D4.4 D^2EPC Digital Platform

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D^2EPC Digital Platform

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Executive Summary

WP4 targets the development and integration of services for digital dynamic Energy Performance Certificates. This new approach linking digital data sources and services implementing the issuing EPC has been developed for the different services in the tasks 4.1, 4.2 and 4.3, also taking the GIS tool from WP3.

This deliverable D4.4 is the last of a series in WP4 and depicts the status of the developments of the digital EPC platform as per Nov. 2022. The feasibility to issue an EPC based on BIM data has been demonstrated, on the one hand for asset-based EPC and on the other hand based on the usage of meter readings for issuing an operational-based EPC. Other services described in D4.2 and D4.3 are detailed with regards to their integration in the D^2EPC platform. The deliverable shows both the options, either utilising the components/services as well as the portal demonstrating usage of platform components. The real implementation of the services is presented, as developed in the tasks 4.1 (asset-based EPC based on IFC files, and operational EPC including data quality assessment), 4.2 (roadmap, forecast) and 4.3 (benchmarking, verification and credibility, performance alerts, notifications) and additionally from task 3.2 holding EPC and GIS data.

This deliverable will be updated at the project end with adaptations and progress made applying the modules for the services at the pilot sites.

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List of Acronyms and Abbreviations

Term	Description
AI	Artificial Intelligence
API	Application Programming Interface
dEPC	Dynamic Energy Performance Certificate
DD	Degree Days (Temperature Difference Room-Ambient) multiplied by the time interval
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
GIS	Geographical Information System
HMI	Human Machine Interface
HVAC	Heating Venting Air Conditioning
IoT	Internet of Things
PEF	Primary Energy Factor, 'primary energy' means energy from renewable and non-renewable sources which has not undergone any conversion or transformation process (European Parliament 2010)
Platform	Environment in which a piece of software is executed
Portal	Site that functions as a point of access to information on the World Wide Web
UI	User Interface

1 Introduction

1.1 Scope and objectives of the deliverable

Task 4.4 features the development of the web platform that integrates all the services, amongst them those issuing EPCs. It includes all necessary interfaces and integration work ensuring that modules from WP4 tasks 4.1, 4.2 and 4.3 but also WP3 are interconnected. Part of the platform is the portal, the front end enabling assessors to issue dEPCs and users to see visual illustrations depicting building performance, benchmarking etc. The D^2EPC platform thus unites the software developed in the preparing tasks and shall use RESTful interfaces. Graphical user interfaces will be designed as (functional) mock ups.

The objective of the document is to specify the implementation of the D^2EPC portal, featuring the platform services showing mock ups. The services themselves were defined in the deliverable D4.1 presenting the building performance module, D4.2 presenting the roadmapping tool for performance upgrade of the building, the AI-driven performance forecasting, and the performance alerts and notifications and D4.3 presenting the building energy performance benchmarking and the energy performance verification and credibility tool.

1.2 Structure of the deliverable

The deliverable structures itself into three main parts targeting:

- Services
- Service integration
- Presentation in the portal

After an introduction, specifying the approach, the interfaces are described. For the visualisation for all services the requirements and the implementation are described. Finally, the integration in the platform is described. The services themselves can be accessed in a M2M setting also without using the portal.

1.3 Relation to Other Tasks and Deliverables

This deliverable bases itself on the preceding deliverables, namely the specification of the dEPC services in D4.1, D4.2 and D4.3, but also incorporates the Web GIS service from WP3. During the first half of the project some implementations were tested and here the actual status of the development is summarized. For the first time in the project the services are presented with their full functionality, in order to be integrated in the portal.

