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D4.1 – Energy Efficient and Sustainable Design Tool v1

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DELIVERABLE 4.1
Energy Efficient and Sustainable Design Tool v1

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0.4	QUE	18.09.2025	Initial content for all sections
0.5	All	18.10.2025	Updates on Section 2 from partners
0.6	QUE	22.10.2025	Interim version ready for internal review
0.7	QUE	30.10.2025	Updated version based on review comments
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Executive Summary

The Energy Efficient and Sustainable Design Tool (EESDT), developed within the AccesS project, is a digital solution designed to support the transition toward energy-efficient, smart, and sustainable buildings. It aims to provide a practical environment for designers, engineers, and facility managers to explore and compare renovation and smartification scenarios before they are applied in reality. Combining Building Information Modelling (BIM), energy performance simulation, and smart readiness assessment, the EESDT helps users understand how different renovation options and smart technologies affect building performance and smart readiness.

The EESDT backend integrates a suite of components (modules) connected through a central data management layer. This suite includes: the IFC (industry Foundation Classes) Model Checker to validate building models to ensure data quality; the BIM-to-BEP Simulator to convert BIM data into simulation-ready models and performs EnergyPlus-based performance calculations; and the BIM-to-SRI Calculator to evaluate the building smart readiness levels across different building domains. Results from these components feed into the Decision Support Engine, which applies multi-criteria analysis to rank renovation scenarios according to energy, cost, and smartness indicators.

The EESDT frontend provides access to data and metadata produced by the EESDT backend through a web-based Graphical User Interface (GUI), where users can navigate 3D building models, configure renovation and smartification scenarios, and view simulation outcomes through interactive dashboards. In more detail, users can explore alternative design and technology combinations, analyse their impact through energy and smart-readiness KPIs, and identify optimal solutions that balance performance, cost, and sustainability objectives.

Within the broader framework of the Universal Accessibility Suite, the EESDT serves as the energy and smart readiness assessment component. It connects digital building representations with evaluation and optimisation tools, complementing other modules focused on accessibility, inclusivity, and smart operation.

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List of Acronyms and Abbreviations

Term	Description
AEC	**Architecture, Engineering, and Construction**
BCF	**BIM Collaboration Format**
BEP	**Building Energy Performance**
BEPS	**Building Energy Performance Simulation**
BIM	**Building Information Modeling**
DHW	**Domestic Hot Water**
ECM	**Energy Conservation Measure**
EESDT	**Energy Efficient and Sustainable Design Tool**
EPW	**EnergyPlus weather file**
HVAC	**Heating, Ventilation, and Air Conditioning**
IDF	**Input Data File**
IDS	**Information Delivery Specification**
IFC	**Industry Foundation Classes**
KPI	**Key Performance Indicator**
PV	**Photovoltaic**
SR	**Smart Readiness**
SaaS	**Software-as-a-Service**
SRI	**Smart Readiness Indicator**
WP	**Work Package**

1 Introduction

1.1 Scope and objectives of the deliverable

Deliverable D4.1 reports on the activities carried out under Task 4.1 – *Energy Efficient and Sustainable Design Tool (EESDT)*, within Work Package 4 (WP4) of the AccesS project. The purpose of this deliverable is to describe the EESDT's modular architecture, including its main analytical components and its web-based User Interface (UI), establishing its role as a key digital component within the AccesS framework for supporting energy-efficient and sustainable building renovation.

Developed as a cloud-based Software-as-a-Service (SaaS) platform, the EESDT enables users to evaluate and compare renovation scenarios based on energy performance, smart readiness, and sustainability criteria. It integrates openBIM-based data management, building energy simulation, and smart-readiness assessment functionalities into a unified framework that supports consistent, transparent, and automated analysis.

In addition to reporting on the current implementation status, the deliverable highlights ongoing and planned minor refinements aimed at improving user interactivity, multi-criteria visualization, and integration with the Universal Accessibility Suite. These enhancements, performed within the corresponding integration task, will extend the decision-support capabilities of the tool and strengthen its role within the wider AccesS platform for digital building design and renovation.

1.2 Structure of the deliverable

This deliverable is organized into the following sections:

- **Section 1: Introduction**

  This section outlines the deliverable's scope and objectives, structure, and relation to other tasks and deliverables, establishing the foundation for the detailed content presented in the subsequent sections.

- **Section 2: EESDT**

  This section describes the EESDT, outlining how its subcomponents contribute to the comprehensive evaluation of building energy performance and smart readiness before and after renovation.

- **Section 3: Conclusions**

  The concluding section summarises the key outcomes and achievements, highlighting progress made in the design of the EESDT and outlining directions for further enhancement and validation activities planned in subsequent project stages.

1.3 Relation to Other Tasks and Deliverables

The development of the EESDT has been carried out in close coordination with other activities of the AccesS project to ensure full consistency with the overall framework architecture, evaluation methodology, and integration and demonstration roadmap. This deliverable builds on several key inputs from earlier work and provides outputs that will directly contribute to upcoming integration and pilot implementation tasks.

The main inputs to this deliverable originated from two foundational sources. First, Deliverable D1.2 AccesS Framework Architecture, Use Cases and Master Planning for Demonstrators provided the technical and conceptual foundation for the tool's development. The system architecture, interoperability guidelines, and use-case definitions established in D1.2 informed the modular design, workflow structure, and data-exchange logic of the EESDT. This ensured architectural consistency with the broader Universal Accessibility Suite and alignment with the project's digitalisation and sustainability objectives.

Second, Deliverable D1.3 AccesS Evaluation Framework defined the methodological basis for the Key Performance Indicators (KPIs) used throughout the project to assess energy efficiency, smart readiness, and environmental performance. These KPIs have been directly implemented in the EESDT's simulation and assessment modules, guaranteeing methodological consistency across the project and enabling comparative analysis between pilot sites and renovation scenarios. On the same time, key considerations retrieved from pilot consultations under WP2 and reflected in D2.1 User-centered Design Approach and Inclusive Active Mobility Solutions have also been considered when building the services of the tool.

The outputs of this deliverable will directly support integration and demonstration activities in later work packages. Within Task 7.2 AccesS Inclusive Toolbox: Integration of Components, the EESDT will be incorporated into the first release of the Universal AccesS Suite as described in Deliverable D7.2 – AccesS Suite v1. The tool will serve as a core analytical and decision-support component, contributing validated energy and smart-readiness KPIs to the common platform environment.

In addition, the EESDT will play a central role in the project's demonstration activities within WP10, WP11 and WP12. It will be deployed across pilot sites to perform baseline assessments, evaluate renovation measures, and verify improvements in energy and smart readiness. These results will feed into the project's evaluation framework and provide quantitative evidence of the tool's effectiveness under real operating conditions.

Through these interconnections, Deliverable D4.4 serves as a bridge between the design phase of *AccesS* and its integration and demonstration phases. It ensures that the EESDT functions both as an independent simulation and evaluation engine and as a fully integrated component of the *Universal AccesS Suite*, supporting the project's overarching aim to promote energy-efficient, inclusive, and smart renovation solutions across Europe.

2 EESDT

The EESDT is a Building Information Modeling (BIM)-based decision-support environment developed to assist building stakeholders, such as facility managers, designers, and energy consultants, in evaluating renovation strategies for improved energy efficiency and smart readiness. Its core purpose is to enable decision-making by combining advanced simulation capabilities with intelligent data management and visualization tools.

Through the EESDT, users can import building models in openBIM Industry Foundation Classes (IFC) format - a vendor-neutral data schema and exchange format, standardized as ISO 16739, that enables the representation and sharing of BIM data across the architecture, engineering, and construction (AEC) sector (European Committee for Standardization, 2020; buildingSMART International, 2025). Developed and maintained by buildingSMART International, IFC provides a structured, machine-readable description of built environment elements—including their geometry, properties, and relationships—ensuring that project information is captured in a consistent and computer-interpretable format. As the backbone of openBIM workflows, IFC facilitates the reliable exchange and interpretation of BIM data across diverse software platforms and stakeholders, eliminating information loss and proprietary constraints, and thereby enabling seamless interoperability throughout the AEC industry.

Using the IFC-based models, the EESDT conducts Building Energy Performance Simulations (BEPS), and Smart Readiness Indicator (SRI) assessments. The results of these analyses are used to derive both energy-related and smart readiness KPIs, which are visualized through an interactive interface that allows users to compare and assess renovation alternatives. Integrating data validation, physics-based simulation, and decision-support functionalities within a single, interoperable platform, EESDT provides a robust foundation for sustainable building renovation planning aligned with European energy and digitalization objectives.

Figure 1 presents a high-level overview of the EESDT architecture, divided into three main layers (Data Sources, Core Components and GUI) and illustrating how multiple data sources, simulation engines, and decision-support components are integrated within a unified framework. These layers are briefly introduced below and analysed in the following sections.

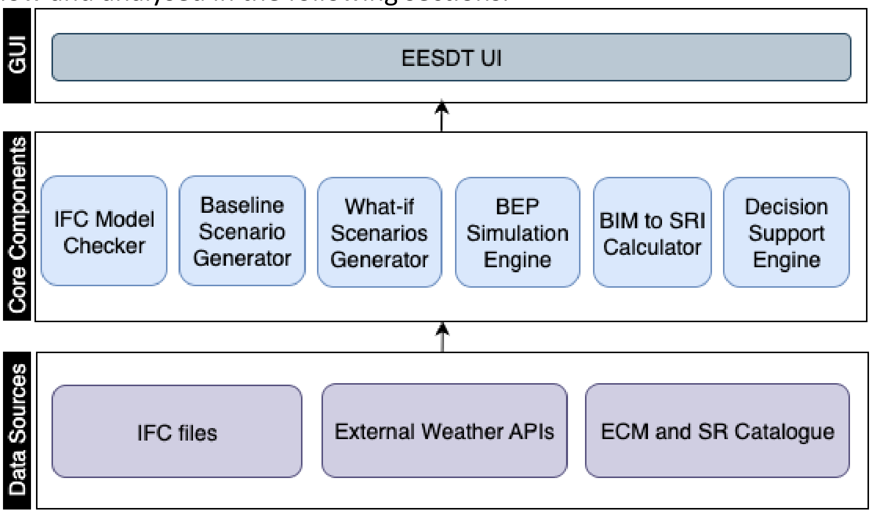

Figure 1: High-level overview of the EESDT architecture

Data Sources: The system takes as input openBIM IFC files extracted from baseline BIM models, EnergyPlus weather files obtained from external weather APIs, and a unified catalogue of Energy Conservation Measures (ECMs) and Smart Readiness (SR) products. This catalogue serves as a central repository of retrofit options and smart building technologies, supporting both energy and digital performance assessments. Together, these data inputs form the basis for generating, evaluating, and optimizing renovation scenarios. Further details are presented in Section 2.1.

