to the Calculation Engine. The D^2EPC Calculation Engine requests SRI related data that are imported through the BIM-based digital twin. The D^2EPC Building Performance module of the Calculation Engine performs the SRI calculation and the report is sent to the Web platform and stored in the Repository.
- **(SmartLivingEPC) Retrieve and validate data from BIM**: The objective is to extract and verify the information that describes all the geometrical structures of the building along with the additional set that describes the thermal performance of building elements, the type of construction material, the description of building technical systems, along with all additional information that a BIM file contains. Building Owners /Real estate agents/ provide EPC assessors with access to the examined building's BIM file. The assessor logs into the SmartLivingEPC Web- Platform and uploads the BIM file. The file is validated, and, in the case of missing fields, incorrect information, or data inconsistencies, the assessor is notified to correct the requested fields. It is then transferred to the CIEM component, where it is stored and converted to the SmartLivingEPC's data model. Finally, a message in the Web-Platform informs the assessor about successful completion of this process.
- **(SmartLivingEPC) SRI Calculation**: The objective is to calculate the Smart Readiness Indicator (SRI) score. The EPC assessor logs into the SmartLivingEPC Web-Platform and requests the existing building information and the required data for the calculation of the SmartReadiness Indicator (SRI). They confirm the information and fill in any missing fields. Then, they request the SRI calculation through the SmartLivingEPC Web platform. The request is transferred to the Asset Rating Engine/SRI component, which performs the analysis, and returns the results, through the Web Platform, to the assessor for validation. The results are stored both in the Web Platform database and in CIEM repository. Finally, the SRI report is issued.

While the above UCs and projects which aim for a complete EPB and SRI solution, openBEP4EU focuses specifically on the calculation engine, design to be integrated with 3rd-party apps, and even more adhering to calculation methods specified in CEN/ISO 52000 family of EPB standards. The engine provides an harmonized calculation for the energy performance of buildings, which can be utilized by different 3rd-party apps and User Interfaces, tailored to the needs of specific types of users and purposes. Nevertheless, from the above use cases the following main needs, relevant to the OpenBEP4EU Digital Toolbox are identified:

- Ability to make EPC-relevant calculations by importing BIM files.
- Ability to calculate SRIs utilizing BIM files and additional data, if available.

Additionally, the following market needs have been identified in D^2EPC project [17]:

Table 3: Market needs identified in the D^2EPC project

User requirements	Description
User friendliness	• The language used on the EPC must be simplified for easier understanding by an ordinary user.
Usability	• Information on a building's energy efficiency, comfort and cost savings, will impact the usability of EPCs as well as purchasing and rental decisions. • Valuable guidance for energy renovation measures is needed.
Security	• Security surrounding the use of IoT devices, sensors and building management systems. • Protection of sensitive data when sharing energy related data with third parties. • Exclusion of exact building location, i.e., only postcode, and personal data in a public database.
Incentives	Incentives for installing smart building technologies for housing companies, real estate agencies and users, especially those who are not owners of the building
Real time information	Users value receiving information on the actual performance of their buildings via a real time platform.
Human-centric comfort indicators	Provision of Comfort indicators including thermal conditions, air quality, visual and acoustic comfort.
Environmental impact indicators	Provision of environmental related indicators
Understanding smart building technologies	There is a need to further educate and inform people about the advantages of smart technologies especially for older age groups.
Indication of building smartness in the EPC	Introduction of smart readiness indicators (SRI) in EPCs. Users will be informed on the ability of buildings to process information and communication technologies and electronic systems and to adjust building operation to needs of occupants and the grid.
Life Cycle Costing	Monetary indicators of the whole life cycle cost of heating, cooling, lighting and appliances.
Geo-location services	Visualization of generated EPCs in a GIS environment, empowering users to perform various types of spatial and attribute queries.
Control of building environment	User control of different building aspects especially indoor thermal comfort conditions, indoor air quality and building system's energy efficiency.
Renovation measures	Information on 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.
Renovation financing instruments	Available financing options presented with a brief description, application instructions or contact information, or a combination of any of these representations.
Indication of actual Energy class	The preferred frequency of building energy class indication ranges from annually, quarterly, monthly and upon request, with annually being the most preferred option.

5.2. Regulations, directives and standards

The **Energy Performance of Building Directive (EPBD)** [18] is a key instrument in the EU's efforts to improve energy efficiency and reduce GHG emissions. It mandates that member states establish strong renovation strategies, introduce minimum performance requirements for new constructions and move towards Near Zero-Energy Buildings. It requires that EPCs are issued when a building is sold and introduces inspection schemes for heating and air-conditioning. The directive also emphasises the importance of smart technologies, introduces the Smart Readiness Indicator and reinforces provisions for EPCs, aiming to make them more reliable and informative. Key elements from the EPBD to be taken into account for the OpenBEP4EU Digital Toolbox include:

- Ability to calculate and issue EPCs in compliance with the EPBD.
- Integration of SRI calculation.

- Support for Near Zero-Energy Buildings assessment.
- Capability to provide recommendations for cost-effective building upgrades.
- Interoperability of the toolbox with smart building technologies.
- Ability to handle both new constructions and renovations in existing buildings.

Even though not in the immediate OpenBEP4EU objectives further flexibility could be considered, to support **national implementations** and methodologies for EPC calculation. The current landscape of EPC calculations is fragmented with country-specific methods which lead to inconsistencies and challenges in comparability. Key features that could enable the adaptation of OpenBEP4EU Digital Toolbox in the future include:

- Ability to adapt calculation methods to fit national regulations and standards.
- Multi-language interfaces and supporting documentation.
- Interoperability with existing national tools and databases.
- APIs to facilitate the interfacing with applications tailored to country-specific needs.
- Compliance to data protection regulations and GDPR.

The CEN/**ISO 52000** [19] family of EPB standards provides a comprehensive framework for assessing the energy performance of buildings, offering a structured approach for calculations and definition of primary energy factors. These are crucial for the implementation of the OpenBEP4EU Digital Toolbox, as they form the basis of the harmonised energy performance indicators. It offers a modular structure that allows flexibility in national implementations, while maintaining a consistent overall framework. It also provides methods for handling different building types, uses and technical systems, which may be taken into account towards providing accurate and reliable assessments. Key elements stemming from the CEN/ISO 52000 EPB standards can be summarised as follows:

- Implement modular calculations to be used for EPCs.
- Support different national data sets, while maintaining calculation consistency.
- Accommodate diverse types of buildings.
- Incorporate both asset and operational aspects.
- Enable the calculation of primary energy use and CO2 emissions based on delivered energy.
- Support the integration of renewable energy systems in the energy performance assessment.
- Facilitate the economic evaluation of energy performance measures.

The **Energy Efficiency Directive** [20] sets efficiency targets at EU level and requires Member States to establish national targets and implement appropriate measures to achieve them. The OpenBEP4EU Digital Toolbox could support the directive by providing a standardised tool for assessing and comparing the energy efficiency of buildings, helping to track progress towards these targets. The **Renewable Energy Directive** [21] is a legal framework to promote the use of energy generated from renewable resources. The OpenBEP4EU Digital Toolbox should take into account the use of on-site and remote renewable sources of energy within the calculations. The **EU Taxonomy for sustainable activities** [22] establishes a classification system to determine which economic activities are environmentally sustainable. The OpenBEP4EU Digital Toolbox could support this framework by providing data that can be utilised by investors to identify and support sustainable building constructions and renovations. The **Sustainable Finance Disclosure Regulation** requires financial market participants to disclose, among others, how they integrate environmental factors into their decisions. The OpenBEP4EU Digital Toolbox could support this reporting, by providing standardised and trustworthy information on building energy performance and enabling financial institutions to assess the environmental impact of their investments in the building sector. The **Ecodesign for Sustainable Products Regulation** the sets performance requirements for energy-related products. Similarly, the **Construction Products Regulation** ensures that construction materials fit their intended purpose, including energy efficiency. The OpenBEP4EU Digital Toolbox could support these two regulations by promoting the use of energy-efficient

building materials in construction and renovation. Key elements from the above broader scope of EU regulations and frameworks, for the OpenBEP4EU Digital Toolbox are:

- Provide standardised tool for assessing and comparing energy efficiency of buildings.
- Consider the use of on-site and remote renewable energy sources.
- Provide information to assess environmental impact of construction and renovation works.
- Report standardised and trustworthy information on building performance tailored to financial institutions.
- Consider the use of energy-efficient building materials.

5.3. State of the Art and existing tools

Prioritising energy efficiency in the building sector is the cornerstone to achieving energy goals and reducing environmental impact, cost savings and enhanced comfort. [23] Research surrounding the development and implementation of EPCs and related tools highlight the necessity for standardisation, harmonization, flexibility and integration of existing frameworks, to ensure that different stakeholders' needs are effectively addressed. While there are ongoing efforts, there is still a pressing need to further harmonise EPC methodologies across the Member States to facilitate comparability and transparency. [24] [25]

Additionally, the integration of Smart Readiness Indicators, i.e., the ability of a building to sense, interpret communicate and actively respond to changing conditions [26], can significantly enhance building performance evaluation. SRIs can significantly improve the accuracy and reliability of EPCs by integrating operational data like energy monitoring, environmental quality, economics, sustainability, and more. [27] At the same time, there is an increasing trend towards digitalisation technologies for EPCs, however, they currently fail to deliver valuable and interpretable information, awareness, quality and user-friendliness, resulting in limited acceptance by the users. [28] However, it must be taken into account that the assessment of energy performance must not be over-simplified, as, in that case, it will be perceived as an administrative burden instead of providing actual value. [29]

Regarding specific software and tools used for EPC calculations, there are various features that they include and different calculation methods that they use, adhering to national regulations. [30] This includes generating ratings for EPCs, operational ratings and reports for heating and cooling inspections. They may utilise Dynamic Simulation [31], with detailed building models and hourly simulations to predict energy consumption, Simplified Building Energy Model [32], as a cost-effective approach to assess energy performance, and other A/C inspection-specific methods.

Key elements from current state of the art to be considered in the OpenBEP4EU Digital Toolbox include:

- Incorporate standardised calculation methods, aligned with the EPBD.
- Provide easily interpretable and valuable information on energy performance.
- Integrate operational data and SRIs

5.4. OpenBEP4EU Digital Toolbox use cases

In this section the use cases for the openBEP4EU Digital Toolbox are analysed. A summary of the use cases is illustrated in the use case diagram of Figure 66.