2 Background

2.1 System architecture

In D1.7 the system architecture was defined – see Figure 1. It includes four layers. Since the infrastructure and physical layer is different for the pilot facilities, there is an interoperability layer. For the project a joint singular data repository is foreseen where all the pilot's data is united. Services from the Service/Processing layer are retrieving data from this repository, amending with manual user input, when necessary. The pilot's data is harvested by the central data repository. The representation layer includes applications, which do have a different characteristic:

- Credibility UI – as tool to check system status and data quality
- Web GIS – as tool to get an overview of the EPC in a region
- D^2EPC Platform – to get insight into EPC of buildings.

Chapter 4 of this deliverable details the functionality as it is seen from the users end in the D^2EPC portal.

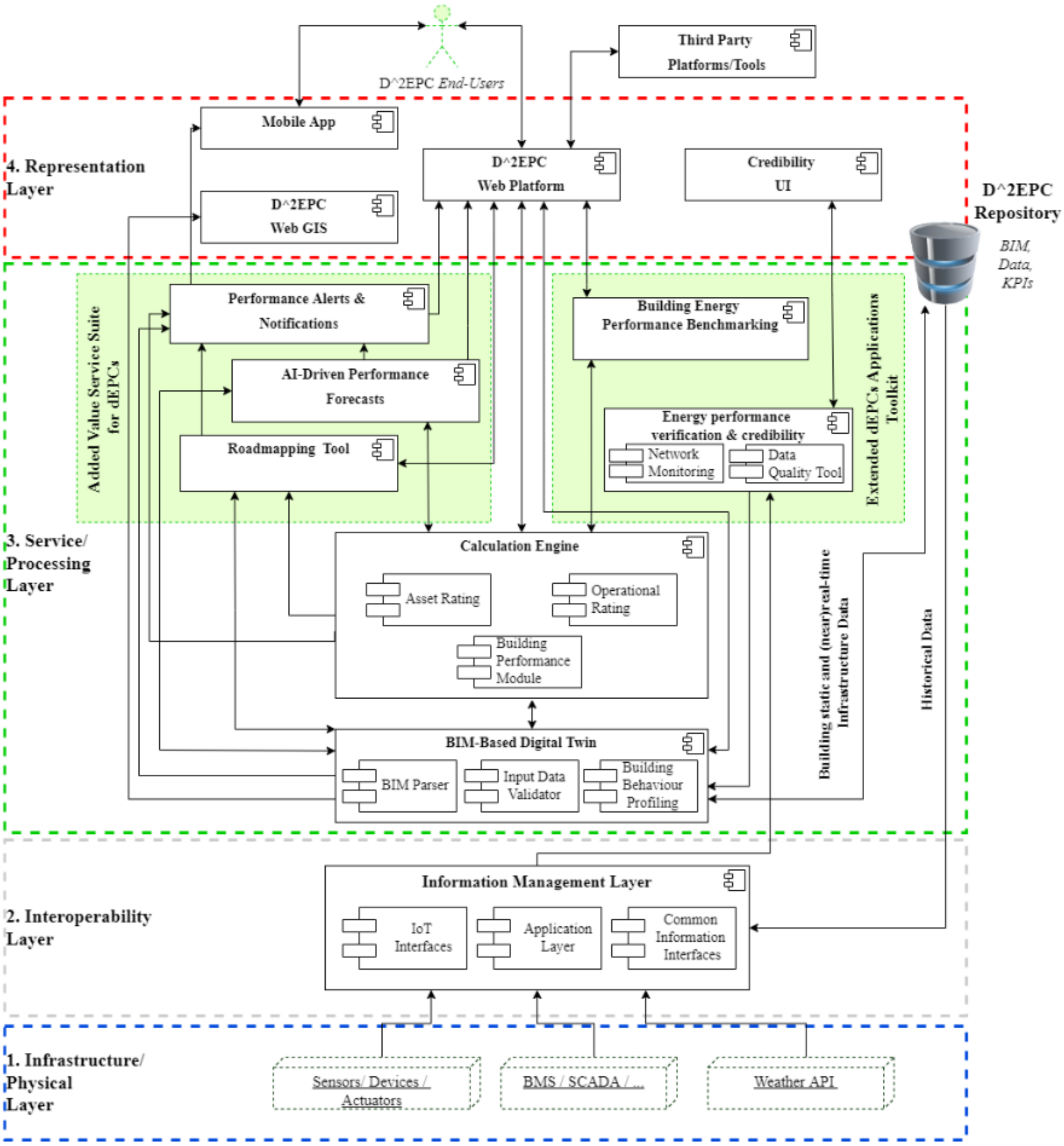


Figure 1. The Extended dEPC Applications Toolkit within D^2EPC

2.2 Strategic approach

2.2.1 System architecture