Core Components and Workflows: At its core, the EESDT combines six interconnected functional components that support all the necessary EESDT workflows. The IFC Model Checker ensures that all BIM models meet the minimum data requirements for energy simulation and smart readiness assessment through automated validation against project-specific rules. The Baseline Scenario Generator acts as an orchestrator of other EESDT component involved in a workflow that aims to process the validated model to estimate the building's current performance profile (baseline scenario). Building on this workflow, the What-if Scenarios Generator is another orchestrator, tailored to a workflow that aims to evaluate renovation scenarios automatically generated by user-selected renovation measures from the ECM & SR catalogue. Each scenario (baseline or renovation) is evaluated through two complementary components: the BIM-to-BEP Simulator and the BIM-to-SRI Calculator. The former produces detailed energy performance results using physics-based simulations, while the latter assesses the smart readiness of the building. The unified outcome of these components is a structured set of performance indicators covering both efficiency and smart readiness aspects of the building. The Decision Support Engine then consolidates this outcome and applies user-defined criteria and optimisation techniques to identify the most effective renovation strategies. The final outputs consist of KPIs, SRI scores, and ranked renovation scenarios.

In summary, to illustrate how the core components operate in practice, the EESDT architecture is structured around the aforementioned complementary workflows, operated by the Baseline Scenario and the What-if Scenario Generator, respectively. Figure 2

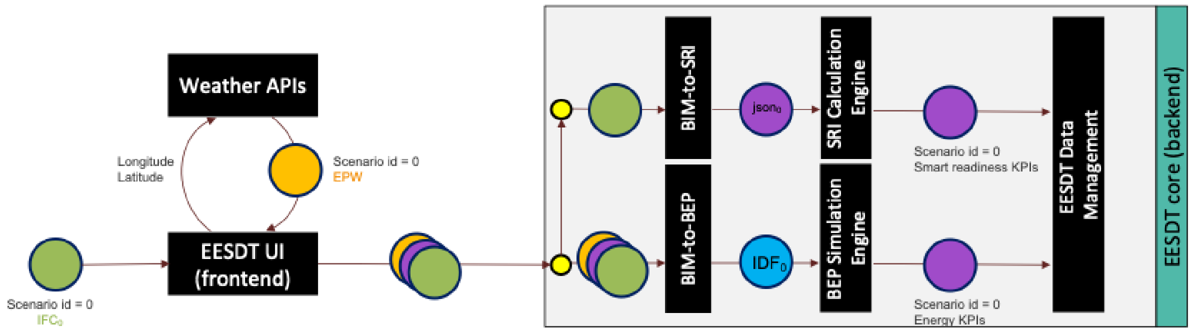

Figure 2: Flowchart of Baseline Scenario Generator

Figure 2 and Figure 3 present flowcharts of these workflows, which are described briefly below. The Baseline Scenario Generator workflow (Figure 2) establishes the reference energy performance of the building by transforming a digital model into a validated energy simulation. Starting from a BIM model prepared in accordance with BIM design guidelines, the data is exported into IFC format and passed through an automated validation process to ensure completeness and consistency. Once validated, the model is enriched with location-specific climate data and expert-defined simulation parameters. These inputs are then converted into a simulation-ready format for the EnergyPlus engine, which produces the baseline performance results. This workflow provides the foundation for all subsequent renovation analyses.

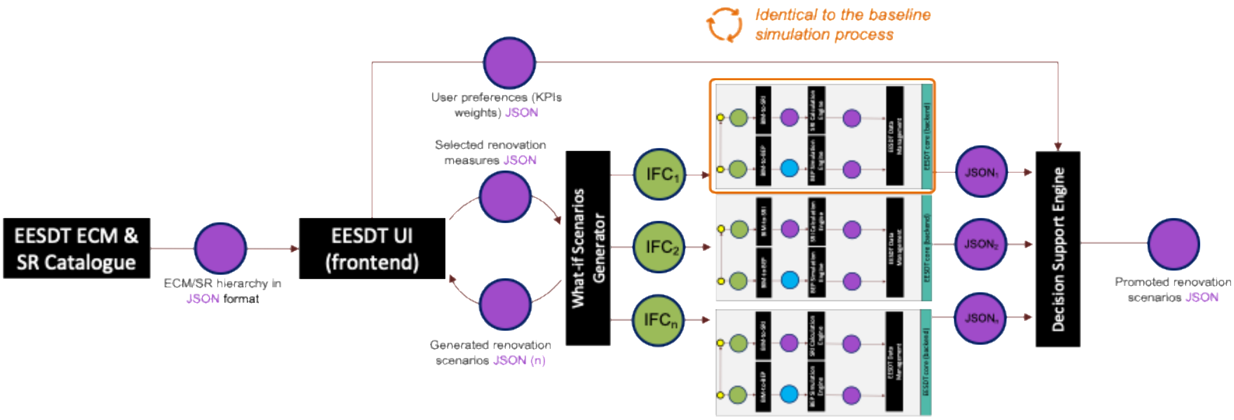

Figure 3: Flowchart of What-if Scenarios Generator

The "What-if Scenarios Generator workflow" (Figure 3) builds upon the validated baseline by introducing alternative renovation measures, such as envelope improvements, system upgrades, or smart technologies. User selections from the catalogue of measures are applied to the baseline model, generating modified IFC and simulation files that represent potential renovation strategies. These scenarios are processed through the same validation and simulation pipeline as the baseline, ensuring comparability and consistency. The resulting outputs are aggregated into a structured dataset of energy and SRIs, which form the basis for decision-making and scenario ranking. While the workflows illustrate the overall process, Section 2.2 provides a closer look at the core components that enable these operations, explaining in greater detail how each element contributes to the tool's functionality.

Graphical User Interface: The Graphical User Interface (GUI) of the EESDT provides an environment where users can visualise BIM models, configure renovation scenarios, and review performance outcomes. It presents the outputs of all system modules into an interactive web application that supports the exploration of energy and SRIs. Through this interface, users can compare baseline and renovated models, interpret simulation results, and identify optimal strategies based on energy performance and smart readiness criteria. Combining visualisation, simulation control, and decision-support functions within a single workspace, the GUI ensures that complex analytical processes are presented in more user-friendly manner. In principle, it acts as the decision-making hub of the EESDT, enabling users to apply optimisation criteria, evaluate trade-offs, and select renovation pathways that best align with their performance objectives. Section 2.3 illustrates and demonstrates the core functionalities and UI elements of the EESDT UI.

2.1 EESDT Data Sources

The effectiveness of the EESDT depends on the quality and diversity of the data it processes. To ensure reliable analyses and consistent results across renovation scenarios, the tool integrates multiple categories of input data, each fulfilling a distinct role within the workflow. The data sources, illustrated in Figure 4, form the foundation of the openBIM-to-BEP simulation process. Although the main focus here is on the data sources that contribute to more robust and less error-prone energy performance simulations, it is important to note that the openBIM format used for collecting both static and dynamic building data, as outlined below, is inherently rich and capable of representing all the information required for smart readiness assessments as well. Additional details on how this data is used for SRI calculations are provided in Section 2.2 (see BIM-to-SRI Calculator).

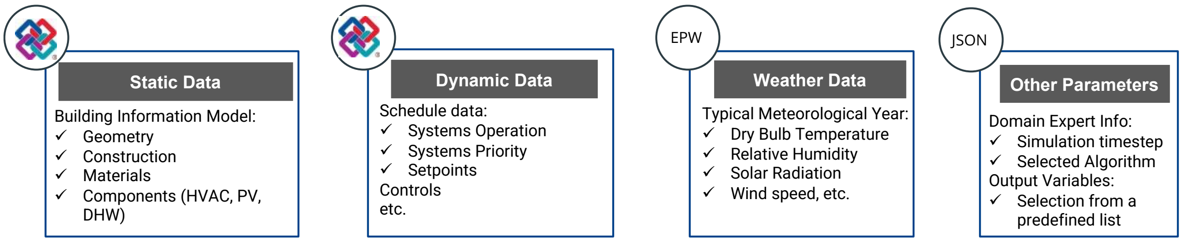

Figure 4: BEPS Engine – Input Categories

Static and dynamic data: A substantial portion of the EESDT's input data originates from the openBIM IFC file format. Within AccesS, the IFC file serves as the primary container for both static and dynamic data required for simulation and assessment. Static data, represented through objects belonging to specific IFC classes, encompasses information such as location and orientation (including geographic coordinates and azimuth) that affect solar exposure and climate zone classification. It also defines the geometry of spaces, surfaces, and construction elements used to establish thermal zones and envelope characteristics. Construction assemblies are described through material properties, including U-values, thermal mass, and infiltration rates. Detailed representations of building systems are also included, covering HVAC types, efficiencies, control schemes, and zone assignments; photovoltaic (PV) systems with panel orientation, tilt, inverter efficiency, and expected output; domestic hot water (DHW) systems specifying source type, storage capacity, insulation, and usage patterns; and control systems such as daylighting controls and automation protocols. Dynamic data extracted from IFC complements this information by representing time-dependent operational parameters. These include occupancy profiles defining presence patterns by zone, day type, and season; lighting and equipment loads that represent internal gains through operational schedules; and temperature setpoints and HVAC control strategies, including schedules for heating, cooling, and ventilation.

In typical practice, IFC files are not authored manually but rather exported from BIM authoring tools—such as Autodesk Revit—using dedicated plugins. However, achieving an IFC export that fully meets the requirements for energy modelling is not a straightforward process. In most cases, multiple iterations are required between the BIM designer and the Building Energy Performance Simulation (BEPS) modeller to produce a complete and simulation-ready model. Figure 5 illustrates the BIM model in Revit and the exported IFC file for the Dutch pilot in AccesS, Droom je Thuis.

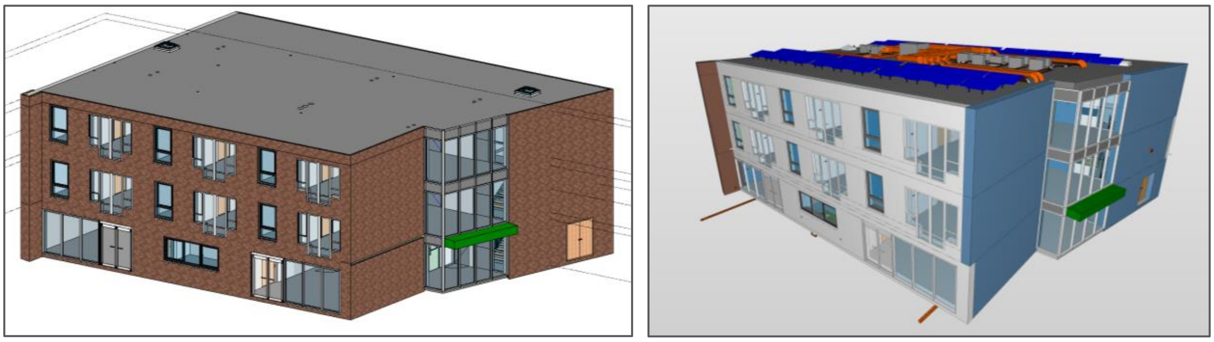

Figure 5: a) BIM model in Revit, b) Exported ifc file for the Dutch pilot Droom-Je Thuis

Recognizing this as a key limitation of the workflow, the AccesS project adopted and significantly extended the BIM modelling guidelines for Revit developed by Giannakis et al. (2019). These guidelines define how key elements should be modelled and exported to support free-floating BEPS models and now provide additional instructions for the correct representation and export of HVAC systems, ensuring that all relevant information is captured consistently and accurately for simulation purposes. Figure 6 presents a screenshot from the updated guidelines shared with the BIM modeler of the Dutch pilot for representing an air-to-water heat pump and an underfloor heating system in Revit, and the resulted BIM after inclusion of the corresponding Revit families that meet the BEPS requirements.