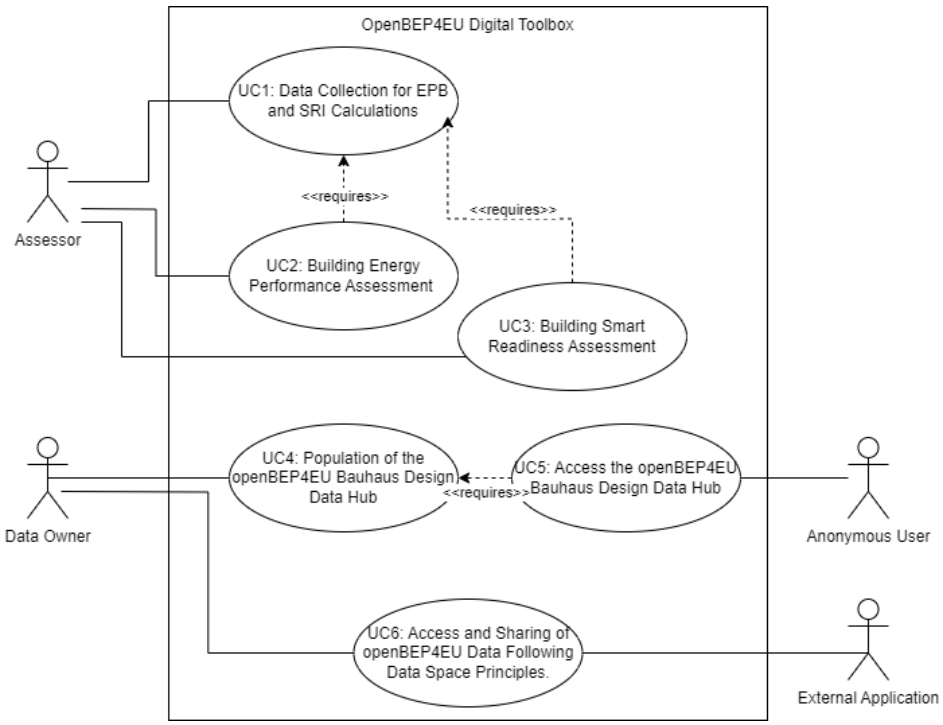

Figure 6: Use case diagram of the OpenBEP4EU Digital Toolbox

Table 4: Data Collection for EPB and SRI Calculations

Use case ID: UC1	**Data Collection for EPB and SRI Calculations**
Scope	To collect building-related data required for EPB (Energy Performance of Buildings) and SRI (Smart Readiness Indicator) calculations through audit tools that integrate with the openBEP4EU ecosystem. The collected data is structured and stored in a common data model for further assessment and processing.
Objectives	• Facilitate efficient and standardised data collection for EPB and SRI calculations. • Ensure accurate and structured data population in the openBEP4EU common data model. • Support energy assessors with user-friendly tools to streamline audits. • Enable automated data transformation and validation before storage.
Features	• User interface for file upload and manual data entry (e.g. structured forms) • ETL (Extract, Transform, Load) tools for processing uploaded/entered data. • Integration with openBEP4EU data repository for structured storage. • Data validation mechanisms to ensure completeness and accuracy. • Role-based access for assessors to manage and submit audit data.
Assets	• User interface to interact for file(s) upload and data entry (e.g., filling out forms). • ETL tool(s) for transforming the uploaded/entered data and populating the openBEP4EU common data model.
Actors	(Energy) assessor

Assumptions	Assessor has knowledge on audit processes required to collect the necessary data.
Preconditions	No preconditions
Trigger	Assessor launches a new audit data input
Post conditions	• The collected data is successfully stored in the openBEP4EU repository. • The data is available for use in EPB and SRI calculations. • The system confirms successful data entry and transformation, ready for further processing.

Related user needs

- Ability to import digital building model in IFC format
- Ability to input additional data needed for energy performance and SRI calculations
- Ability to store the digital building model and audit data

Table 5: openBEP4EU Building Energy Performance Assessment

Use case ID: UC2	**Building Energy Performance Assessment**
Scope	Simulate and assess building energy performance based on EPB standards to evaluate existing buildings and retrofitting scenarios.
Objectives	• Perform energy performance simulations for existing buildings ("as-is") to establish baseline assessments based on standardized EPB methodologies. • Simulate and evaluate retrofitting scenarios, where each scenario is represented by a unique input dataset aligned with the common data model. • To populate the common data model with structured simulation results for future analysis and regulatory compliance. • To interpret and utilize energy performance results for building assessment and optimization.
Features	• Implementation of calculation as defined in the EPB standards to support a range of building types (residential, non-residential) and HVAC system configurations. • Full adherence to the computational methods and expected outputs outlined in the CEN/ISO 52000 EPB standards family. • Capability to process different levels of input complexity, from simplified models to detailed multi-zone building simulations. • Support for increasingly complex cases, including mixed-use spaces and advanced HVAC configurations. • Integration with third-party applications for streamlined data input, simulation execution, and result visualization. • Standardized output generation that aligns with EPB and ISO standards for regulatory and design use cases.
Assets	• Application to enable users to select buildings from a list of populated common data models, initiate EPB simulations, and visualize results. • Common data model repository to store building data collected through audits, following a standardized structure for energy performance simulations. • Simulation engine which processes building models, performs EPB calculations, and generates outputs compliant with CEN/ISO 52000 EPB standards.
Actors	(Energy) assessor
Assumptions	• The simulation accuracy depends on the completeness and accuracy of data provided by the Assessor in UC1.

	• Adjustments may be required if certain cases have significant computational or modelling limits.
Preconditions	UC1 has been executed at least once and there is at least one building model and data for calculating energy performance.
Trigger	The Assessor triggers the relevant action in the application which is related to launching the building energy performance simulation.
Post conditions	• The simulation results are successfully stored for further analysis and reporting. • The system confirms successful execution and allows users to visualize and export results.

Related user needs:

- Ability to calculate energy performance, aligned with regulatory standards
- Ability to generate reports with KPIs that guide energy efficient renovations
- Ability to generate reports that support compliance assessment
- Ability to do the calculations via a 3rd-party application

Table 6: Building Smart Readiness Assessment

Use case ID: UC3	**Building Smart Readiness Assessment**
Scope	Calculate the SRIs of a building, based on standards to evaluate existing buildings and retrofitting scenarios.
Objectives	• Perform SRI calculation based on standardized methodologies. • To populate the common data model with structured SRI results for future analysis and regulatory compliance. • To interpret and utilize SRI results for building assessment and optimization.
Features	• Implementation of calculation as defined in the standards to support a range of building types (residential, non-residential) and HVAC system configurations. • Capability to process different levels of input complexity, from simplified models to detailed multi-zone building simulations. • Integration with third-party applications for streamlined data input, simulation execution, and result visualization. • Standardized output generation that aligns with EPB and ISO standards for regulatory and design use cases.
Assets	• Application to enable users to select buildings from a list of populated common data models, initiate SRI assessment, and visualize results. • Common data model repository to store building data collected through audits, following a standardized structure for SRI simulations. • Simulation engine which processes building models, performs SRI calculations, and generates outputs compliant with CEN/ISO 52000 EPB standards.
Actors	(Energy) assessor
Assumptions	• The calculation accuracy depends on the completeness and accuracy of data provided by the Assessor in UC1. • Adjustments may be required if certain cases have significant computational limits.
Preconditions	UC1 has been executed at least once and there is at least one building model and data for calculating energy performance.
Trigger	The Assessor triggers the relevant action in the application which is related to launching the building SRI calculation.
Post conditions	• The calculation results are successfully stored for further analysis and reporting.

	• The system confirms successful execution and allows users to visualize and export results.

Related user needs:

- Ability to calculate SRIs, aligned with regulatory standards
- Ability to do the calculations via a 3rd-party application

Table 7: openBEP4EU Population of the openBEP4EU Bauhaus Design Data Hub

Use case ID: UC4	**Population of the openBEP4EU Bauhaus Design Data Hub**
Scope	This use case describes the process in which a user with the appropriate privileges upload information to the Bauhaus Data Hub. The information includes site-specific energy performance data, project-level metrics and compliance data, design simulations and compliance checks, post-renovation feedback, product specifications and certifications, energy performance reports, anonymized data for policy formulation
Objectives	• Upload information as a file or data entry
Features	• Log in • File upload • Data entry
Assets	• Relevant information in file or data format
Actors	Data owner (building owner, assessor, etc.)
Assumptions	User has credentials with assigned privileges to upload files and enter data
Preconditions	User has logged in to the Bauhaus Data Hub
Trigger	User clicks the 'Add file' button
Post conditions	The relevant file is stored to the Bauhaus Data Hub database.

Related user needs:

- Ability to upload files and datasets
- Ability to setup specific user roles with privileges to upload specific types of information
- Ability to store files and datasets

Table 8: openBEP4EU Access the openBEP4EU Bauhaus Design Data Hub

Use case ID: UC5	**Access the openBEP4EU Bauhaus Design Data Hub**
Scope	This use case describes the process in which a user accesses information stored in the Bauhaus Data Hub. The information includes: site-specific energy performance data, project-level metrics and compliance data, design simulations and compliance checks, post-renovation feedback, product specifications and certifications, energy performance reports, anonymized data for policy formulation
Objectives	• Access information
Features	• Data store • Web viewer
Assets	• Relevant information in file or data format
Actors	Anonymous or logged in user with access and read privileges
Assumptions	User accesses the Bauhaus Design Data Hub web user interface
Preconditions	Information is stored and shared in the Bauhaus Design Data Hub
Trigger	User clicks the 'Find' button
Post conditions	No post conditions

Related user needs:

- Ability to access and read stored files and datasets online

Table 9: openBEP4EU Access and Sharing of openBEP4EU Data Following Data Space Principles.

Use case ID: UC6	**Access and Sharing of openBEP4EU Data Following Data Space Principles.**
Scope	This use case describes the process in which an external data consumer is capable of retrieving data (building data and simulation results), from the building data repository provided by building owners compliant with IDSA and GAIA-X principles ensuring data sovereignty and secure communication.
Objectives	Building data and simulation results data exchange process between stakeholders through secure communication.
Features	• Negotiation of data between provider and consumer. • Agreement for data sharing between provider and consumer. • Secure data sharing of building data and simulation results.
Assets	• Data space connector. • Building Data Repository. • Graphical User Interface for administering file share.
Actors	• Data Provider (openBEP4EU Digital Toolbox), • Data consumer (external application)
Assumptions	Building data is stored in the Building Data repository.
Preconditions	Local deployed connectors Proper configuration of the connectors
Trigger	User initiates the communication with the data provider through an external application.
Post conditions	User acquires the wanted building data through the external application.

Related user needs:

- Ability to access and read stored files and datasets through an external application with Data Space principles.

5.5. Summary of stakeholder needs

The above user needs are further analysed grouped and ID-tagged in order to make it possible to track requirements, documented later, in specific sources from stakeholder needs. The source of the summarised stakeholder needs is referenced and traced to specific analysis elements as follows:

- ME: derived directly from stakeholder main expectation (paragraph 0)
- BO: derived from the business objectives (paragraph 4.2)
- eBUC: derived from literature UCs (paragraph 5.1)
- RS: derived from regulations and standards (paragraph 5.2)
- SOTA: derived from State-of-the-art and tools (paragraph 5.3)
- UC: derived from UCs (paragraph 5.4)

The needs are categorised into 3 categories:

- In scope of the openBEP4EU Digital Toolbox, as implemented in the project: relevant requirements will be documented and are targeted for implementation during the project.
- In scope, but for the future: relevant requirements will be documented, but are targeted for implementation beyond the project.
- Out of scope: relevant requirements will not be documented and will not implemented even in future extensions of the Digital Toolbox.