The actual IT landscape is dominated by portals. They offer functionality to users and arrange services along a vertically integrated value chain exposing only certain interfaces of third parties. The target is keeping people on the portal while monetizing all data which was disclosed. For a public service as EPC this would be acceptable but reduces the pace for innovation. There is an alternative concept comprising an open decentralised architecture (Sieker 2022) matching different requirements being agnostic to the nature of the client service.

EPC approaches differ in Europe. Some member states allow certified software from private developers, specific for single regions. The other extreme is a national state-controlled EPC system. So, D^EPC is committing to an approach, allowing both a central single portal utilising D^2EPC services and entities to integrate D^2EPC services into their applications. This would detail the system architecture into the following layered structure shown in Figure 2:

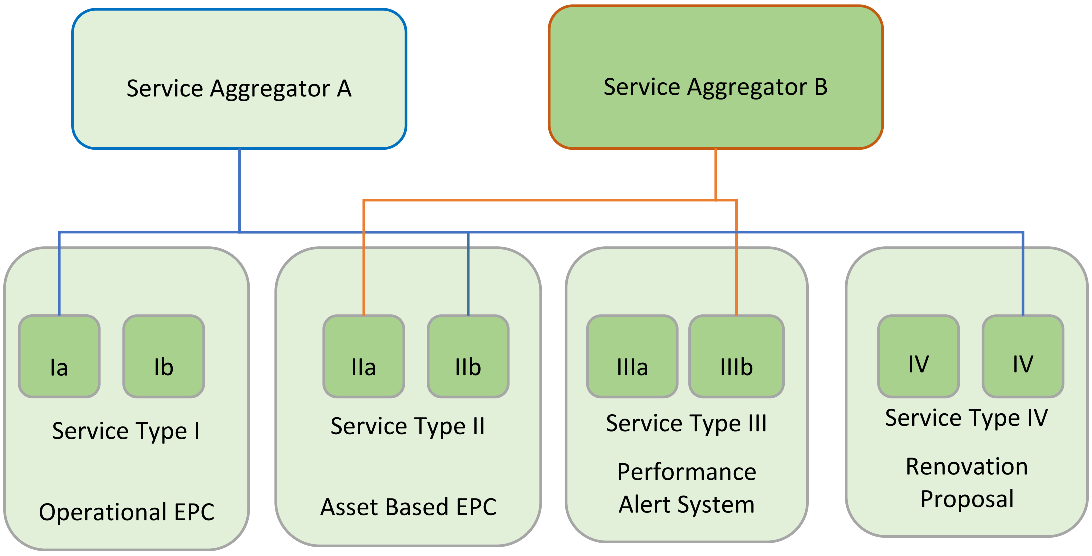


Figure 2 Layered D2EPC Service Usage

So called service aggregators are bundling desired services to a customized offer. Translating that to the concrete implementation we get the following approach, differentiating for the user groups/usage scenarios as shown in Figure 3. Each user group has access to the services of interest.