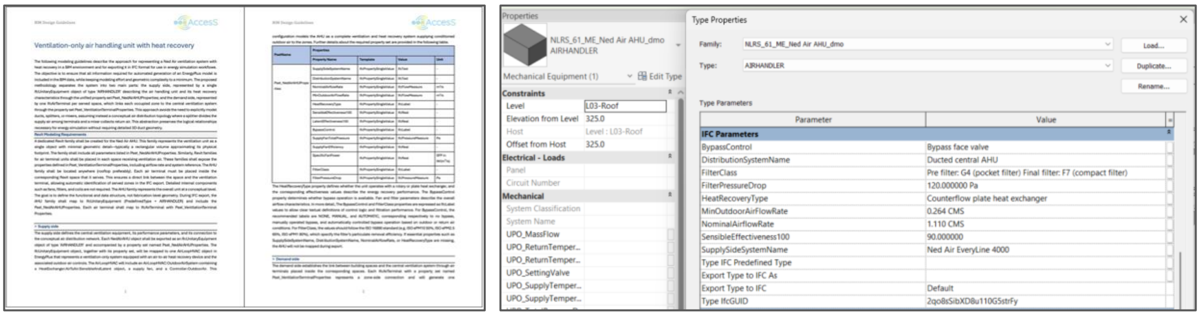

Figure 6: Screenshots from the AccesS BIM Guidelines for designing a ventilation-only air handling unit with heat recovery (left) and the corresponding family with the requested properties after successful modelling in Revit

Weather data and other parameters: The EESDT incorporates EnergyPlus as its BEP simulation engine, which requires detailed and hourly weather data for a whole year to produce reliable results. Weather condition inputs are provided in the EnergyPlus Weather (EPW) file format, a standardized data structure containing key climatic parameters such as dry-bulb temperature, relative humidity, solar radiation (global, direct, and diffuse), wind speed and direction, and, where available, atmospheric pressure and precipitation. These datasets enable simulations to account for local climate variations, which are particularly important when evaluating passive design strategies, natural ventilation performance, and the potential contribution of renewable energy systems.

Figure 7: Screenshot of the .epw file for the location of the Dutch pilot from the EnergyPlus repository

To automate the retrieval of appropriate weather data, geolocation parameters—including latitude, longitude, and elevation—are extracted directly from the IFC model. Using this information, the EESDT connects to external weather data APIs compatible with EnergyPlus to retrieve Typical Meteorological Year (TMY) datasets in EPW format corresponding to the building's location. Subset of the EPW file, automatically retrieved from the EnergyPlus repository (https://energyplus.net/weather-location/europe_wmo_region_6/NLD/NLD_Amsterdam.062400_IWEC), based on the longitude and latitude extracted from the IFC file, is depicted in Figure 7. TMY data represent long-term, statistically derived hourly weather records constructed from multiple years of measured data to capture typical climatic conditions for a given site. This approach ensures that simulations reflect representative average-year weather patterns, making TMY datasets particularly suitable for evaluating the performance of renovation measures. By avoiding the influence of extreme or atypical weather events, TMY-based simulations provide a stable and comparable basis for assessing different design alternatives, allowing for more meaningful long-term performance evaluations.

Beyond building and environmental data, the simulation process also requires project-specific configuration parameters to adapt analyses to user-defined needs and computational constraints. These are managed through expert-defined configuration files written in JSON format, specifying parameters such as the simulation timestep, heat balance algorithms, convergence criteria, and output variables (Figure 8). These configuration parameters have been carefully selected after numerous simulations to achieve a balance between accuracy and computational complexity. For computational efficiency, only the minimum set of output variables required for the energy KPI calculations is activated, ensuring that simulation runs remain manageable while maintaining the analytical depth necessary for performance evaluation.


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Figure 8: Subset of the "Other parameters" in JSON format for achieving a balance between accuracy and computational complexity

Building renovation and smartening measures: The Energy Conservation Measures (ECM) and Smart Readiness (SR) Products Catalogue serves as a repository of renovation actions and smart technologies that can be applied to building models to support energy performance and smart readiness evaluation. This catalogue underpins the What-if Scenarios Generator and provides the data needed for both energy performance and smart readiness evaluation. At the data model level, both renovation measures and smart products are represented through a common schema, ensuring that the application of interventions is consistent, traceable, and reproducible across projects.

The ECM subset of the catalogue includes a broad range of passive, active, and renewable measures. Passive measures focus on improving the building envelope to enhance thermal performance and reduce energy losses, including wall, roof, and glazing improvements. Active measures target the efficiency of mechanical systems, such as high-efficiency boilers and heat pumps, while renewable measures introduce on-site generation technologies, including photovoltaic systems. Each measure includes relevant metadata, such as expected impacts on energy performance, applicability conditions, and life-cycle considerations, enabling informed evaluation and prioritization of renovation scenarios.

Smart Readiness Products extend the same framework by introducing automation, sensing, and control functionalities that enhance the digital intelligence of the building and align with the SRI framework. These products capture the presence of smart technologies such as adaptive thermostats, predictive control systems, and automated shading, providing the information necessary to evaluate their influence on building performance and smart readiness. Each SR product entry includes metadata describing its functionality domain, impact areas, and expected enhancement of smart capabilities. This structured approach ensures interoperability with other EESDT tools and supports consistent, reliable assessment of both energy performance and smart readiness.

By consolidating both traditional renovation measures and smart technologies within a single, standardized catalogue, the EESDT platform enables stakeholders to explore, simulate, and evaluate building improvement scenarios in a systematic and transparent manner, supporting data-driven decision-making for sustainable design and renovation.

2.2 EESDT Core Components

Building upon the data sources described earlier, the EESDT is structured around six interconnected core components. Together, these components ensure that digital building models are transformed into reliable energy performance simulations and renovation scenarios, supporting evidence-based decision-making. While the overall workflows for baseline and what-if scenarios have already been outlined in the architecture section, this subsection explains the function of each component in more detail and highlights how they interoperate.

IFC Model Checker: The IFC Model Checker is the first component in the EESDT workflow and is responsible for verifying that all uploaded BIM models contain the data required for subsequent energy performance simulations and smart readiness assessments. It ensures that IFC files meet the project's minimum data requirements, data structure conventions, and interoperability standards before they are used in scenario generation and analytical processes. By performing this initial quality check, the Model Checker guarantees that only complete and consistent models progress to subsequent steps, reducing the likelihood of errors in energy simulations and smart readiness evaluations.

The tool defines the required data schema for compliant models, specifying the types of entities, attributes, and property sets that must be present. Uploaded BIM models are automatically checked against these requirements, and a structured report is generated summarizing the model's compliance, highlighting any missing or inconsistent data, and providing guidance for corrective actions. This approach ensures that all models entering the EESDT workflow are simulation-ready, standardized, and interoperable, supporting reliable, reproducible, and transparent analyses. By integrating automated validation into the platform, the IFC Model Checker provides a robust foundation for data integrity, enabling stakeholders to trust the quality of input models and the results derived from them.

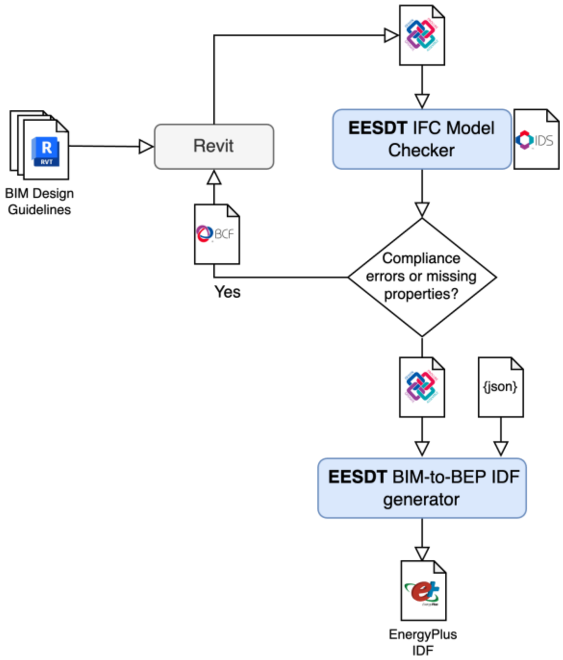

Figure 9: The role of the IFC Model Checker in the EESDT

An example of a validation report for the Dutch pilot is depicted in Figure 10.

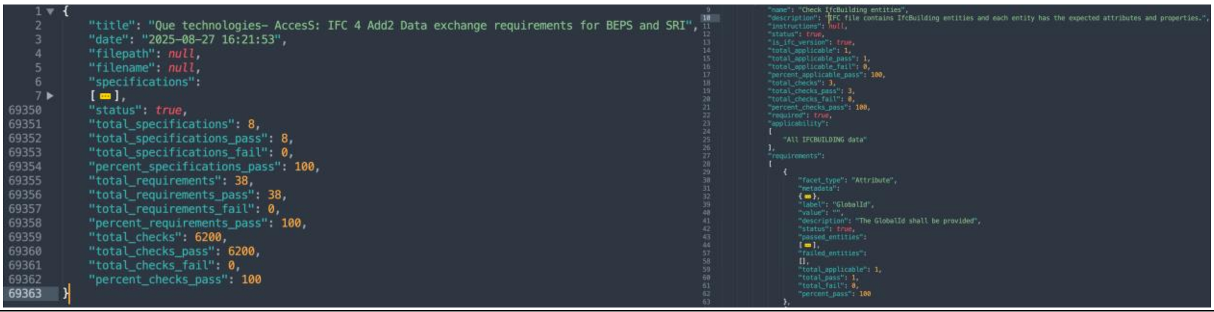

Figure 10: Validation report for the Dutch pilot – summary (left): 6200 total checks, all passed, meaning that uploaded IFC is valid; drill in the IfcBuilding specification (right)

Baseline Scenario Generator: The Baseline Scenario Generator, introduced in Figure 2, is a core component of the EESDT platform responsible for creating an initial energy simulation model of a building based on the information contained in the uploaded BIM file. When a user submits a model through the EESDT interface, the system analyses the building's geometry, semantics, and location metadata to identify its characteristics and context. The generator automatically retrieves the relevant climatic data for the building's location to ensure that the environmental conditions used in the simulation accurately reflect real-world conditions.

Once the necessary data is collected, the generator initiates the baseline simulation workflow within the EESDT core environment. This process establishes the reference model that underpins subsequent energy performance and smart readiness analyses, serving as the foundation for all comparative scenario evaluations within the platform.

BIM-to-SRI Calculator: Traditionally, assessing a building's SRI has relied on manual checklists, surveys, and expert interviews, which can be time-consuming, subjective, and inconsistent. The BIM-to-SRI Calculator introduces a digital, model-based approach to automate this assessment using BIM.