Table 10: Summary of stakeholder needs

Stakeholder need ID	Description	Source	In scope	For future	Out of scope
SN-01	Calculate energy performance KPIs and SRIs	ME, BO, eBUC, RS, UC	X		
SN-02	Unified/harmonised calculation of KPIs and SRIs / Provide standardised tool for assessing and comparing energy performance of buildings / Incorporate standardised calculation methods, aligned with the EPBD	ME, BO, RS, SOTA	X		
SN-03	ISO-compliant calculation	ME, BO, UC	X		
SN-04	EPBD-compliant calculation	ME, RS, SOTA	X		
SN-05	Transparent assessment of the impact of different materials	ME	X		
SN-06	Reports with actionable information to improve energy performance / Renovation measures needed / Ability to generate reports with KPIs that guide energy efficient renovations	ME, eBUC, UC		X	
SN-07	Recommendations balancing energy savings and value of investment costs / Estimated ROI, cost of renovation measures, impact of renovation options on thermal conditions, information related to the maintenance and operational cost of renovation measures / Capability to provide recommendations for cost-effective building upgrades / Facilitate the economic evaluation of energy performance measures	ME, eBUC, RS		X	
SN-08	Evaluate risks for buildings, related to energy performance and climate change	ME			
SN-09	Accurate assessment of property value / Monetary indicators / Report standardised and trustworthy information on building performance tailored o financial institutions	ME / eBUC / RS			
SN-10	Monitoring of effectiveness of policies and programs / Set realistic targets for energy performance policies and programs / Support policy making	ME, BO	X		
SN-11	Gather energy performance results from different buildings / Ability to allow external users access data that is setup as shareable	ME, UC	X		
SN-12	Documentation of calculation methods	ME	X		
SN-13	Ability to easily integrate, interface and customise / APIs to facilitate the interfacing with applications tailored to country-specific needs / Ability to do the calculations via a 3rd-party application	ME, BO, RS, UC	X		
SN-14	Interoperability with smart home devices / Interoperability with smart building technologies	ME, RS		X	
SN-15	Data protection	ME, eBUC, RS	X		

SN-16	Help with adopting energy saving behaviour	ME			X
SN-17	Documented APIs	ME	X		
SN-18	Stable and reliable backend service	ME	X		
SN-19	Reasonable licensing with technical support and commercial use	ME	X		
SN-20	Drive investment in energy performance / Incentives for smart technologies / Consider and promote the use of energy-efficient building materials	BO, eBUC, RS	X		
SN-21	Clear reports to understand the energy performance of a building / Provide easily interpretable and valuable information on energy performance	BO, eBUC, SOTA	X		
SN-22	Real-time actual performances	eBUC		X	
SN-23	Comfort indicators including thermal conditions, air quality, visual, acoustic comfort	eBUC	X		
SN-24	Environmental indicators / Provide information to assess environmental impact of construction and renovation works	eBUC, RS	X		
SN-25	Training material on smart technologies	eBUC			X
SN-26	Visualisation in GIS environment	eBUC			X
SN-27	User control of building aspects, indoor thermal comfort conditions, indoor air quality, building energy performance	eBUC		X	
SN-28	Support for Near Zero-Energy Buildings assessment.	RS		X	
SN-29	Ability to handle both new constructions and renovations in existing buildings	RS			X
SN-30	Ability to adapt calculation methods to fit national regulations and standards. / Implement modular calculations to be used for EPCs	RS		X	
SN-31	Multi-language interfaces and supporting documentation	RS			X
SN-32	Interoperability with existing national tools and databases / Support different national data sets, while maintaining calculation consistency.	RS		X	
SN-33	Accommodate diverse types of buildings	RS	X		
SN-34	Incorporate both asset and operational aspects / Integrate operational data and SRIs	RS, SOTA		X	
SN-35	Enable the calculation of primary energy use and CO2 emissions based on delivered energy	RS	X		
SN-36	Support the integration of renewable energy systems in the energy performance assessment / Consider the use of on-site and remote renewable energy sources	RS	X		
SN-37	Ability to import digital building model in IFC format	UC	X		
SN-38	Ability to input additional data needed for energy performance and SRI calculations	UC	X		
SN-39	Ability to store the digital building model and audit data	UC	X		

SN-40	Ability to access and read stored files and datasets through an external application.	UC	X		
SN-41	Ability to upload files and datasets	UC	X		
SN-42	Ability to setup specific user roles with privileges to upload specific types of information	UC	X		
SN-43	Ability to store files and datasets	UC	X		
SN-44	Ability to access and read stored files and datasets online	UC	X		

6. User Requirements

Based on the stakeholder needs and use cases, a comprehensive set of user requirements for the OpenBEP4EU Digital Toolbox has been elicited and documented. Each requirement is described in a standardized format (with a unique ID, description, rationale, and priority), ensuring traceability back to stakeholder expectations and use case scenarios. The requirements cover functional aspects (e.g., the ability to import building data, calculate specific performance metrics, generate reports) as well as non-functional aspects (such as usability, security, and interoperability). For instance, requirements ensure that the calculation engine conforms to the CEN/ISO 52000 EPB series methodology for energy performance to guarantee consistency with national EPC calculations, and that the tool can handle climate zone and building configuration variations for EU-wide applicability. There are also requirements for incorporating dynamic data inputs, such as allowing measured energy consumption or IoT sensor data to be optionally used to refine the EPC assessment, anticipating future dynamic EPC needs identified by research.

Each requirement has been cross-checked against the 2024 recast EPBD (EPBD IV) provisions and relevant standards to ensure policy alignment. For example, where the EPBD IV emphasizes the inclusion of greenhouse gas indicators and a renovation passport, corresponding requirements in OpenBEP4EU ensure the engine can output CO_2 emission metrics and structured renovation recommendations. Additionally, interoperability requirements mandate that the toolbox uses open data formats (like BuildingSMART's IFC for building models and JSON/CSV for results) and can interface with national EPC registries or the Common European Energy Data Space for buildings.

To aid innovation, some requirements address modularity and open source deployment, the engine must be modular so it can be updated or extended (e.g., to add new indicators like life-cycle carbon or new control algorithms) and it will be released under an open license to encourage uptake by Member States and third parties. All requirements were validated with project partners and a sample of end-users, ensuring they are not only technically sound but also practically relevant and user-friendly.

6.1. System overview

6.1.1. Context and scope

A top-level functional overview of the OpenBEP4EU Digital Toolbox is depicted in Figure 77.

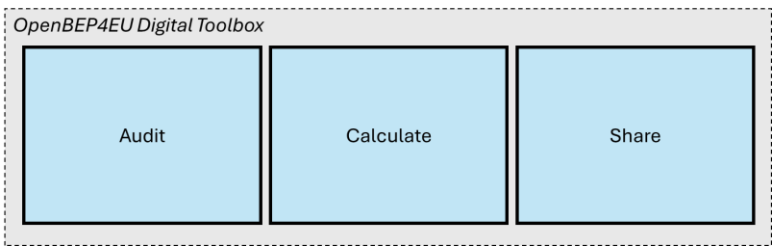

Figure 7: OpenBEP4EU Digital Toolbox high-level functions

The OpenBEP4EU Toolbox includes 3 main high-level functions:

- **Audit**: Provides tools for the recording and storing the building data needed for the energy audit.
- **Calculate**: Provides tools for the calculation of energy performance KPIs and SRI.
- **Share**: Provides tools for sharing data, EPB parameters, good practices etc.

A breakdown of the top-level functions, considering the specific features of the components, is depicted in Figure 88.

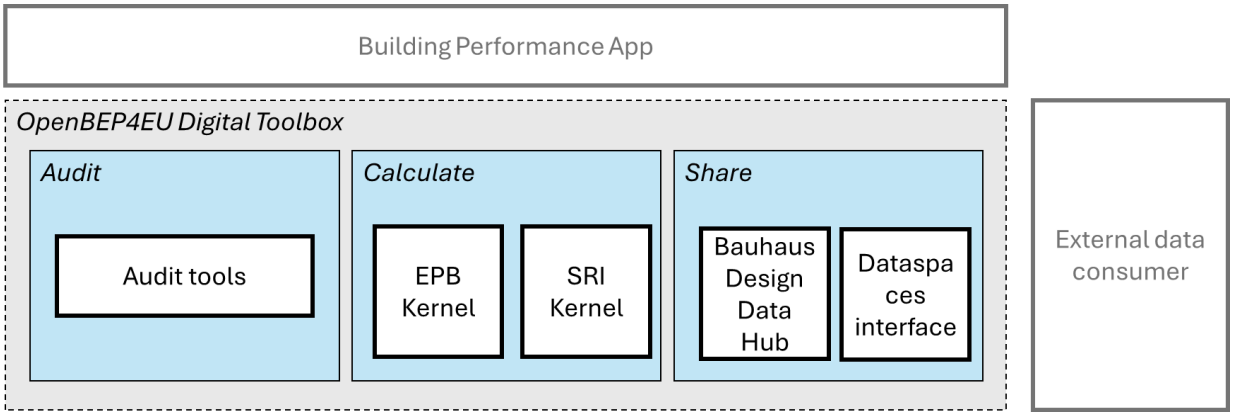

Figure 8: OpenBEP4EU Digital Toolbox functional blocks

The Digital Toolbox includes the following specific functional blocks that provide the above main functions:

- **Audit tools**: Provides tools for getting the data from the building model and user related to the building audit.
- **EPB Kernel**: Provides the calculation tool for the energy performance KPIs.
- **SRI Kernel**: Provides the calculation tool for the SRI.
- **Bauhaus Design Data Hub**: Provides the repository functionalities for EPB parameters, good practices, etc.
- **Dataspaces interface**: Provides the tools for secure sharing of data to external entities.

Additionally, the following external entities are considered within the context of the Digital Toolbox:

- **Building Performance App**: An application developed by a 3rd-party that uses the Calculate function of the OpenBEP4EU Digital Toolbox. This sub-purpose of the application that is within context is providing energy performance KPIs and SRI, in practice acting as a User Interface between the Digital Toolbox and the end-user. The application itself may provide a handful of other functionalities, which however are out of the context of the Digital Toolbox and therefore are not taken into account in the design. This allows to build tailored applications for different overall purposes and targeting different stakeholders, but using harmonised calculations for energy performance and SRIs, provided by OpenBEP4EU Digital Toolbox. In the scope of openBEP4EU, a reference implementation of the features that are required from the 3rd-party app will be done. The reference implementation is called here-on 'Building Performance App'.
- **External Data Consumer**: Any external entity that finds value in the data generated or stored in the OpenBEP4EU Digital Toolbox, including the building data, EPC parameters, good practices, etc., and wants to access them.

6.1.2. Main functions

The OpenBEP4EU Digital Toolbox provides the following main functions:

- **FUN1 – Audit** (collecting, recording and storing the building data needed for EPC and SRI assessment, including importing digital building models (BIM))
  - ***FUN1.1 - Import building model***: Enables the importing and processing of digital building models, extracting relevant data needed for energy performance and SRI audit.
  - ***FUN1.2 - Input additional data***: Enables the user to provide additional data that is not available in the digital building model and is required for energy performance and SRI audit.