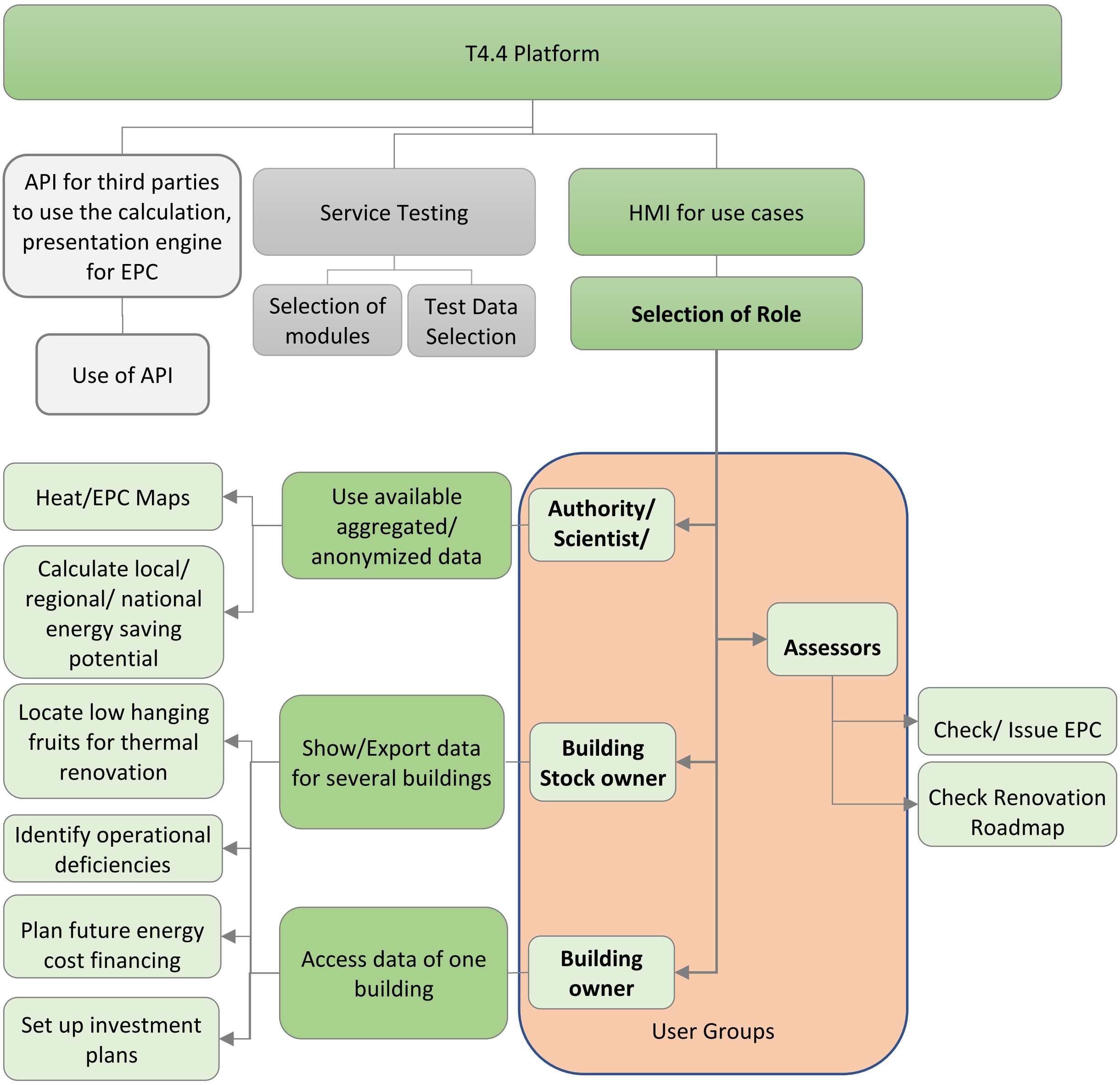


Figure 3 Functional System Architecture

In the best case, the aggregation of services is done via scripts pursuing a Low/Zero Code approach, but it is also possible using API via web interfaces from a Thin Client at the user's device (Javascript and HTML-forms).