By analysing digital representations of buildings, it evaluates the smart readiness of technical systems such as heating, cooling, energy storage, and control devices. Unlike conventional methods that assign a single level to an entire system, this approach provides equipment-level insights, showing both the main functionality level and any additional advanced capabilities present in a building. This allows stakeholders to understand where and how smart features are implemented, rather than only whether a system is "smart" overall.

The methodology works with standard BIM models and does not require additional manual annotations, making it scalable, interoperable, and compatible with existing design and delivery workflows. The assessment begins with the extraction of relevant building systems and components from the digital model, which are then evaluated according to predefined criteria reflecting smart control capabilities and responsiveness. Results are aggregated for each service to highlight the dominant smart readiness level and any higher-performing subgroups, and a structured report is produced containing building information and assessed SRI levels for each system.

The generated data is stored in a centralized management system and presented through a user-friendly interface, enabling building owners, designers, and facility managers to make informed decisions regarding building operations, upgrades, or renovations. This approach provides automated and objective evaluation, fine-grained equipment-level insights, and works entirely with standard BIM data without additional manual effort, supporting informed decision-making for building operations and smart upgrades.

BIM-to-BEP Simulator: The BIM-to-BEP Simulator is a core component of the EESDT platform that enables the transformation of openBIM data into simulation-ready energy models and the automated execution of building performance simulations, providing a fully integrated workflow that links digital building models with advanced simulation tools to generate KPIs consistently and efficiently. Developed using widely adopted programming standards, the simulator establishes the analytical connection between BIM-based models and the EnergyPlus simulation environment, automating the process from model transformation to performance evaluation and allowing users to obtain reliable energy indicators directly from standardized building data. It interprets and structures geometric, material, and system information contained in BIM files to create accurate baseline models of buildings, ensuring that the physical characteristics of the building, including its envelope, internal spaces, and technical systems, are correctly represented in the simulation environment, which guarantees consistency between the digital model and the real building while enabling automated, reproducible analyses. The simulator then performs energy performance simulations using validated numerical models, automatically incorporating local climate data based on the building's geographical information and running simulations to assess energy consumption, system efficiency, and KPIs such as heating and cooling demands, electricity and fuel use, and renewable energy contributions. All results are compiled into a standardized output format and transferred to the EESDT Data Management component, where they can be accessed and visualized within the EESDT user interface through interactive charts, tables, and reports. By automating the entire workflow from BIM data interpretation to energy simulation and reporting, the BIM-to-BEP Simulator streamlines the assessment of building performance, supporting transparent, data-driven decision-making for sustainable renovation and design while reducing manual effort and maintaining consistency, accuracy, and traceability across all analytical stages.

What-If Scenarios Generator: The **What-If Scenarios Generator**, introduced in Figure 3, is developed to support evidence-based decision-making for building renovations. The workflow begins with the EESDT ECM & SR Catalogue, which provides a structured JSON hierarchy of renovation measures organized into four categories: passive measures such as insulation, active measures such as HVAC systems, renewable energy systems, and control strategies such as smart thermostats, as aforementioned. These options are presented through the UI, where end-users can select their preferred renovation strategies. Once the user inputs are received, the What-If Scenarios Generator compiles all feasible combinations of the selected renovation measures, with each combination represented as a discrete renovation scenario in JSON format. These scenarios are returned to the UI for review and selection and are also translated into corresponding IFC models to ensure semantic consistency and interoperability. Following the generation of the renovation IFC files, the workflow proceeds in the same manner as the baseline simulation process. Each IFC model is transformed into the necessary input files for both the SRI Calculation Engine and the BEPS Engine. These engines run simulations for every renovation scenario, producing KPI results that quantify both energy performance and smart readiness. The generated KPIs are stored in the EESDT Data Management component.

Decision Support Engine: The **Decision Support Engine (DSE)** forms the analytical core of the EESDT platform, supporting the evaluation and ranking of building renovation scenarios across multiple performance dimensions, including energy efficiency, cost, and smart readiness. By consolidating outputs from other EESDT analytical modules, the DSE enables a comprehensive assessment of how different renovation strategies perform from technical, economic, and sustainability perspectives. Designed to promote evidence-based and transparent decision-making, the DSE provides users with clear insights into the trade-offs between renovation options, helping identify strategies that align with both performance objectives and policy priorities. Its analytical workflow ensures objectivity, reproducibility, and interpretability, supporting reliable and informed choices in the planning and evaluation of sustainable building upgrades. Developed entirely in Python, the DSE operates as an independent microservice within the EESDT backend. It retrieves normalized scenario data from the Data Management module, executes the multi-criteria evaluation process, and produces structured outputs that summarize scenario rankings and performance relationships. These results are made accessible to the EESDT user interface, where they can be visualized through interactive graphs, tables, and dashboards.

From a computational standpoint, the DSE is already fully integrated and operational within the EESDT backend environment. Its analytical components, data exchange mechanisms, and result-generation workflows are complete and functional. Updates also as part of the integration to the Suite will be focused on designing and implementing interactive visualization and control features that make complex multi-criteria results—such as performance rankings, trade-off analyses, and efficient scenario sets—more intuitive and user-friendly. Planned interface functionalities include interactive plots, dynamic weighting controls, sensitivity sliders, and scenario comparison dashboards. These enhancements aim to make the decision-support process more transparent, accessible, and engaging for users with varying levels of technical expertise.

By combining computational robustness with ongoing advancements in interactivity and visualization, the DSE contributes to a more transparent, data-driven, and user-centered approach to sustainable renovation decision-making within the EESDT platform.

2.3 EESDT User Interface

This section provides a comprehensive walkthrough of the EESDT user interface, guiding the reader through the main functionalities required to operate the tool effectively. The walkthrough begins with project setup, then explains how to access and manage existing projects, before presenting the main interface layout and its core features. It then presents the key components of the interface, including navigation features, the model tree, baseline and renovation simulation functionalities. Following this structured overview, users gain a clear understanding of how to interact with the EESDT environment and make efficient use of its core capabilities.

It should be noted that user authentication is not part of EESDT itself. Instead, authentication will be delivered through the Universal Access Suite under Task 7.2 *Access Inclusive Toolbox – Integration of Components* (M12–M22, M30–M32), which will provide a single sign-on mechanism.

Project Selection: As illustrated in Figure 11, the tool provides a clear and intuitive interface for selecting a project. The process begins by selecting one of the available projects through a gallery view where projects are represented by a thumbnail under the *"Select from available projects"* icon. This visual representation enables quick identification of the desired project.

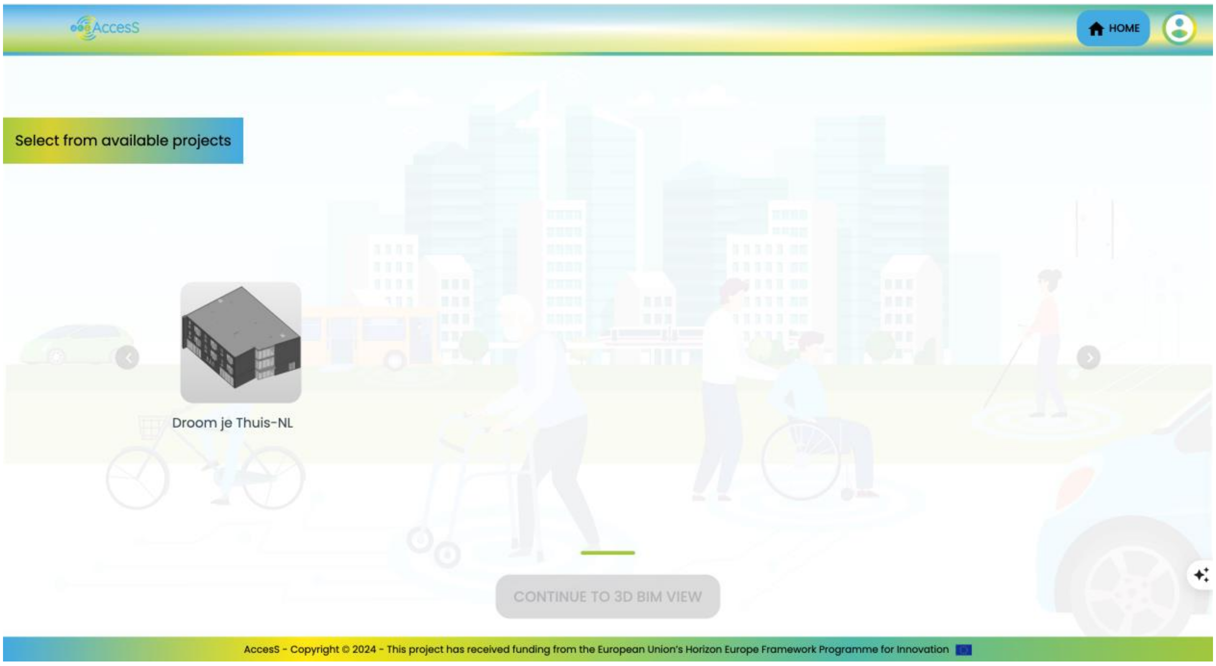

Figure 11: Interface view showing the pilot project selection process (no project selected)

Selecting a project is as simple as clicking on the corresponding thumbnail. The chosen project is then highlighted (Figure 12), providing clear visual confirmation and reducing the risk of selection errors.

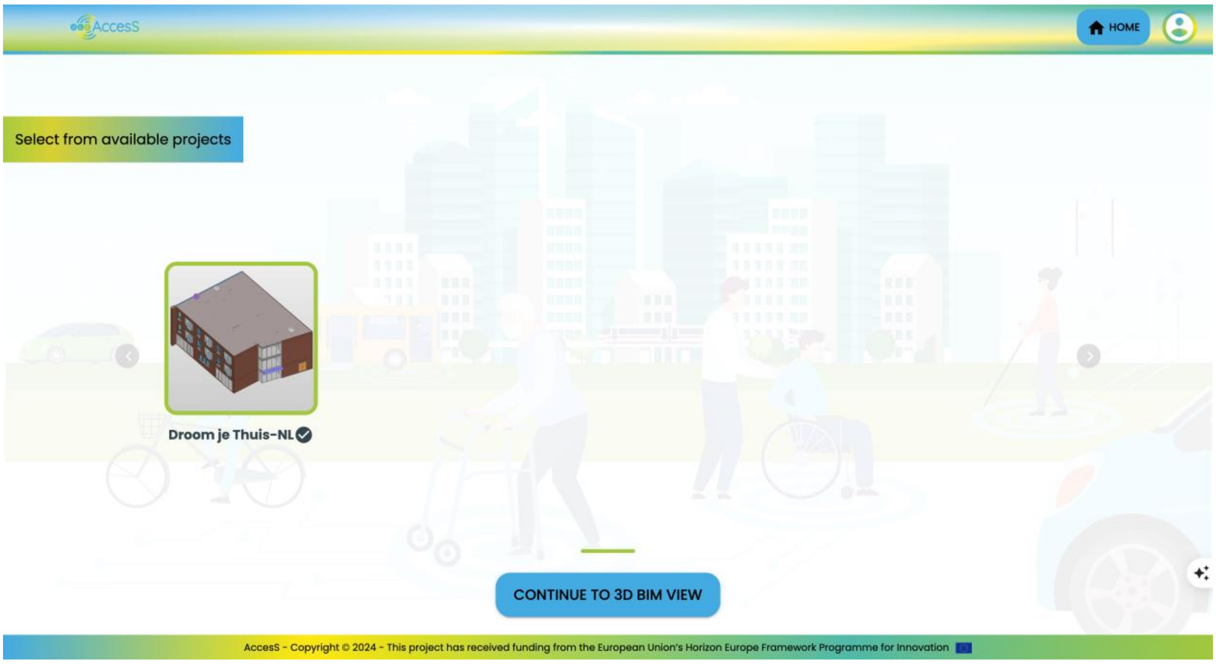

Figure 12: Interface view showing the pilot project selection process (project selected)

After selecting one of the projects, the user should press the *"CONTINUE TO 3D BIM View"* button. When the button is pressed, its colour changes from blue to yellow (Figure 13).