- **FUN2 – Calculate** (calculation of EPB and SRI indicators in alignment with the CEN/ISO set of EPB standards and the EU SRI methodology)
  - ***FUN2.1 - Calculate energy performance KPIs***: Enables the calculation of energy performance KPIs of a building, based on the audit data.
  - ***FUN2.2 - Calculate SRI***: Enables the calculation of the SRI of a building, based on the audit data.
  - ***FUN2.3 - Generate report***: Generates different kinds of tailored reports.
- **FUN3 – Share** (sharing data, EPB and SRI parameters, and good practices across platforms)
  - ***FUN3.1 - Dataspaces share***: Enables the secure sharing of persistent data with external entities.
  - ***FUN3.2 - Browse data hub***: Enables browsing the information that is available in the Bauhaus Design Data Hub
  - ***FUN3.3 - Add in data hub***: Enables the addition of information in the Bauhaus Design Data Hub.

The above functions are traced to relevant stakeholder needs as follows:

Table 11: Traceability of stakeholder needs to main functions

Main function ID	Stakeholder needs IDs
FUN1.1	SN-18, SN-19, SN-33, SN-37, SN-39
FUN1.2	SN-18, SN-19, SN-33, SN-38
FUN2.1	SN-01, SN-02, SN-03, SN-04, SN-05, SN-12, SN-13, SN-17, SN-18, SN-19, SN-23, SN-27, SN-28, SN-29, SN-30, SN-32, SN-33, SN-36
FUN2.2	SN-01, SN-02, SN-03, SN-04, SN-05, SN-12, SN-13, SN-14, SN-17, SN-18, SN-19, SN-22, SN-23, SN-27, SN-28, SN-29, SN-30, SN-32, SN-33, SN-34, SN-36
FUN2.3	SN-06, SN-07, SN-08, SN-09, SN-18, SN-19, SN-20, SN-21, SN-24, SN-26, SN-31, SN-35, SN-36, SN-40
FUN3.1	SN-10, SN-13, SN-17, SN-18, SN-19, SN-45
FUN3.2	SN-10, SN-11, SN-16, SN-18, SN-19, SN-20, SN-25, SN-31, SN-4
FUN3.3	SN-15, SN-18, SN-19, SN-41, SN-42, SN-43

6.1.3. User roles

The following user roles are defined for the OpenBEP4EU Digital Toolbox:

- **Anonymous user**: Any user that has not been authenticated and authorised in any way.
- **Assessor**: Any user that uses the OpenBEP4EU Digital Toolbox through a 3rd-party app (Building Performance App) to assess the energy performance of a building or SRIs. It represents any stakeholder class that uses the engine for this purpose.
- **Data Hub visitor**: A user, who is logged in, with authorisation to access information stored on the Bauhaus Design Data Hub. Data Hub visitor includes the Anonymous user
- **Data Hub uploader**: An authenticated and authorized user with privileges to upload files and data to the Bauhaus Design Data Hub. Data Hub uploader includes the Anonymous user and the Data Hub Visitor.
- **Data Hub admin:** An authenticated and authorised user of the Bauhaus Design Data Hub with administrator privileges. Data Hub admin includes the Anonymous user, the Data Hub uploader and the Data Hub Visitor.

6.2. Requirements

The final catalogue of requirements is documented in this paragraph.

6.2.1. Functional requirements

FUN1 – Audit

ID RQ-01	**Function(s)** FUN1.1	**Source** SN-37
Import IFC The assessor must be able to import data needed for the calculation of EPB KPIs and SRI utilising the building's digital model in IFC format.		

ID RQ-02	**Function(s)** FUN1.2	**Source** SN-38
Input additional data The assessor must be able to input additional data needed for the calculation of EPB KPIs and SRIs through a graphical user interface.		

FUN2 – Calculate

ID RQ-03	**Function(s)** FUN2.1	**Source** SN-01
Trigger calculation of EPB KPIs While the audit data for a building are stored in the Building Data Repository, the Assessor must be able to trigger the calculation of the EPB KPIs for this building.		

ID RQ-04	**Function(s)** FUN2.2	**Source** SN-01
Trigger calculation of SRI While the audit data for a building are stored in the Building Data Repository, the Assessor must be able to trigger the calculation of the SRI for this building.		

ID RQ-05	**Function(s)** FUN2.1, FUN2.3	**Source** SN-01, SN-35, SN-08, SN-09, SN-23, SN-24
View EPB KPIs The assessor must be able to view KPIs related to the Energy Performance of a building, including at least primary consumption per area.		

ID RQ-06	**Function(s)** FUN2.1, FUN2.2, FUN2.3	**Source** SN-27
Customise levels The assessor could be able to set specific optimum targets for KPIs related to indoor thermal comfort conditions, indoor air quality and building energy efficiency.		

ID RQ-07	**Function(s)** FUN2.2, FUN2.3	**Source** SN-01
View SRI The assessor must be able to view Key Performance Indicators (KPIs) related to the Smart Readiness of buildings. These shall include, at a minimum: The overall SRI score (expressed as a percentage) and its corresponding class (A–G), Domain-level performance scores across the seven key SRI impact criteria (e.g., Energy Efficiency, Comfort, Energy Flexibility, etc.), Functional domain scores (e.g., Heating, Cooling, Lighting, etc.),		

Aggregated scores per impact criterion across all services These outputs shall be derived in accordance with the official SRI calculation methodology and presented in a clear, structured format that facilitates assessment, reporting, and auditing.

ID RQ-08	**Function(s)** FUN2.1, FUN2.3	**Source** SN-30
Adapt calculation methods The assessor could be able to adapt the calculation methods.		

ID RQ-09	**Function(s)** FUN2.1, FUN2.2, FUN2.3	**Source** SN-05, SN-06, SN-20
Renovation support The assessor could be able to view recommendations related to renovation actions that would improve the energy performance and SRI of a building. The recommendations may include also expected cost information of the recommended renovations.		

FUN3 – Share

ID RQ-10	**Function(s)** FUN3.2	**Source** SN-10, SN-11, SN-44
Access data The External Data Consumer must be able to fetch data from the Building Data Repository utilising a compatible interface.		

ID RQ-11	**Function(s)** FUN3.2	**Source** SN-10, SN-11, SN-44
View Data Hub info The Anonymous user must be able to view files that are available with ‘public’ permissions in the Bauhaus Data Hub.		

ID RQ-12	**Function(s)** FUN3.2	**Source** SN-10, SN-11, SN-44
View Data Hub info The Data Hub visitor must be able to view files that are available with ‘registered-only’ permissions in the Bauhaus Data Hub.		

ID RQ-13	**Function(s)** FUN3.2	**Source** SN-10, SN-11
Aggregated analytics on Data Hub The Data Hub visitor could be able to view customisable aggregated statistics on the datasets that are available in the Bauhaus Data Hub.		

ID RQ-14	**Function(s)** FUN3.3	**Source** SN-10, SN-11, SN-41, SN-42, SN-43
Upload Data Hub info The Data Hub uploader should be able to upload files and datasets to the Bauhaus Data Hub.		

ID RQ-15	**Function(s)** FUN3.3	**Source** SN-10, SN-11, SN-41
Upload Data Hub info – set permissions The Data Hub uploader should be able to set access rights to ‘public’ or ‘registered-only’ for the files and datasets they have uploaded to the Bauhaus Data Hub.		

ID RQ-16	**Function(s)** FUN3.3	**Source** SN-15
Uploader delete own data The Data Hub uploader should be able to delete the files and datasets they have uploaded to the Bauhaus Data Hub.		

ID RQ-17	**Function(s)** FUN3.3	**Source** SN-15
Admin delete data The Data Hub admin must be able to delete any file and dataset uploaded to the Bauhaus Data Hub.		

6.2.2. Usability

ID RQ-NF-01	**Function(s)** FUN2.3	**Source** SN-21
Understandability of reports The assessor should be able to view the reported EPB KPIs and SRI with clear titles and format that can be understood overall in less than 2 minutes. It is assumed that the assessor has core background knowledge on terms related to the energy performance of buildings.		

ID RQ-NF-02	**Function(s)** FUN2.1, FUN2.2	**Source** SN-17
API documentation The system must provide API documentation following the OpenAPI Description format.		

6.2.3. Interfaces

ID RQ-NF-03	**Function(s)** FUN2.1, FUN2.2	**Source** SN-13
Common API The system must provide a common API for accessing building data and triggering the calculation of EPB KPIs and SRI.		

ID RQ-NF-04	**Function(s)** FUN2.1, FUN2.2	**Source** SN-18
API error feedback The system must respond through its API with error codes and description that help the user in identifying and resolve issues, including at least a) building data requested not valid in Building Data Repository, b) building data requested not present in Building Data Repository, c) runtime error with the calculation of EPB KPIs for a building, d) runtime error with the calculation of SRI for a building, e) error in storing the EPB KPIs in the Building Data Repository for a building, f) error in storing the SRI in the Building Data Repository for a building.		

ID RQ-NF-05	**Function(s)** FUN1.2, FUN2.2	**Source** SN-14, SN-22, SN-34
Operational integration The system could be able to gather and parse operational data from the building operation. This data may be collected by building sensors and integrated modules.		

ID RQ-NF-06	**Function(s)** FUN1.1, FUN1.2	**Source** SN-32
Connect with national databases The system could support the importing of building models and data from national databases.		

6.2.4. Data persistence

ID RQ-NF-07	**Function(s)** FUN1.1	**Source** SN-39
Data persistence of model The system must store the digital building model in IFC format to the Building Data Repository.		

ID RQ-NF-08	**Function(s)** FUN1.2	**Source** SN-39
Data persistence of data The system must store the additional data needed for the calculation of EPB KPIs and SRI to the Building Data Repository.		

ID RQ-NF-09	**Function(s)** FUN2.1	**Source** SN-01
Data persistence of EPB KPIs The system must store the calculated EPB KPIs to the Building Data Repository.		

ID RQ-NF-10	**Function(s)** FUN2.2	**Source** SN-01
Data persistence of SRIs While the SRI of a building is calculated, the system must store the calculated SRI to the Building Data Repository.		

6.2.5. Compliance

ID RQ-NF-11	**Function(s)** FUN2.1, FUN2.2	**Source** SN-02, SN-03, SN-05, SN-12
Compliance to ISO The system should perform the EPB calculations in conformance with the methods specified in CEN/ISO 52000 family of EPB standards.		

ID RQ-NF-12	**Function(s)** FUN2.1, FUN2.2	**Source** SN-28
NZEB The system could support the assessment of NZEBs.		

ID RQ-NF-13	**Function(s)** FUN2.1, FUN2.2	**Source** SN-33
Diverse types of buildings The system must support the assessment of different kinds of buildings, including at least apartments, detached houses, small commercial building and offices.		

ID RQ-NF-14	**Function(s)** FUN2.1, FUN2.2	**Source** SN-36
Support renewables The system must support the assessment of buildings taking into account energy generated by renewable energy sources, including at least solar thermal collectors.		

ID RQ-NF-15	**Function(s)** FUN2.1, FUN2.2	**Source** SN-02, SN-04
Compliance to EPBD The system should perform the EPB and SRI calculations in conformance with the EPBD.		

ID RQ-NF-16	**Function(s)** All	**Source** SN-15
Compliance to GDPR The system must comply to the GDPR.		