2.2.2 Access to EPCs

For the project the use of the portal is the single-entry point. The functionality developed within the project D^2EPC is made accessible to different user groups. For some it is important to secure accessibility, so the services are used. While for professionals the access via bookmarks in browser is acceptable, access for citizens using QR-code is more convenient. This way links to the EPC may be read via Smart Phone Camera. This may relate to own buildings but also to view EPC for public buildings. Examples comprise energy labelling of product since 2021 (Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten kein Datum) and will be introduced in some regions in Europe for EPC for buildings too, according to personal information. For the project such QR usage is considered a feature of added value and might be demonstrated via manually web based QR-Generator.

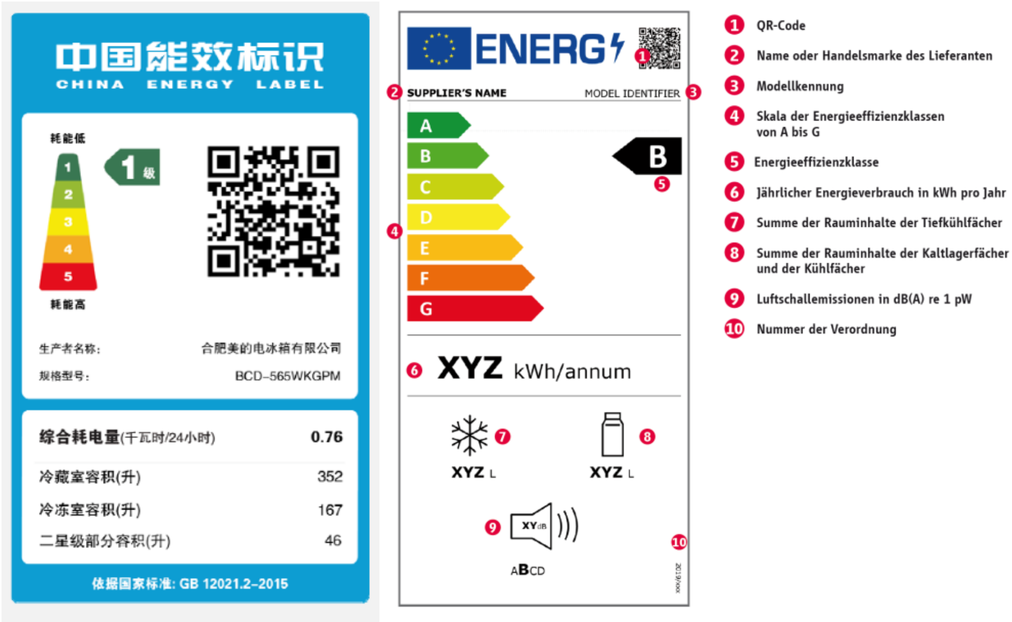


Figure 4 Examples for integration of QR-Code into energy labels

3 dEPC visualisation

3.1 Requirements

The services are aggregated for the different user groups. Dedicated services are developed standing for each component/tool of the D^2EPC architecture. The RESTful services should be accessible either directly by providing a proper interface or through a common services host. The API shall be defined for the endpoint in a common syntax as OpenAPI (formerly Swagger). The service shall be verbose returning syntax and error messages (unless it relates to authentication errors). For testing API services like postman, Postcode etc. could be used.

3.1.1 General Requirements

Within Task 4.4 the services developed in WP4 are integrated in one portal to be able to test them. To be able to test, the tools shall allow repeated usage with test data. This data stems from the pilot buildings and are including building data as IFC file if available and data streams from meters as minim requirement. Wherever necessary to test the full functionality manual input shall be possible to overcome deficiencies in automated data provision.