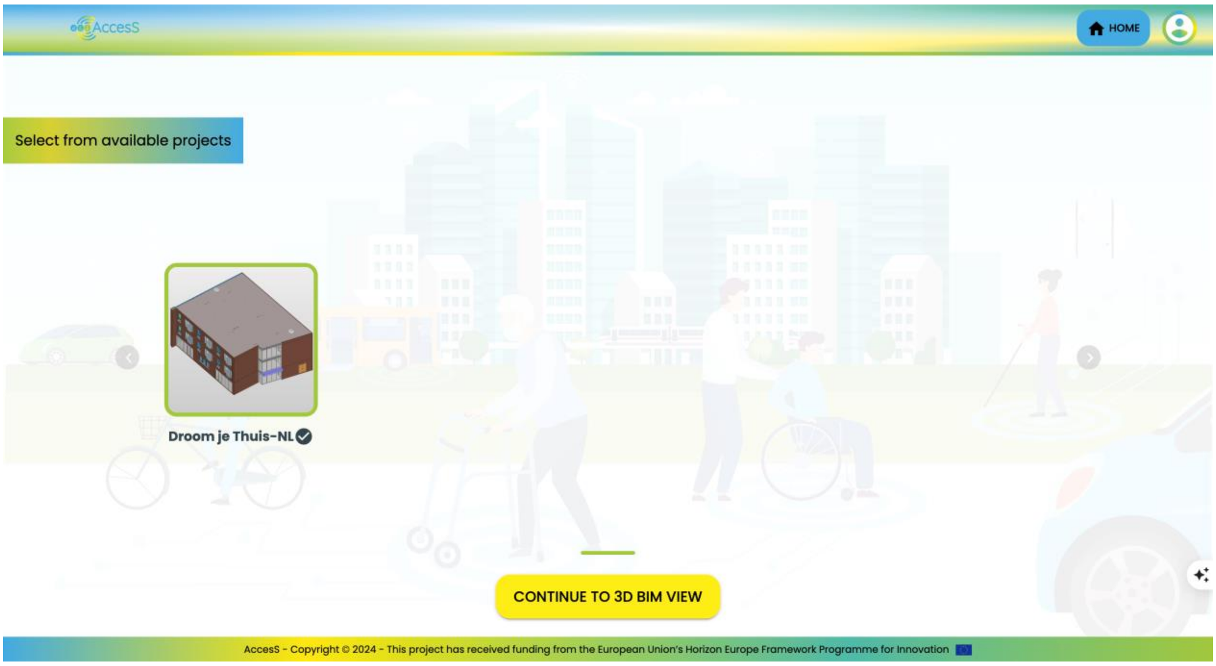

Figure 13: Interface view showing the pilot project selection process (project selected and *"CONTINUE TO 3D BIM View"* button pressed)

Overview of the User Interface and Core Features: Once a project is opened (e.g., the Droom je Thuis, Netherlands pilot), the EESDT application layout becomes accessible, as shown in Figure 14. The design prioritises efficient navigation and seamless interaction with project data. In the top-left panel, three main options are available: Model Tree, Baseline, and Renovation. These serve as entry points to different aspects of the project and are explained in the following subsections. On the bottom panel, several functional controls enhance usability: Search allows quick location of elements, Properties displays additional information about the selected element, Element Focus adjusts the view to the selected element, and Camera Reset restores the default perspective.

Figure 14: Interface layout after project selection

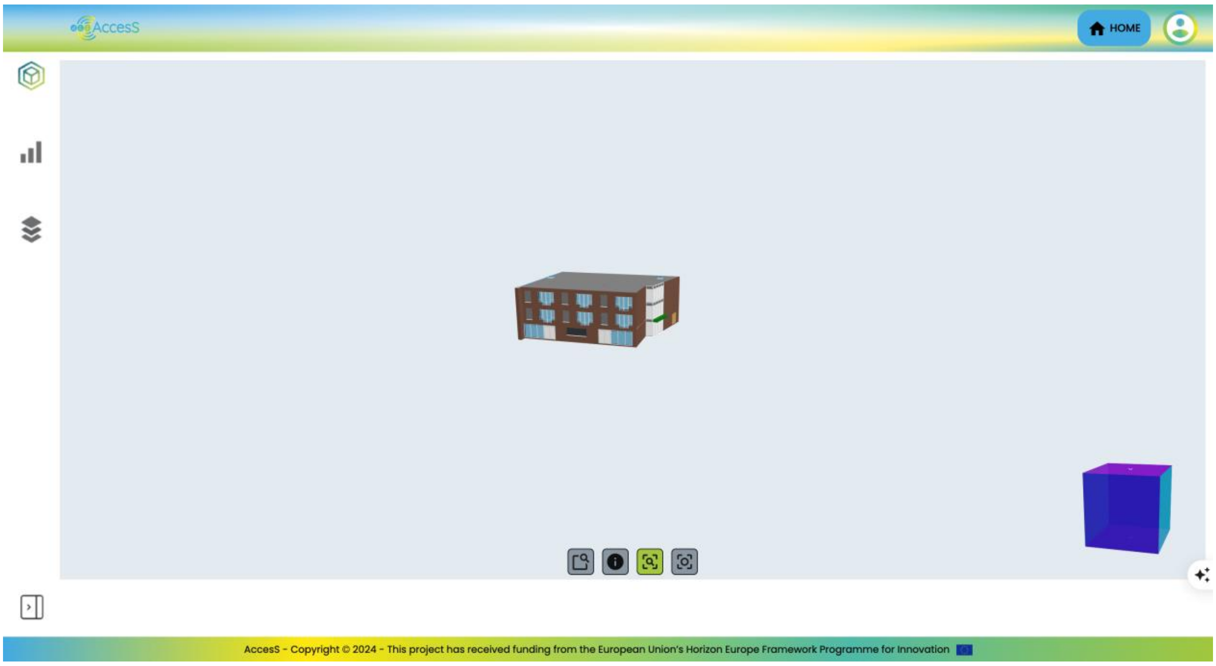

Figure 15: Full-screen mode of Interface layout

For enhanced exploration, users can activate a full-screen mode (Figure 15) that provides immersive and distraction-free views of the building model. This functionality is particularly useful for presentations and in-depth analysis.

Model Tree Structure and Functionality: The Model Tree provides a structured representation of building elements within the application, enabling efficient navigation through different components. When the IFC file is expanded (Figure 16) the categories *"BuildingElement"*, *"Covering"*, *"IFCFLOWTERMINAL"*, *"Member"*, *"Plate"*, *"Space"*, *"StairFlight"* appear in the left panel, while the central screen presents a 3D model of the building to give visual context of the selected elements.

Figure 16: Model Tree with expanded Building Element

The *"BuildingElement"* category can be further expanded (Figure 16 and Figure 17) to reveal subcategories such as *"BuildingElementProxy"*, *"Railing,"* and "Roof" allowing users to explore specific building elements in more detail.

Figure 17: Model Tree with expanded BuildingElementProxy within BuildingElement

The application also includes **visibility controls** (Figure 18 and Figure 19). Users can hide all elements, leaving a blank screen, or isolate specific elements such as doors. This functionality helps declutter the view and focus on components of interest.

Figure 18: Interface View with all elements hidden (“Hide all”)

Figure 19: Interface View with isolated elements (doors only)

Search and selection tools further support navigation (Figure 20). A query, such as for "masonry", quickly identifies relevant elements. When an element is selected and the "Element Focus" button is activated (further explained below in the "Navigation within the User Interface" section), the interface focuses on it in the main view (highlighted in yellow colour) while displaying a list of matches in the side panel. This provides immediate feedback and context for the user.

Figure 20: Search for a building element (window)

When hovering over a wall, their colour changes to green, signalling readiness for selection (Figure 20). Once selected, the colour changes to yellow, and the corresponding details appear in the Properties box , accessed through the *"Menu Properties"* button (Figure 21).

Figure 21: Properties box displaying properties of a selected wall

Figure 22: Properties box repositioned on the screen

Moreover, the Properties box itself is flexible (Figure 22) and can be repositioned on the screen. This adaptability supports a more personalised workflow and enhances overall usability. Finally, by scrolling down in the Properties box, it is possible to access more information about the properties of the selected element.

Navigation within the User Interface: As illustrated in Figure 23, the EESDT user interface provides a detailed three-dimensional (3D) view of the building model. Navigation within the 3D scene is supported by the Pan mode, located in the central part of the screen below the search bar.

Figure 23: 3D Building Model Navigation in the EESDT User Interface

This mode enables users to move and visualise the building interactively, with zoom functionality controlled via the mouse wheel. To move the model, users hold down the left mouse button while moving the mouse, whereas zooming is performed by scrolling.

The bottom bar contains additional display options and tools. The first of these is the Search bar, which appears at the top centre of the screen. It includes a text field labelled *“Enter text to search”* along with *Search* and *Clear* buttons. By entering a term (e.g., “slab” or “window”), users can quickly locate specific building elements and visualise them directly within the 3D view.

Below the search function, the sidebar provides viewing and information tools. The Menu Properties button opens a box displaying the properties of a selected element. When no element is selected, the box remains empty (Figure 24), but once an element is chosen, the relevant details are displayed (Figure 25).