7. System architecture

This section describes the first version of the architecture, translating the user requirements into a structured design of the system's components and their interactions. The architecture follows a modular, layered approach to facilitate maintainability and scalability. Core functional blocks of the Digital Toolbox include: the Audit Tools module (handling data import, user inputs, and pre-processing), the EU Kernel EPC Engine (which contains the calculation logic compliant with CEN/ISO 52000 EPB series and encompasses both the EPB Kernel for energy performance and the SRI Kernel for smart readiness), the Bauhaus Design Data Hub (a central repository for reference data, best practices, and results, effectively serving as the project's implementation of a digital building logbook concept), and the Dataspaces Interface (managing secure data sharing and external access). Surrounding these, a set of APIs and integration services allow external applications (such as the "Building Performance App" or national EPC databases) to interact with the Toolbox.

The architecture prioritizes interoperability and openness. All internal and external interfaces use standard protocols and data models (e.g., REST/HTTP API with JSON outputs for results, IFC for BIM data input, and potentially semantic web standards for data cataloguing in the hub) to ensure that the system can easily connect with other software and data platforms. This is aligned with the Common European Energy Data Space principles of sovereign data sharing and interoperability. The use of an open source tech stack means that Member States' IT agencies or third-party developers can deploy and modify the system, lowering adoption barriers. The architecture also incorporates security and user management (to protect sensitive building data) and scalability considerations (so it can handle large volumes of calculations or numerous concurrent users, as might be needed if adopted at national scale). A high-level component diagram illustrates how an external Building Performance App interacts with the Kernel Engine via the API, and how data flows into the Data Hub and out through the Dataspaces Interface to authorized external data consumers.

By designing the system in this modular way, each component (Audit, EPB engine, SRI engine, Data Hub, etc.) can be developed and tested independently, and future enhancements (like adding a life-cycle carbon calculator or a link to a renovation passport tool) can be integrated with minimal disruption. Overall, this first architecture lays the groundwork for an innovative, interoperable and extensible platform that meets the project's open source and usability ambitions.

7.1. Intended audience of architecture

The architecture design of the OpenBEP4EU Digital Toolbox is addressed to a diverse audience with different concerns as follows:

- **End-users** who interact with the system, including Assessors / Energy auditors, Building material manufacturers, Building owner/managers, Construction and development companies, Energy Service Companies (ESCOs), Financing Institutions, Insurance companies, Tenants, with the following main concerns:
    - Appropriateness for use: they are concerned with the system usability, performance and reliability. They want to ensure that the architecture facilitates an intuitive and efficient system.
    - Risks of operation: they are concerned with data protection and system failures that could disrupt or compromise their data. They want to ensure that the architecture facilitates secure data store and transfer.
    - Purpose of the system: they are concerned with what are the purposes of the system. They want to have a clear understanding of the system purpose by reviewing the architecture.
- **Acquirers** of the system who fund and authorise the system development and deployment, including Public Authorities and the EC, with the following concerns:

- Feasibility: they are concerned with the project's resources and time to implement the system. They want to have assurance that the system can be built within the specified project constraints.
- Risks of operation: they are concerned with data protection and system failures that could disrupt or compromise their data. They want to ensure that the architecture facilitates secure data store and transfer.
- Appropriateness for use: they are concerned with the system usability, performance and reliability. They want to ensure that the architecture facilitates an intuitive and efficient system.
- Purpose of the system: they are concerned with what are the purposes of the system. They want to have a clear understanding of the system purpose by reviewing the architecture.

- **Developers and maintainers**, both core developers of the system as well as developers of external applications that interact with the system, including Researchers and developers, Smart Home Technology developers and Third-party app developers, with the following concerns:
  - Feasibility: they are concerned with the project's resources and time to implement the system. They want to have assurance that the system can be built within the specified project constraints.
  - Maintainability, deployability, scalability: they are concerned with the system's quality, modularity and scalability. They want to ensure that the system facilitates development and maintenance.
  - Purpose of the system: they are concerned with what are the purposes of the system. They want to have a clear understanding of the system purpose by reviewing the architecture.
  - Interconnectivity: they are concerned with the availability of mechanisms to interact with the system. They want to have sufficiently documented APIs.

7.2. Selection of architectural viewpoints

For the description of the architecture the following viewpoints are selected, following 4+1 architectural view model [33]:

- **Scenarios**
  - *Stakeholders to be addressed*: All.
  - *Concerns to be addressed*: Appropriateness for use, Purpose of the system
  - *Modelinq techniques*: BPMN diagrams
  - *Rationale*: This view describes how the use cases are implemented as a role-based flow, validating the system's ability to address the stakeholder requirements within the expected use.
- **Logical view**
  - *Stakeholders to be addressed*: All
  - *Concerns to be addressed*: Appropriateness for use, Feasibility, Risks of operation
  - *Modelinq techniques*: block diagram
  - *Rationale*: This view depicts the system's functional capabilities in order to provide a clear understanding of the overall conceptual system design and organisation of functional elements.
- **Development view**
  - *Stakeholders to be addressed*: Developers and maintainers
  - *Concerns to be addressed*: Feasibility, Maintainability, deployability, scalability, Interconnectivity
  - *Modelinq techniques*: block diagram

- *Rationale*: This view depicts the actual system component packages and software organization to facilitate development and integration. It acts as a blueprint for the system implementation.

- **Process view**
  - *Stakeholders to be addressed*:
  - *Concerns to be addressed*:
  - *Modelinq techniques*: UML sequence diagrams
  - *Rationale*: This view focuses on the dynamic behaviour of the system through its main structural elements and their interactions, demonstrating processes and data flows to support system operation and integration.

It needs to be noted that for the implementation of the Bauhaus Data Hub, an open-source Content Management System, more specifically Drupal, will be utilised. For that reason, the Bauhaus Data Hub is mentioned in the logical architecture, but is not further elaborated in other views, as the relevant documentation can be found at https://www.drupal.org/documentation.

7.3. Architectural views

7.3.1. Scenarios

The scenarios complement the Use Cases previously mentioned in paragraph 2.2.2. The main building assessment scenario includes UC1, UC2 and UC3 and is depicted in Figure 9.

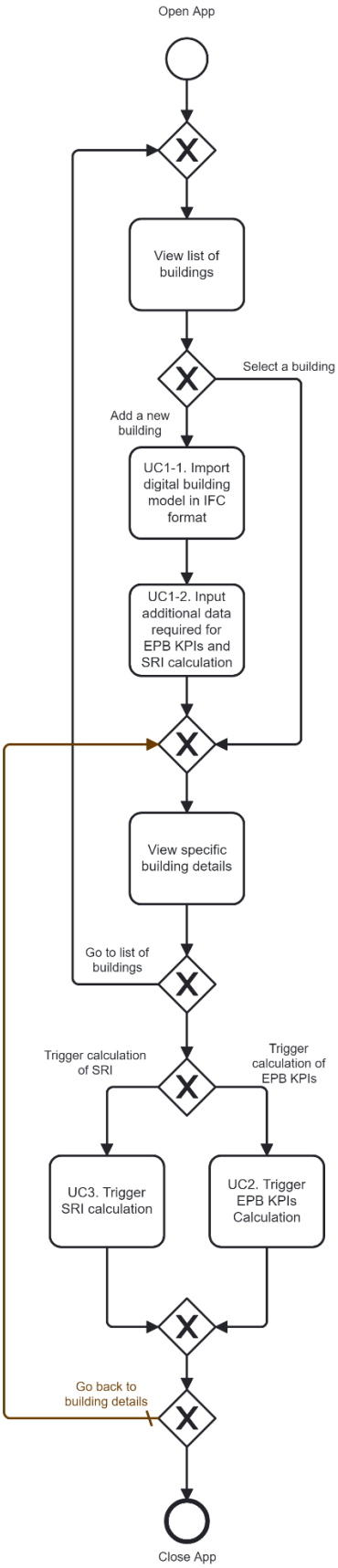

Figure 9. Main building assessment scenario

The main scenario, i.e. without considering errors, consists of the following steps:

- **View list of buildings**:
  - Related functions: N/A
  - The Assessor launches the Building Performance App.
  - The Building Performance App requests the list of buildings from the Building Data Repository.
  - The Building Data Repository returns the list of buildings for which the user has the relevant access permissions.
  - The Building Performance App presents the list of buildings to the Assessor.
- **UC1.1 Import digital building model in IFC format**:
  - Related functions: FUN1.1
  - The Audit tools present a form to import the building model in IFC format.
  - The Assessor selects a file from their device and upload it to the Audit tools.
  - The Audit tools validate and extract relevant data from the uploaded IFC file.
  - The Audit tools request the addition of a building to the Building Data Repository.
  - The Audit tools store the extracted data and the IFC building model to the Building Data Repository.
- **UC1.2 Input additional data required for EPB KPIs and SRI calculation**
  - Related functions: FUN1.2
  - The Audit tools present additional data input form to the Assessor.
  - The Assessor adds the additional audit data.
  - The Audit tools store the additional data to the Building Data Repository.
- **View specific building details**
  - Related functions: FUN2.3
  - The Building Performance App requests the audit data (previously collected data that are needed for the calculation of EPB KPIs and SRI) and EPB KPIs and SRI (if available) of the selected building from the Building Data Repository.
  - The Building Performance App presents the audit data and EPB KPIs and SRI (if available) to the Assessor.
- **UC2 Trigger EPB KPIs calculation**
  - Related functions: FUN2.1
  - The Building Performance App requests the calculation of the EPB KPIs calculation of the selected building from the EPB Kernel
  - The EPB Kernel calculates the EPB KPIs of the selected building.
  - The SRI Kernel stores to the Building Data Repository the EPB KPIs of the selected building.
- **UC3 Trigger SRI calculation**
  - Related functions: FUN2.2
  - The Building Performance App requests the calculation of the SRI calculation of the selected building from the SRI Kernel
  - The SRI Kernel calculates the SRI of the selected building.
  - The SRI Kernel stores to the Building Data Repository the SRI of the selected building.

Another scenario concerns the share of data through the Dataspaces Interface and is depicted in Figure 10.

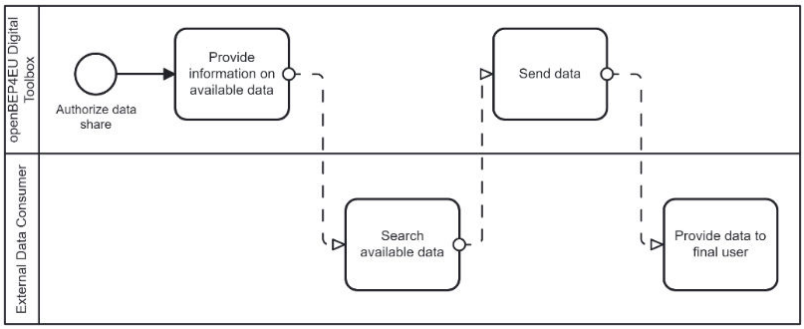

Figure 10: Sharing data with Dataspaces principles

The Sharing data with Dataspaces principles scenario consists of the following steps (related functions: FUN3.3):

- **Provide information on available data**:
  - The Data Owner (e.g., the owner of the building) authorizes the sharing of data.
  - The Data Provider (e.g., the entity that operates the instance of the openBEP4EU Digital Toolbox where the data is stored) publishes the information of the available data (i.e., metadata)
- **Search available data**:
  - The Data Consumer searches the information of the available data.
  - The Data Consumer requests a specific dataset.
- **Send data**:
  - The Data Provider sends the requested data to the Data Consumer.
- **Provide data to the final user:**
  - The Data Consumer received the requested data.
  - The Data Consumer presents the received data to the final user.