The functional requirements are given in the subsequent chapter. Summarizing for the non-functional requirements the tools shall:

Be easy to learn

Why: so new staff may start working after a short period of time
Fulfilled: if time needed for productive usage with briefing less than 2 hrs
Priority: not a criterion for the research prototype

Be sufficiently accurate in terms of assumptions for non-measured input

Why: to be able to present correct results to the users under all circumstances
Fulfilled: 10% deviation allowed
Priority: high (not very high since it is a research prototype)

Be reliable

Why: to be able to produce correct results, which might be reproduced, issuing EPC later with the unchanged building
Fulfilled: follow calculation rules and take the right units
Priority: high (not very high since is a research prototype)

Allow credibility checks by the assessor

Why: to be able to present correct results
Fulfilled: if several types of checks are possible
Priority: high (not very high since it is a research prototype)

Be highly accessible

Why: allow diffusion of the approach
Fulfilled: low installation or usage requirements
Priority: medium, since research prototype

Be applicable to the EU building stock

Why: targeting comparable EPC in the EU. The EPC shall be issued for all pilot buildings in the project
Fulfilled: same rating for buildings of different construction type but same energy demand
Priority: medium (not very high since it is a research prototype)

Have acceptable Performance

Why: to ensure high usability
Fulfilled: if 1 sec answering time is achieved
Priority: medium (since it is a research prototype)

Have good usability

Why: allow usage by visually impaired
Fulfilled: high color contrast, larger font size, help system…
Priority: medium (since it is a research prototype)

Feature heartbeat check in management console

Why: check uptime of the tools/data acquisition
Fulfilled: available
Priority: low (since it is a research prototype)

Be interoperable to be used in a portal

Why: the calculation engine is to be used in other tools
Fulfilled: if input data is provided via API (GET, POST) and the result is transferred back (as JSON)
Priority: high

In the prototypical environment the most important requirements focus on the ability to demonstrate functionality.

3.1.2 Requirement for the testing bed in EPC

The main requirement for the D^2EPC portal is to show new functionality in a pilot environment to be able to evaluate feasibility and acceptance. This comprises the following main characteristics:

- Asset based EPC:
  - Use of IFC files to compile the EPC with fewer manual input and less errors
  - Better basis for setting up calculated and optimized renovation plans by using IFC files.
- Operational EPC
  - Usage of metered data acquired via API to reduce errors and allow smaller time intervals between issuing operational EPC. Also, if degree day data is available earlier, the EPC can be more up to date. A delay of one week seems to be acceptable.
  - Energy monitoring component being able to introduce more indicators stemming from automated data acquisition, ability to measure influencing factors like occupancy and room temperature where possible (in public buildings)

Details on the functionality may be found in D4.1, D4.2 and D4.3. For the concrete implementation we must differentiate between public or demonstration buildings with existing SCADA systems providing data and typical residential buildings, where the digitalization is possible, but must be fought for negotiating with building owners and measuring service providers or energy providers.

3.1.3 Integration challenge

Measurements in apartments have been challenged by privacy concerns in the residential buildings and are made technologically difficult because of WLAN attenuation. So, the wish to normalize the energy demand by correcting for the room temperature and the occupancy seems not to be achievable for the moment and needs a new attempt from legislation embedding in the billing of the heating/cooling consumption. Usage of average monthly values seem to create less opposition. So, for the usual case that EPC are issued for buildings, we envisage the following system architecture shown in Figure 5 for the pilots to be considered in a productive system.