Figure 24: Properties Box when no element is selected

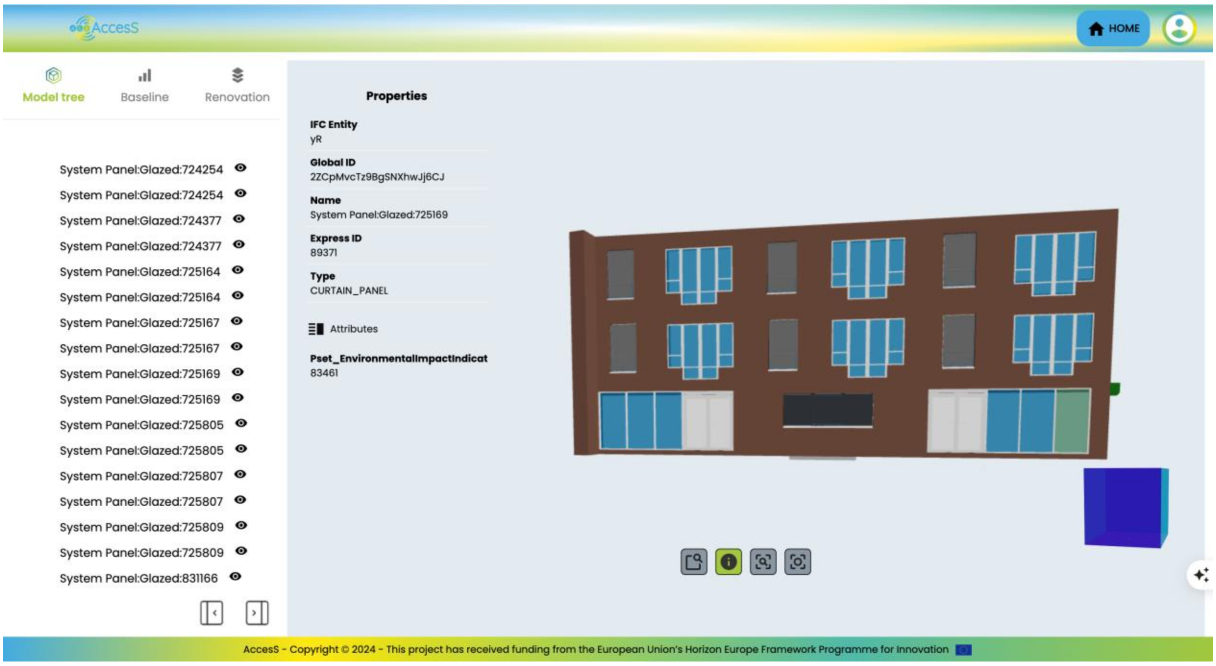

Figure 25: Properties box when a Curtain Panel is selected

The Element Focus button (Figure 26) allows users to centre the view and zoom directly onto a selected building element, ensuring precise inspection of specific components.

Figure 26: Element Focus for centring the view and zoom directly onto a selected building element

Finally, the Camera Reset button (Figure 27) restores the model to its default orientation and zoom level. This function is especially useful for returning to a standard overview of the entire model after navigating or zooming into details.

Figure 27: Interface view when "Camera Reset" button restores the model to its default orientation and zoom level

Baseline Simulation: The "Baseline" option, located as the third button on the left sidebar, enables users to perform an energy simulation of the building's initial condition (Figure 28). At this stage, a "Run simulation" button is displayed, accompanied by the message *"No available KPIs. Please run the baseline simulation"*, which signals that no results have been generated yet.

Figure 28: Interface view of Baseline Scenario before running simulation

Clicking the **"Run simulation"** button initiates the EnergyPlus baseline simulation. During execution, the interface updates to display a *"Processing…"* status message.

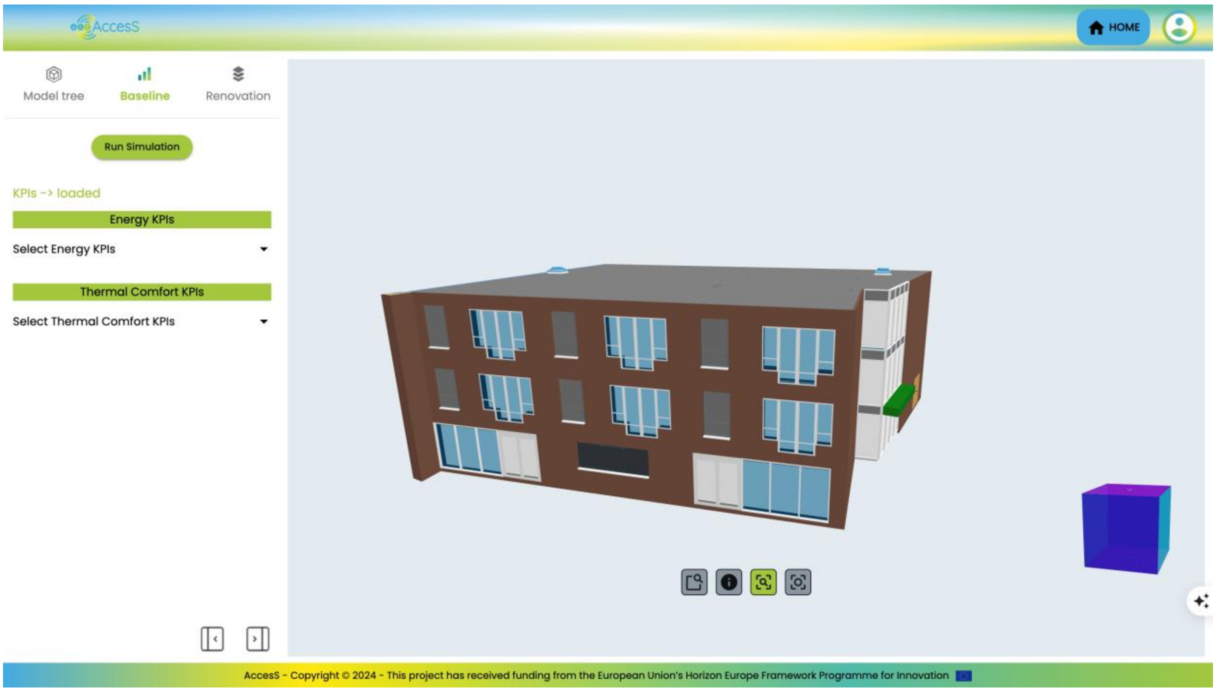

Figure 29: Interface view of loaded KPIs for baseline scenario

Once the simulation finishes and the energy-related and smartreadiness KPIs have been computed, the system updates the status message to *"KPIs -> loaded"* (Figure 29). At this point, users can explore the calculated results. A **dropdown menu** provides the list of available KPIs, along with tick boxes that allow users to select which indicators they wish to display (Figure 30).

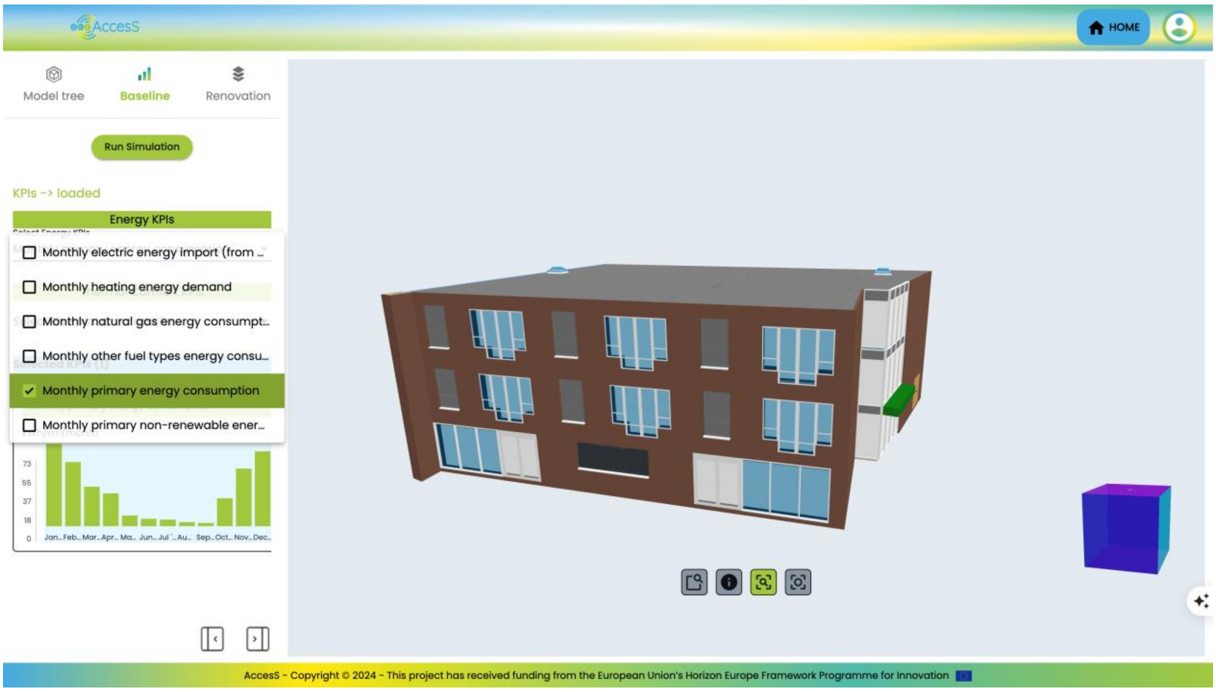

Figure 30: Selection of KPIs from Dropdown menu

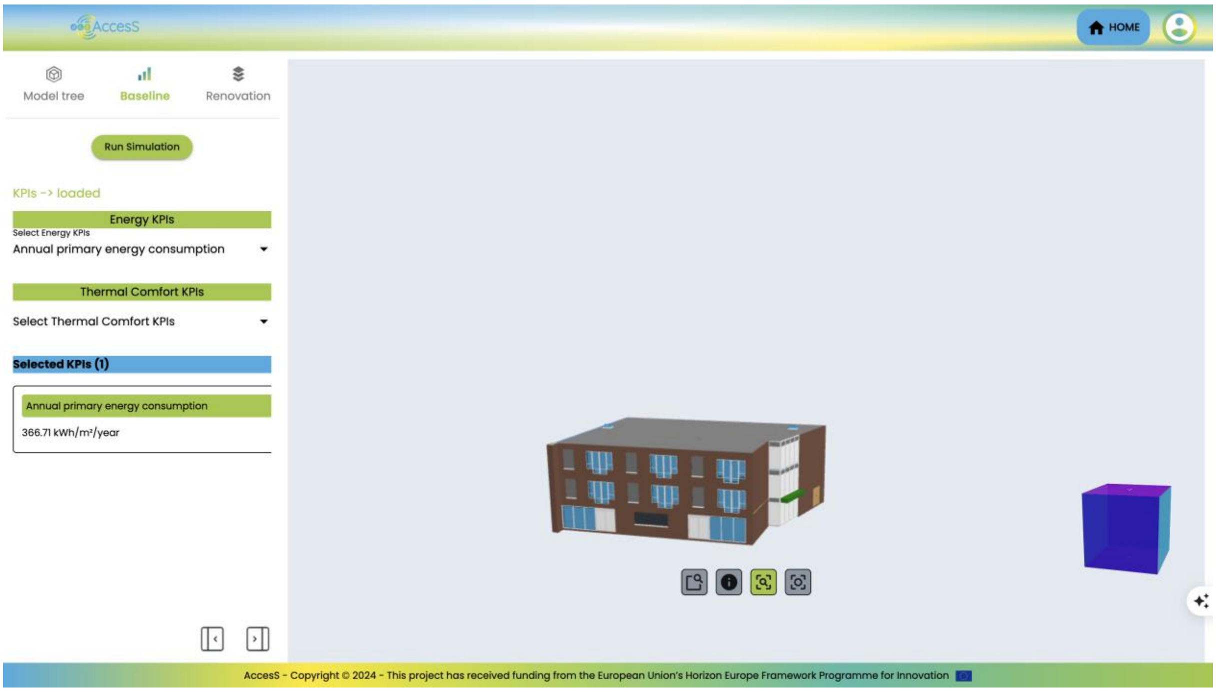

Figure 31: Calculated KPIs for the Baseline Scenario in single value format

Finally, when one or more KPIs are selected, their corresponding values are presented in the interface either as single values (Figure 31) or timeseries (Figure 32). This step completes the baseline performance evaluation workflow, giving users direct access to the quantitative outcomes of the simulation.