7.3.2. Logical view

A high-level logical view (functional blocks) is depicted in Figure 8.

The main information flows are further elaborated in Figure 11.

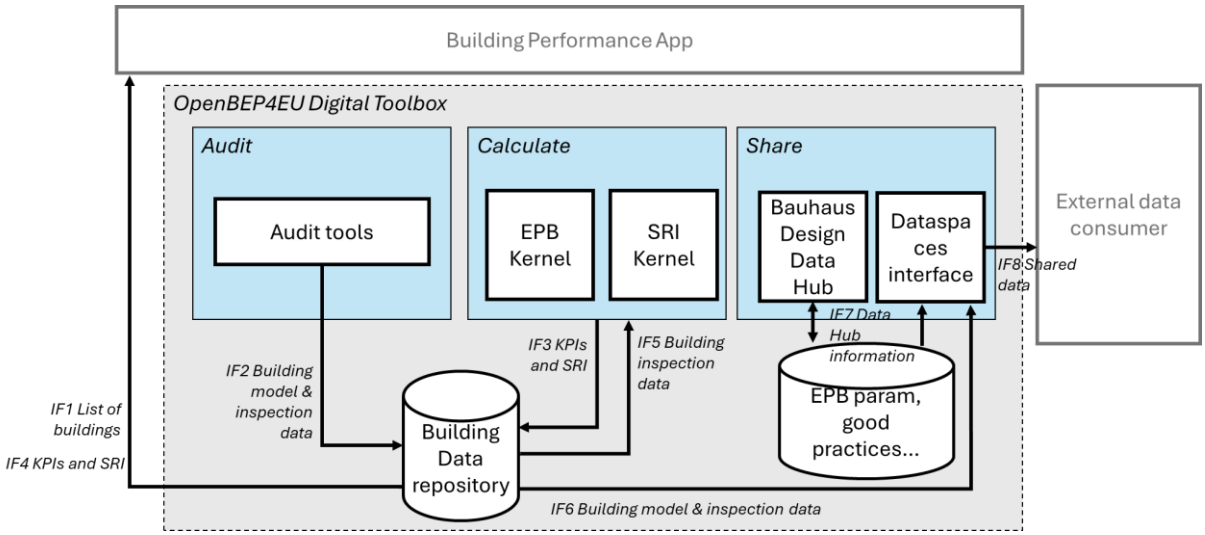

Figure 11: OpenBEP4EU Digital Toolbox Logical view

The logical architecture (Figure 11) encompasses two high-level persistence stores, in addition to the logical blocks described in paragraph 6.1:

- **Building Data Repository**: Contains the digital building models and additional data required for the calculation of energy performance KPIs and SRI.
- **EPB param, good practices...**: Contains all the information that is made available through the Bauhaus Design Data Hub.

The following information flows are defined:

- **IF1 List of buildings**: The list of buildings for which relevant data has been imported and stored.
- **IF2/IF6 Building model & inspection data**: The digital model of the building and that data required for the calculation of energy performance KPIs and SRI.
- **IF3/IF4 KPIs and SRI**: The calculated energy performance KPIs and SRI for a building
- **IF5 Building audit data**: A building's data required for the calculation of energy performance KPIs and SRI.
- **IF7 Data Hub information**: Any kind of information that is stored in the Bauhaus Design Data Hub.
- **IF8 Shared data**: Any data, including building model, audit data, KPIs, SRIs and Bauhaus Data Hub information that is shared with external entities.

7.3.3. Development view

For the development view the actual components mostly correspond to the logical view with small differences, more specifically the addition of a main API Gateway, that facilitates the communication between the Digital Toolbox and the Building Performance App, and the Kernels Data Access, which takes care of the Data Ingestion of the audit data to the engines, as well as storing the results of the calculations to the Building Data Repository.

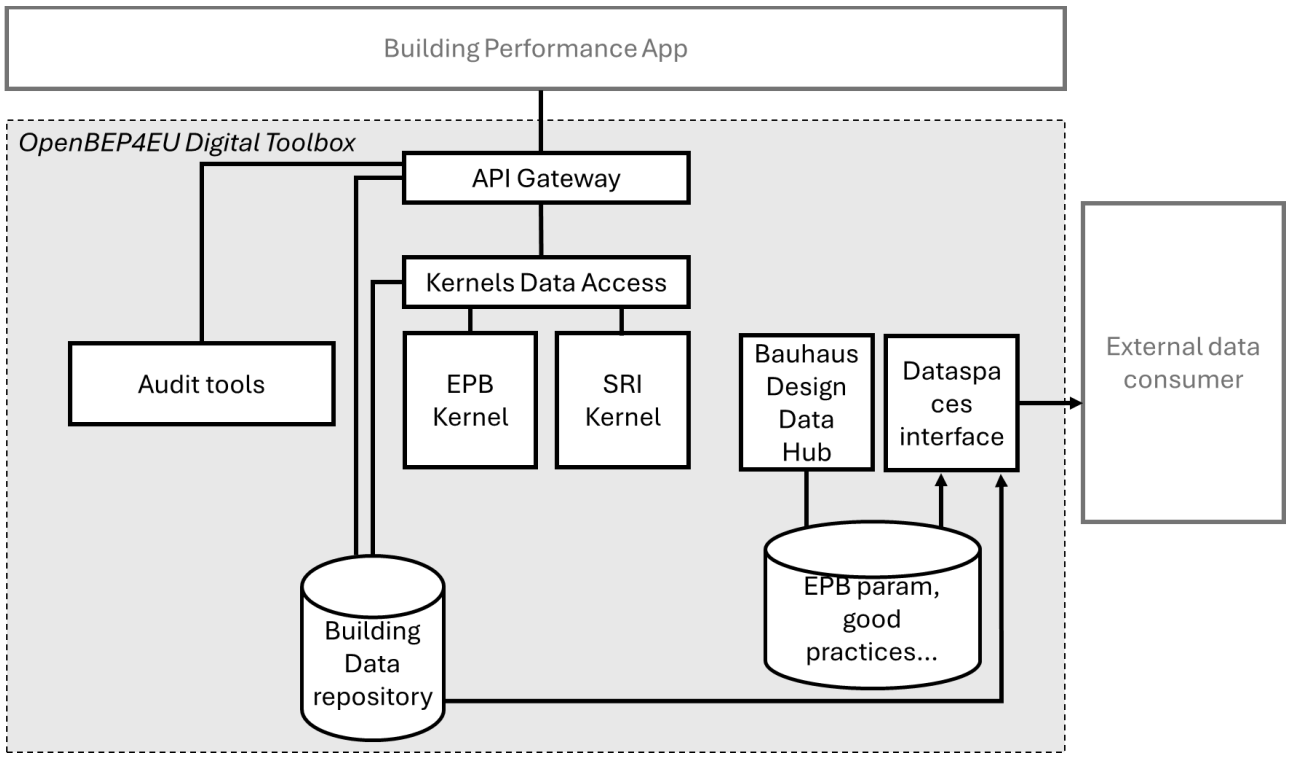

Figure 12: OpenBEP4EU Digital Toolbox Development view

The above view is to facilitate the OpenBEP4EU Digital Toolbox development by employing the Separation of Concerns principle [34], where each element is developed and maintained by a specific partner in the consortium. Building on this, Component-Based Development [35] is facilitated by the descriptions of the components as follows[3]:

Audit tools

- Description: The Audit tools component facilitates the collection, transformation, and validation of building-related data required for EPB calculation. It enables users to upload or manually enter data, which is structured according to a common data model for further processing.
- Responsibility: EUP
- Related functions: FUN1.1, FUN1.2
- Interfaces (Exchanges building and audit data with the API Gateway (IF2) for storage in the Building Data Repository)

Direction	Title	Description	Information flow ID
Out	Add building model	Addition of a building	IF2
Out	Add audit data	Addition of audit data for a building	IF2
Out	Store building model	Store the building model in the Data Repository	IF2
Out	Store audit metadata	Store the metadata required for EPB/SRI calculation	IF2

API Gateway

- Description: This component acts as the main API towards 3rd-party apps, i.e., the Building Performance App reference component. It routes requests, responses and data between the 3rd-party app to the Audit tools, EPB and SRI kernels and the Building Data repository.
- Responsibility: EDLUX
- Related functions: FUN1.2, FUN2.1, FUN2.2, FUN2.3
- Interfaces (Building Data Repository access is omitted)

Direction	Title	Description	Information flow ID
In	Receive new building request	Receive request to add a building	IF2
Out	Add new building	Add a building to the Building Data Repository	IF2
In	Receive new audit data request	Receive request to add audit data for a building	IF2
Out	Add audit data	Add audit data for a building to the Building Data Repository	IF2
In	Receive EPB KPIs trigger	Receive request to trigger the calculation of the EPB KPIs for a building	N/A
Out	Trigger EPB KPIs calculation	Trigger the calculation of the EPB KPIs for a building	N/A
In	Receive SRI trigger	Receive request to trigger the calculation of the SRI for a building	N/A
Out	Trigger SRI calculation	Trigger the calculation of the SRI for a building	N/A

[3] The interfaces descriptions are indicative and are subject to changes during the implementation

Kernels Data Access

- Description: This component takes care of the data access for the EPB and SRI Kernels. More specifically, when it accepts requests to trigger the calculations for a building, it fetches the data from the Building Data Repository and ingests it to the relevant Kernel. Similarly, when the calculation is completed, it accepts the data from the kernels and stores it to the Building Data Repository.
- Responsibility: EDLUX
- Related functions: FUN2.1, FUN2.2
- Interfaces (Building Data Repository access is omitted)

Direction	Title	Description	Information flow ID
In	Receive EPB KPIs trigger	Receive request to trigger the calculation of the EPB KPIs for a building	N/A
Out	Request EPB KPIs calculation	Send audit data to the EPB Kernel and request the calculation of the EPB KPIs for a building	IF5
In	Store EPB KPIs	Receive EPB KPIs for a building to store to the Building Data Repository	IF3
In	Receive SRI trigger	Receive request to trigger the calculation of the SRI for a building	N/A
Out	Request SRI calculation	Send audit data to the SRI Kernel and request the calculation of the SRI for a building	IF5
In	Store SRI	Receive SRI for a building to store to the Building Data Repository	IF3

EPB Kernel

- Description: The EPB Kernel is responsible for executing EPB assessments in accordance with standardized methodologies. It processes input data from building characteristics and simulations to compute EPB metrics, supporting regulatory compliance and energy efficiency optimization.
- Responsibility: QUE
- Related functions: FUN2.1, FUN2.3
- Interfaces: The EPB Kernel interacts with multiple systems and data sources to perform calculations and provide results. It receives structured input data and calculation requests and returns computed KPIs.