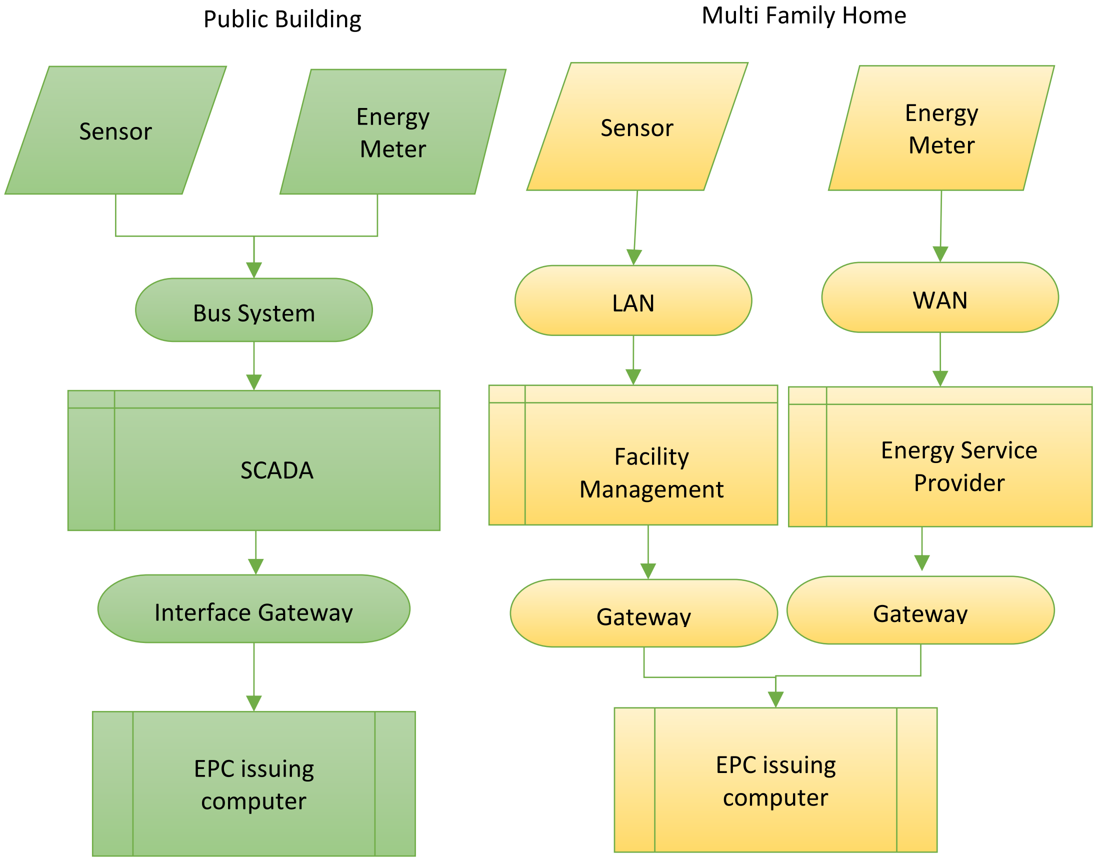


Figure 5. Comparison of DAQ for operational EPC for two different types of buildings

In a typical case the energy provider is in the possession of the meter data. But according to regulations like the **European Energy Directive, EED** customers must be given access to smart meter data starting 2020. Once this is guaranteed for all users, the two systems will become more similar but not identical since grid/network operators are not offering an API with automated data provision for M2M, but only data download. But the stronger focus on data protection in the scenario for multifamily homes will remain, so it is wise to have longer measuring periods and more apartments per building as requirements to level out the behavioural impact. So, deprived of the possibility having KPI for occupancy and room temperature some characteristics could be beneficial:

- The measuring period for the energy flow is covering several renting periods with different residents per flat
- The population of residents in the buildings is diverse

The reviewer also should check:

- Absence of technical reasons which could influence infiltration losses and cause differing indoor temperatures
- Level of occupancy, so no special considerations must be made, accounting for the real change in building energy demand (the change in non-adiabatic hull area is the driver, not the used floor area)?

If all points are achieved then the reliability of the operational EPC will be very high. Infiltration differences between the storeys can lead to deviating average room temperatures. Under such conditions multiple measurements are needed to determine the average value for correction. Differences in average room temperature lead to bigger errors in milder climates with higher average ambient temperature in winter. From the opposite side the impact on cooling energy is higher with less hot climates. The confidence interval of a partially normalized energy demand for heating/cooling thus can be given for each climate.