Figure 32: Calculated KPIs for the Baseline Scenario in timeseries format

Renovation – Measures Selection and Simulation: The final option on the left sidebar, labelled "Renovation", supports the definition of renovation measures and the evaluation of the building's performance under improved conditions (Figure 33). When this option is selected, two tabs become available: *Measures selections* and *Scenarios results*. In the example shown, the *Measures selections* tab is highlighted in green, signalling that the interface is currently focused on the definition of renovation actions.

Figure 33: Renovation module interface showing the 'Measures selections' tab, where users can select renovation measures from the ECM & SR catalogues

Renovation measures are selected from the structured JSON-based ECM & SR catalogue, allowing filtering by four categories: Passive, Renewable, Active and Control, reflecting the types of actions described in the *Data Sources* section of this deliverable (Section 2.1). Before running the simulation, the ”Scenarios results” tab shows the message “No renovation scenarios found” (Figure 36).

Figure 34: 'Measures selections' tab with the menu of Passive ECMs expanded.

Figure 35: ECM & SR selection

When a category is chosen, the system displays a list of available measures from which the user can select specific renovation actions (Figure 35). After selecting measures, the “Run simulations” button is activated. Upon pressing “Run Simulations”, the interface updates to show a *“Processing”* status message, indicating that renovation scenarios of different renovation measure combinations are being evaluated. At this stage, the system locks user selections and automatically generates corresponding IFC files for each scenario, which are then processed by the EESDT backend.

Figure 36: Scenarios Results tab before running What-if Scenarios Generator

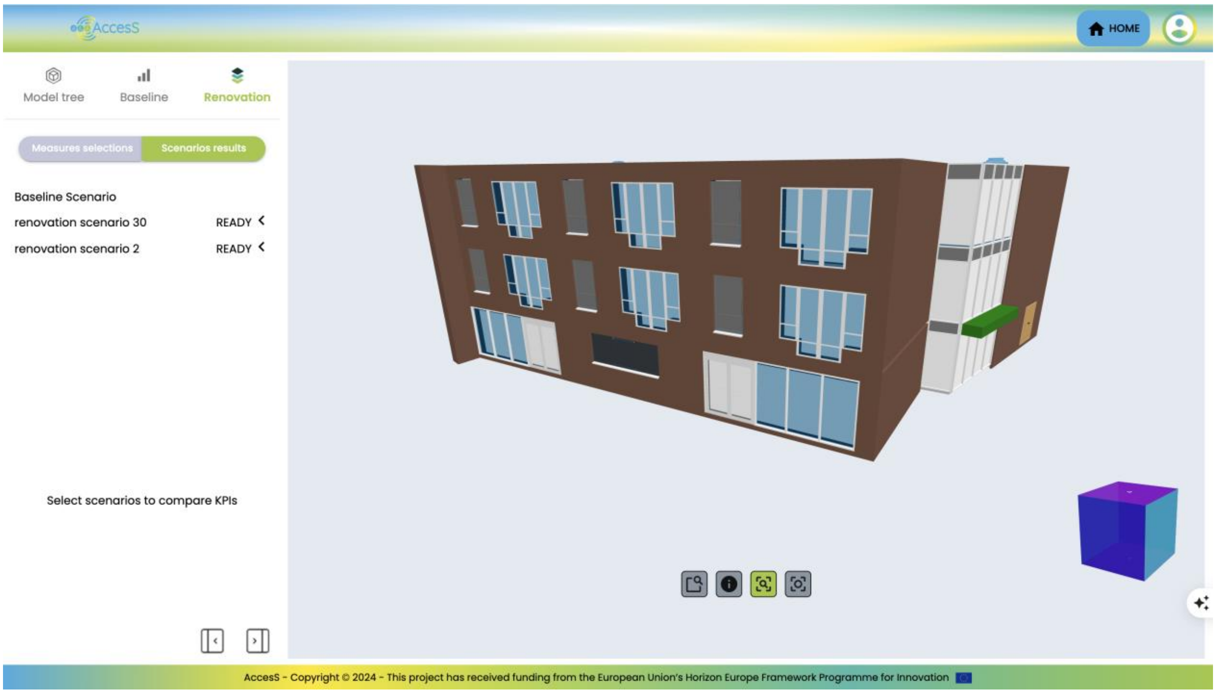

Figure 37: Scenarios results tab after simulations are completed

Once the simulation has been completed, the interface switches to the *Scenarios results* tab, where users can then review the simulation outputs corresponding to the selected renovation actions. The interface shows the Baseline Scenario and the Renovation Scenarios that are "READY" meaning that the analysis is complete (Figure 37). Users can expand the renovation scenarios to view the measure combination that corresponds to each simulated renovation scenario (Figure 38).

Figure 38: Expanded renovation scenario menu showing the description of measure combination for each renovation scenario

The UI also supports decision support functionality, enabling side-by-side comparison of baseline and renovation scenarios based on selected KPIs. Users are prompted to "Select Scenarios to compare KPIs" (Figure 37). Users can select to compare a baseline and a renovation scenario (Figure 39) or two renovation scenarios (Figure 40). Users can also press the right arrow on the bottom to expand the left side menu for better visualization of the results in the next steps. (Figure 39, Figure 40). Once the scenarios are selected as shown in Figure 39, it is possible to select "Energy KPIs" from a dropdown menu (Figure 41).