Direction	Title	Description	Information flow ID
In	Receive building model & audit data	Receives building model and relevant audit data for EPB KPI calculations.	IF2 / IF6
In	Receive calculation request	Receives a request to calculate EPB KPIs for a specific building.	IF4
Out	Provide KPIs to Kernels Data Access	Sends computed EPB KPIs to Kernels Data Access	IF3

SRI Kernel

- Description: The SRI Kernel is responsible for executing Smart Readiness Indicator (SRI) assessments in accordance with standardised methodologies. It processes input data from audits and computes SRI scores for buildings, facilitating regulatory compliance and building optimization.
- Responsibility: EUP
- Related functions: FUN2.2, FUN2.3

- Interfaces (Receives structured audit data and calculation requests from the Kernels Data Access component (IF4, IF5); returns computed SRI results to be stored in the Building Data Repository via the same intermediary (IF3).)

Direction	Title	Description	Information flow ID
In	Receive audit data	Receive audit data required to perform SRI calculation	IF5
In	Receive calculation request	Receive the request to perform the SRI calculation	IF4
Out	Output SRI results	Return calculated SRI results to be stored in the Building Data Repository	IF3

Dataspaces interface

- Description: The Dataspaces interface is responsible for making available shareable data in a dataspaces approach, both in terms of disseminating metadata of available data and taking care of the data transfer
- Responsibility: ED
- Related functions: FUN3.1
- Interfaces

Direction	Title	Description	Information flow ID
In	Data and metadata available	Data and metadata that are available for sharing in the Building Data Repository and the Bauhaus Data Hub repository	IF6/IF7
Out	Data and metadata available	Dissemination of metadata of available data and data transfer to external entities	N/A

7.3.4. Process view

In this paragraph, the process view of the OpenBEP4EU Digital Toolbox in the form of sequence diagrams, considering the steps of the main scenario and the elements at the development view. This is the initial specification, which will be further refined during the development.

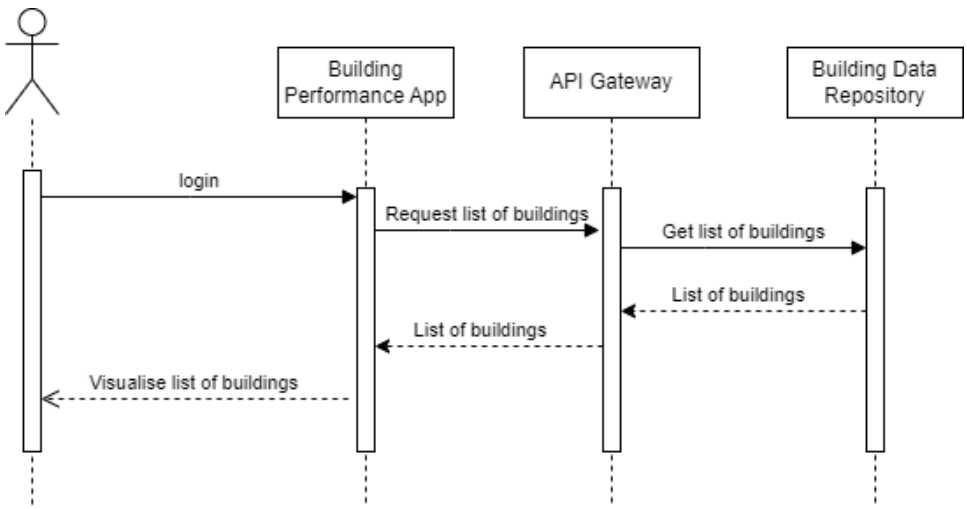

Figure 13: Sequence diagram for 'View list of buildings'

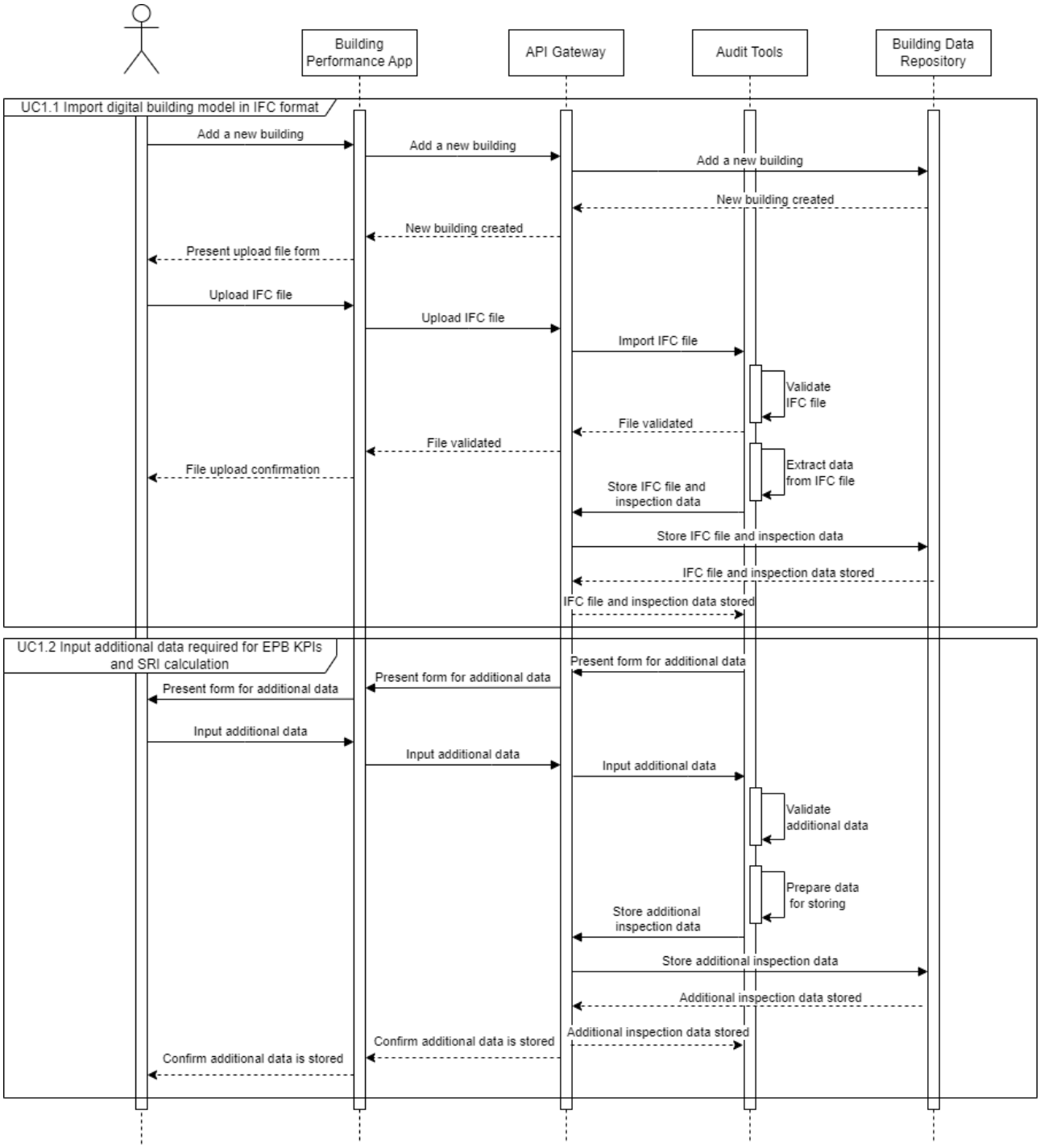

Figure 14: Sequence diagram for " UC1.1 Import digital building model in IFC format " and " UC1.2 Input additional data required for EPB KPIs and SRI calculation "

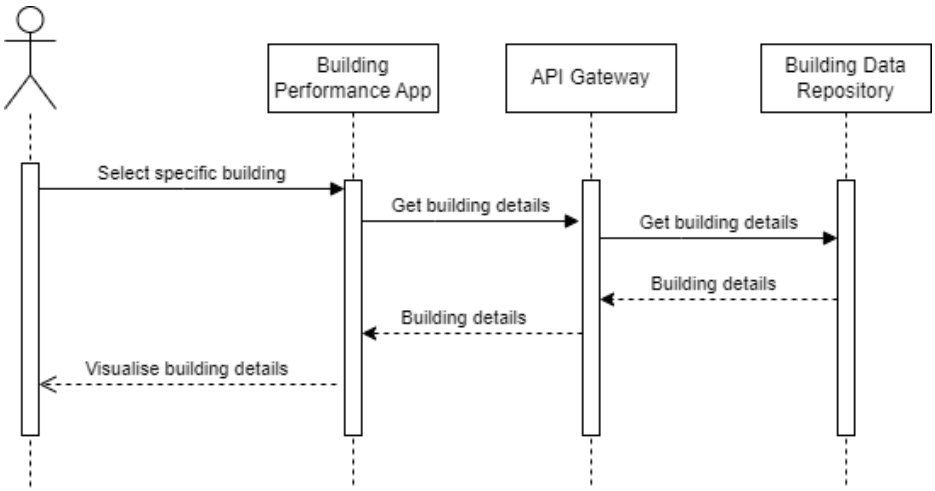

Figure 15: Sequence diagram for "View specific building details"