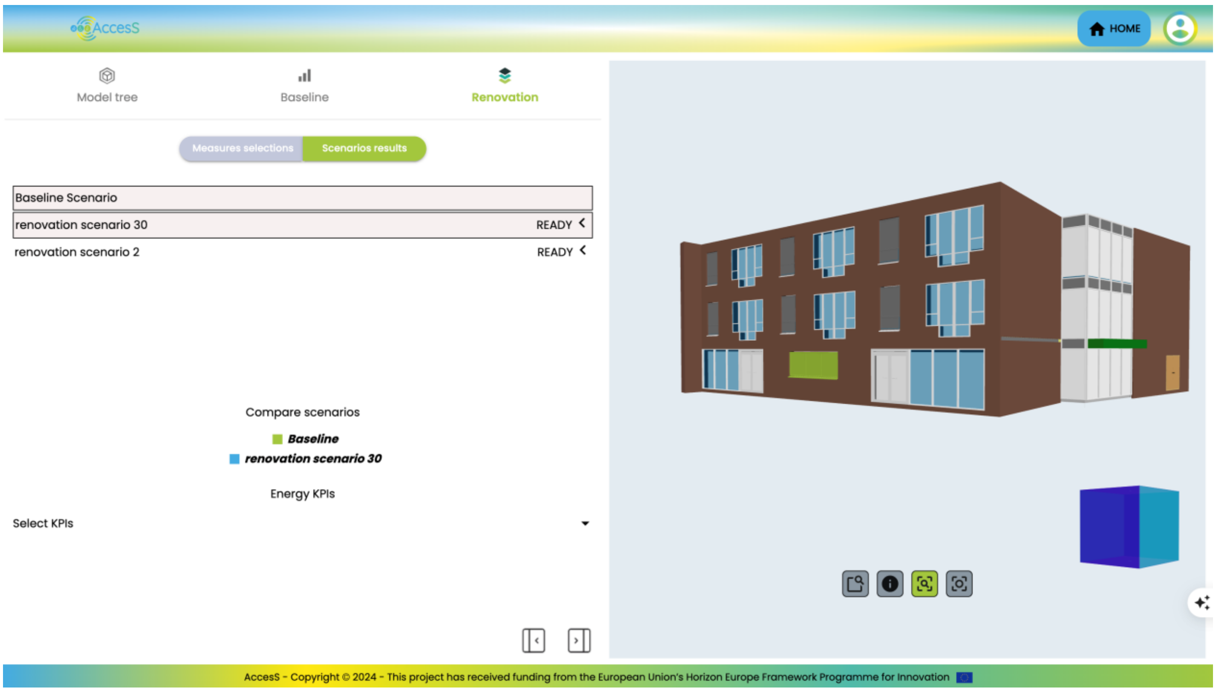

Figure 39: Selection of a baseline and a renovation scenario for KPIs comparison

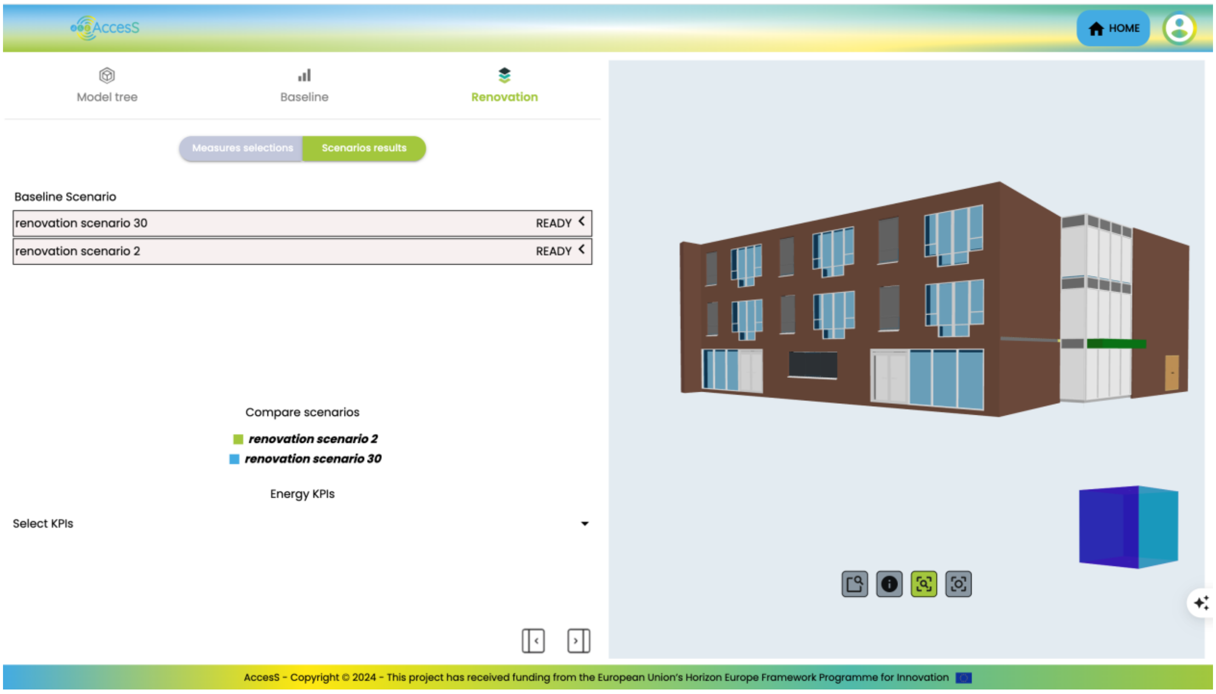

Figure 40: Selection of two renovation scenarios for KPI comparison

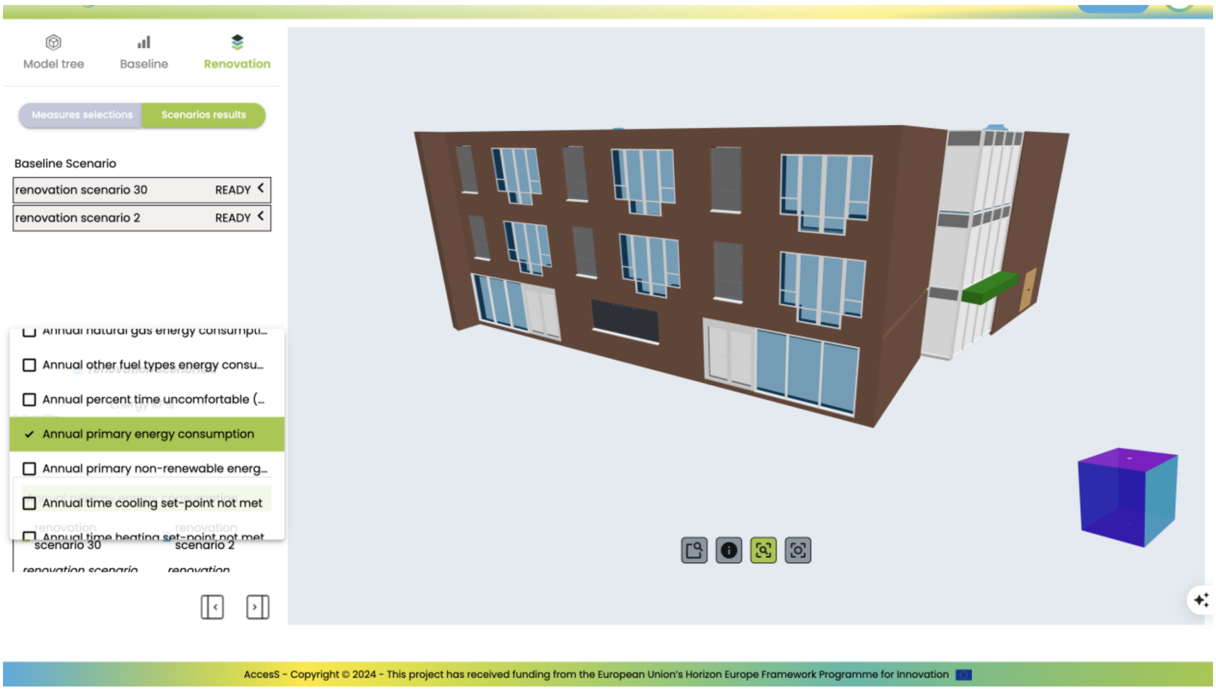

Figure 41: Selection of KPIs for which to compare the selected scenarios

Upon selecting the scenarios and the KPIs for which to compare, KPI results are visualised either as singe values for annual KPIs (Figure 42) or timeseries for monthly KPIs (Figure 43). When placing the cursor of the bar chart, a box appears showing the value of the KPI for the corresponding renovation scenario and month (Figure 43).

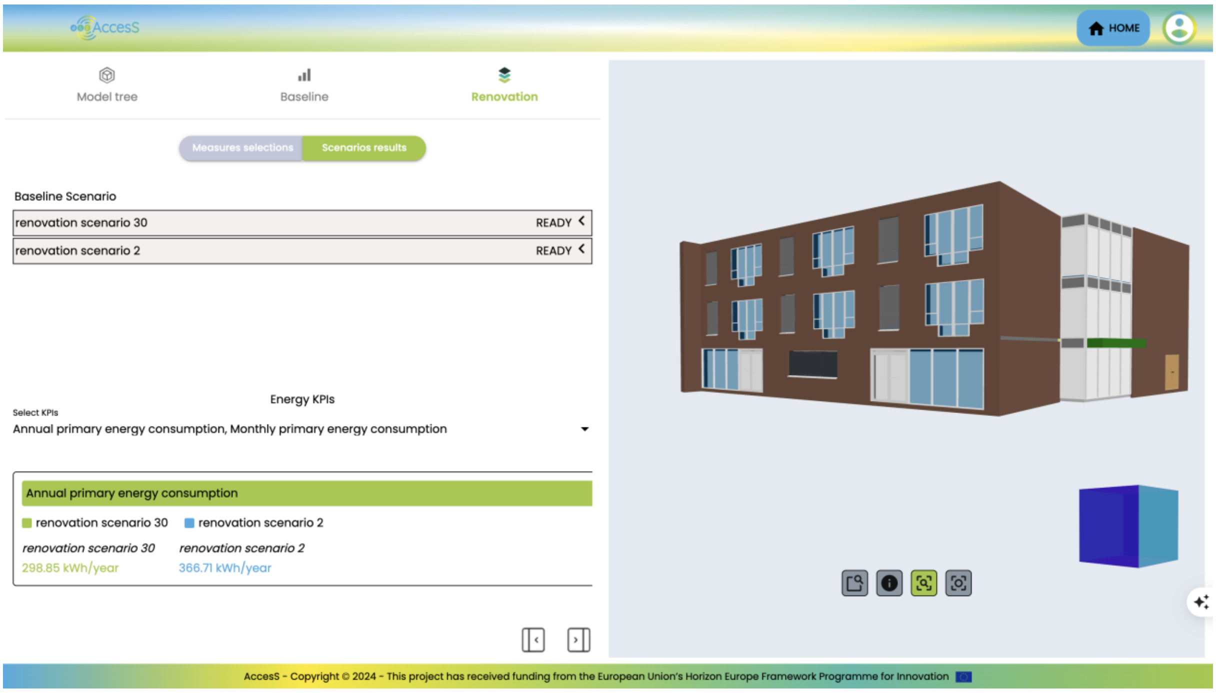

Figure 42: KPI comparison for selected scenarios. Results visualized as single values.

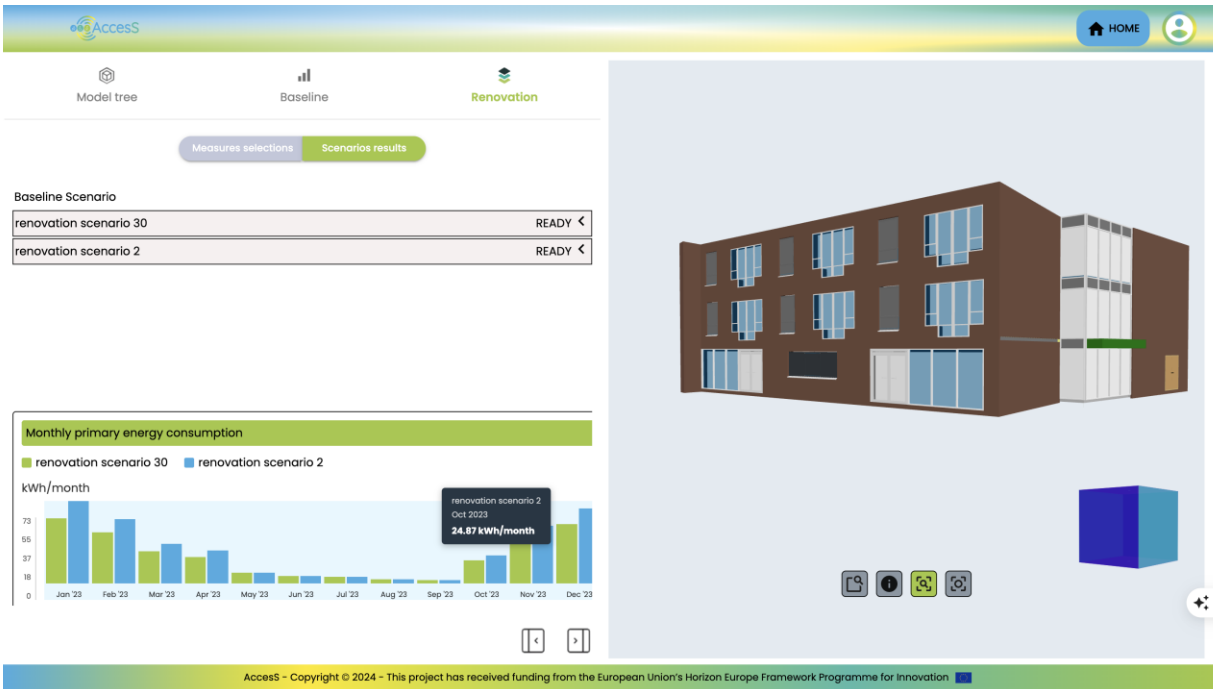

Figure 43 KPI comparison for selected scenarios. Results visualized as time series.

3 Conclusions

This report has presented the design, implementation, and current development status of the EESDT, prototyped and delivered under Task 4.1 of the AccesS project. Its content has summarised the work carried out between M5 and M17, emphasizing on the evolution of the EESDT from a conceptual framework to a fully functional prototype, which successfully integrates openBIM, energy performance simulation, and smart-readiness assessment workflows within a unified data management framework.

The EESDT has been implemented as a cloud-based SaaS application in our efforts to achieve scalability, maintainability, and straightforward access through the web. All backend components have been containerised to guarantee platform independence and reproducibility, while the web-based GUI has been designed to offer a practical environment for managing workflows, exploring renovation scenarios, and interpreting simulation and calculation results.

Methodologically, the EESDT has achieved a significant step towards accelerating and simplifying the evaluation of building renovation and smartification strategies. Utilising existing BIM data, the EESDT eliminates the need of developing separate input data models for energy performance simulation and smart readiness assessment from scratch. The BIM-to-BEP Simulator enables energy performance simulations for both baseline and what-if scenarios, while the BIM-to-SRI Calculator introduces a rule-based mechanism for determining smart-readiness levels, both directly from IFC models. Complementing these components, the Decision Support Engine adds a multi-criteria evaluation layer with the aim of selecting renovation options that achieve a balance between key objectives such as investment cost, energy efficiency, and building intelligence.

The progress achieved in Task 4.1 demonstrates the technical maturity, interoperability, and integration potential of the EESDT within the broader AccesS framework. Further development activities aligned with WP7 integration and testing activities are focused on refining the visualisation and UI features of the Decision Support Engine, improving the clarity of multi-criteria results, and preparing the tool for full integration within the Universal Accessibility Suite.

Therefore, D4.1 represents a significant milestone in the development of the AccesS digital toolset. It shows how openBIM principles, integrated simulation workflows, and decision-support techniques can be combined in a single framework to promote energy-efficient, intelligent, and inclusive renovation planning. The work completed so far provides a solid foundation for the next phases of validation, optimisation, and demonstration, supporting AccesS's overarching goal of achieving a greener, smarter, and more accessible built environment.

4 References

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