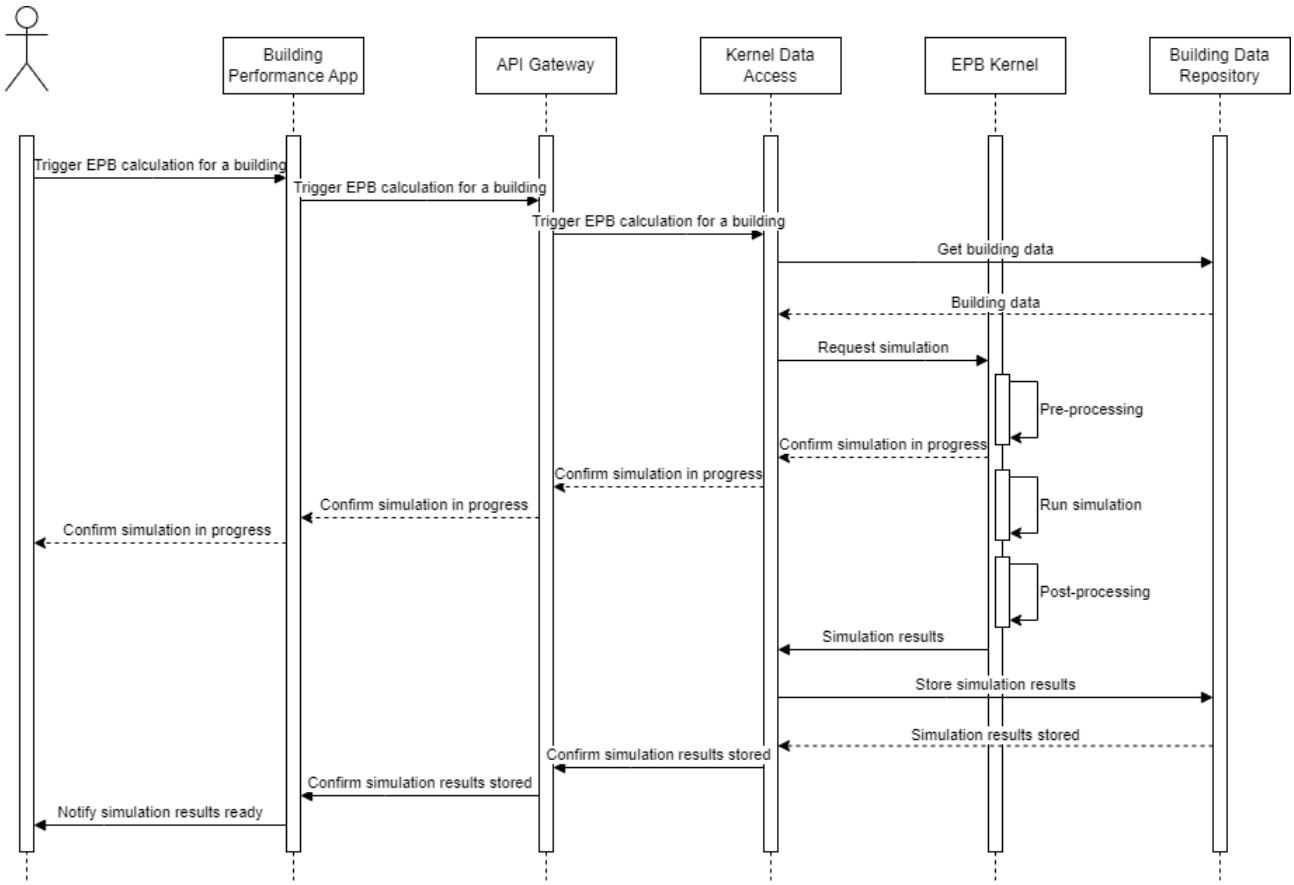

Figure 16: Sequence diagram for " UC2 Trigger EPB KPIs calculation"

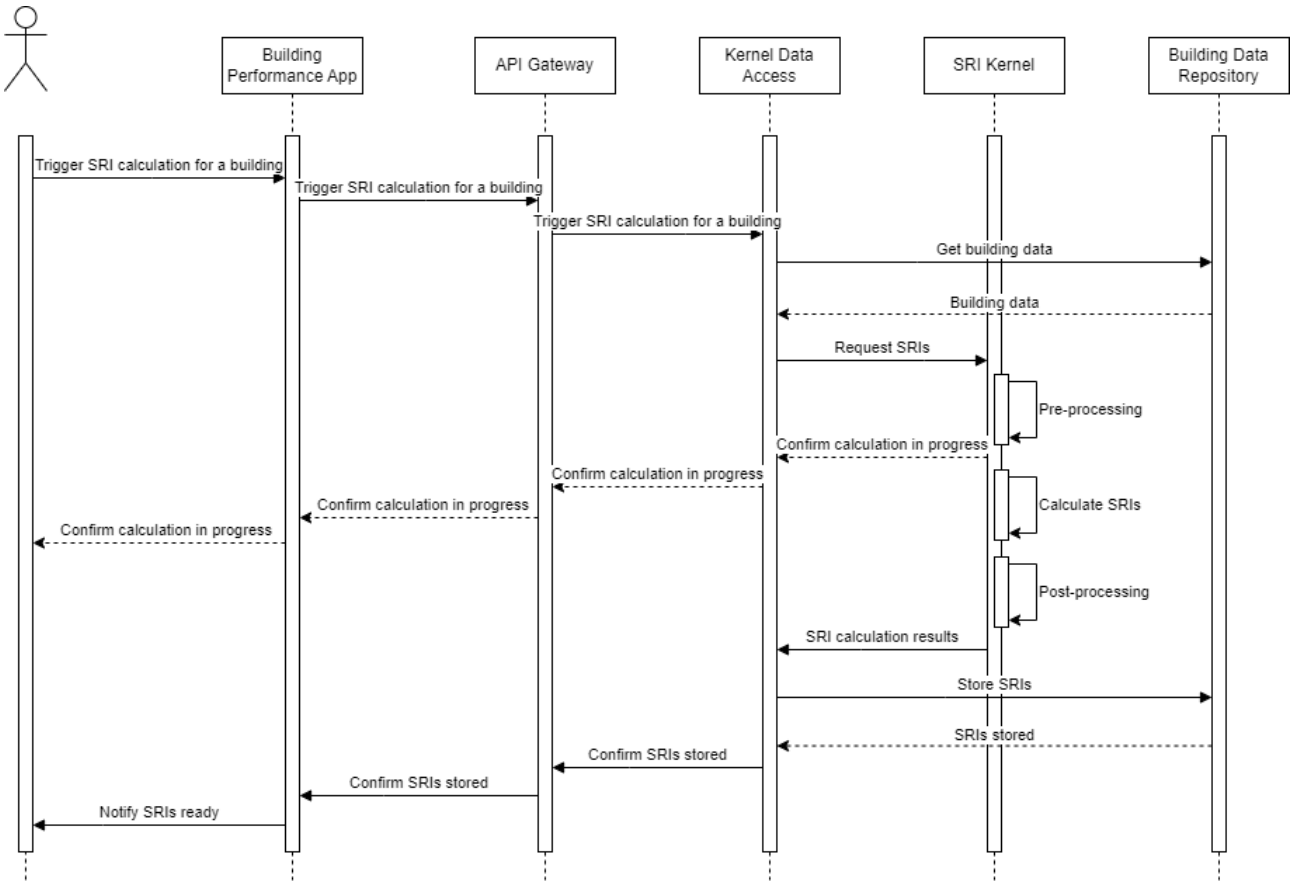

Figure 17: Sequence diagram for "UC2 Trigger SRI calculation"

Complementing the above scenario, illustrates the process for the Sharing data with Dataspaces principles use case.

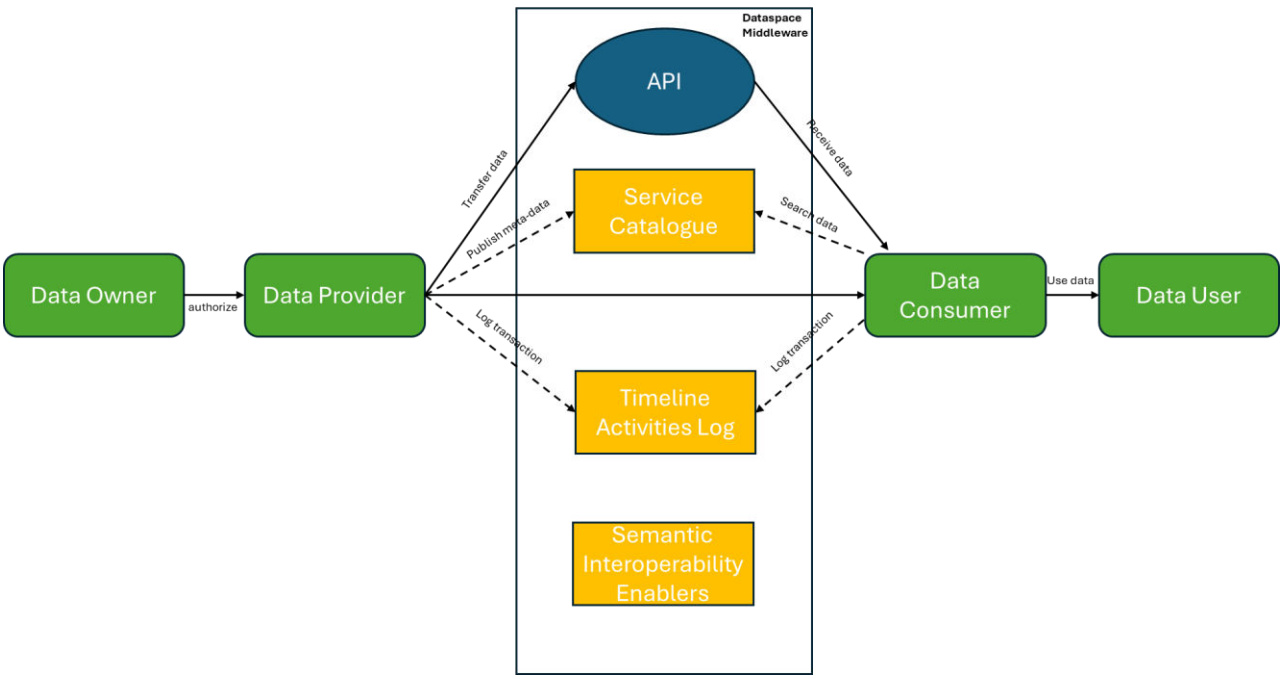

Figure 18: Process for "Sharing data with Dataspaces principles"

8. Conclusions

In brief, D2.1 – "User Needs and Requirements Report" illustrates and describes the following accomplishments:

- Identification of the stakeholders of the OpenBEP4EU Digital Toolbox.
- Understanding of the business environment and business use cases of the OpenBEP4EU Digital Toolbox through a systematic analysis.
- Identification of the necessary features of the OpenBEP4EU Digital Toolbox and the necessary architecture components for achieving them.
- Extraction of the user requirements for the OpenBEP4EU Digital Toolbox and the methodology for their verification and validation.
- Developed an initial version of the OpenBEP4EU Digital Toolbox architecture to be utilised for the implementation.

D2.1 – "User Needs and Requirements Report" serves as a foundation document for the implementation of the OpenBEP4EU Digital Toolbox in the context of WP2, as well as the high level innovative procedures and value added services of WP3 and WP4.

This report has identified and documented the user needs, requirements, and initial architecture for the OpenBEP4EU Digital Toolbox. The process ensured alignment with stakeholder expectations, industry good practices, and EU directives, laying a solid foundation for subsequent development. The analysis underscored critical success factors for next generation EPC & SRI tools: accuracy and compliance with European standards, user-centric design, data interoperability, and openness. OpenBEP4EU's requirements and architecture directly address these factors, for example, by incorporating standardized calculations (ensuring consistency with EPBD-aligned methods) and enabling new features like SRI and data hubs that go beyond current EPC practices. The adoption of an open source approach is expected to facilitate widespread uptake and collaborative improvement of the toolbox, as stakeholders across Europe can adapt the engine to their needs and contribute to its evolution.

Looking forward, the next steps involve implementing the specified requirements in the toolbox development, followed by thorough testing and validation in demonstration sites. Feedback loops will be essential, as the prototype is tested with end-users (assessors, building owners, etc.), additional needs or refinements may emerge. The project will remain attentive to the ongoing 2024 recast EPBD legislative process and related initiatives (like the rollout of digital building logbooks and renovation passport schemes) to ensure the toolbox remains ahead of the curve in terms of compliance and features. Future updates of the architecture might integrate new modules, for instance, if operational rating becomes mandatory or if new KPIs (such as indoor environmental quality metrics) gain prominence, the flexible design will allow their inclusion. The consortium also plans to coordinate with other EU funded activities, facilitated by the EPB Center, to disseminate results and harmonize approaches, fostering a community of practice around the EU Kernel EPC Engine. By doing so, OpenBEP4EU will contribute significantly to the transformation of EPC schemes into more reliable, smart, and user-friendly instruments for achieving Europe's energy and climate goals.

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