3.1.4 Validation and Credibility (including Monitoring)

Credible data strengthen the mutual trust between involved parties which is mandatory for the issuance of EPCs. For this reason, the collected data are required to maintain a high level of quality and adequacy to ensure the reliability of the utilised information for contracting purposes. Within D^2EPC, several mechanisms are integrated to perform checks on both static (e.g., user input) and dynamic data (e.g., IoT datasets). Furthermore, in the project's main platform, specialised user-interfaces are included that provide insights to assessors and users on the usability of the collected data and warn them in cases when various problems occur (e.g., missing information, extreme values etc.). More specifically, the integrated mechanisms shall:

1. check whether the user input or data parsed from BIM (static data) are inherently unique (e.g., IDs, addresses etc.) have the correct data type (e.g., numeric), are chosen from a valid set of values, are within preset ranges and are consistent with data streamed by other D^2EPC components
2. warn the user that the input did not meet the specified criteria
3. verify the timeseries data extracted from the pilot IoT devices (dynamic data) are in the expected form (format, size/interval, shape), detect and cleanse –where feasible- extreme and missing values in the said data and further check their overall correctness (i.e., specified ranges per metric)
4. generate alerts when several data quality problems occur in the extracted data and notify the user in the main platform
5. indicate if data is not available in the required measuring interval
6. highlight times in history where no reliable data is available, visualize in curves (expected interval, stored values)
7. indicate via daemon the actual status of the data acquisition (valid data, invalid, none) and send a message if no or invalid data is detected
8. warn via e-mail if changes in the API are advertised (optional)
9. detect and notify via messaging services, when SSL certificates are invalid (optional)

The points 5, 6 are valid for the input form for EPC especially, 8 and 9 are options for a commercial system checking before the assessor is starting to issue an EPC to avoid absence of data.

3.1.5 Roadmapping tool

The D^2EPC Digital Platform will cooperate with the Roadmapping tool so optimal recommendation will be presented in the Platform. The end-user by making requests through the Platform will activate the Roadmapping tool module. The Roadmapping tool module using asset-based data from BIM-based Digital Twin will examine possible renovation actions for building envelope, technical systems, and renewable energy systems (RES), as described in D4.2. The results of the Roadmapping tool are sorted by the payback years for all possible renovation actions. The results of the Roadmapping tool will be forwarded to the Digital Platform in order to assist in optimal strategy-making of the end-user.

The results of the Roadmapping tool cover a variety of indicators and measurements. The results can be depicted in a total renovation table, bar charts, and bubble graphs.

The total renovation table results will present the Roadmapping tool total results for every feasible renovation action. Also, the end-user will be informed about the financial or environmental impact of every feasible renovation action. The context of the table results will refer to various indicators for each renovation measurement. The indicators are depicted in the columns in Table 1.

Table 1: Roadmapping table with all possible renovation action

RENOVATION ACTION	Primary Energy [kWh]	Energy saving [%]	Cost [EUR]	Cost saving [%]	Emissions [kg CO_2/kg]	Emissions saving [%]	Renovation Cost [EUR]	Payback years
Roof	149,727.4	27.7	12,971.5	26.7	18,055.3	52.4	4,126.7	0.9
Upgrade of DHW system	103,562.6	50	8,671.7	51	28,327	25.3	12,500	1.4
Heat pump/Residential	135,036.3	34.8	10,665.4	39.7	70,771	86.6	10,800	1.5
Floor	158,500	23.5	13,418	24.2	35,640	6	8,062	1.9
Wall	140,184.3	32.3	11,988.6	32.3	25,140.4	33.7	12,557.8	2.2

Based on Table 1 various bar charts can be structured, which will depict both financial and environmental indicators. The end-user can choose the desired indicator of Table 1 and the Digital Platform will visualize the data through a bar chart in order to compare the different renovation scenarios. Below for the variants the bar charts of primary energy saving (Figure 6), payback years (Figure 7), the annual cost for energy bills (Figure 8), and CO2 emissions (Figure 9) are presented.

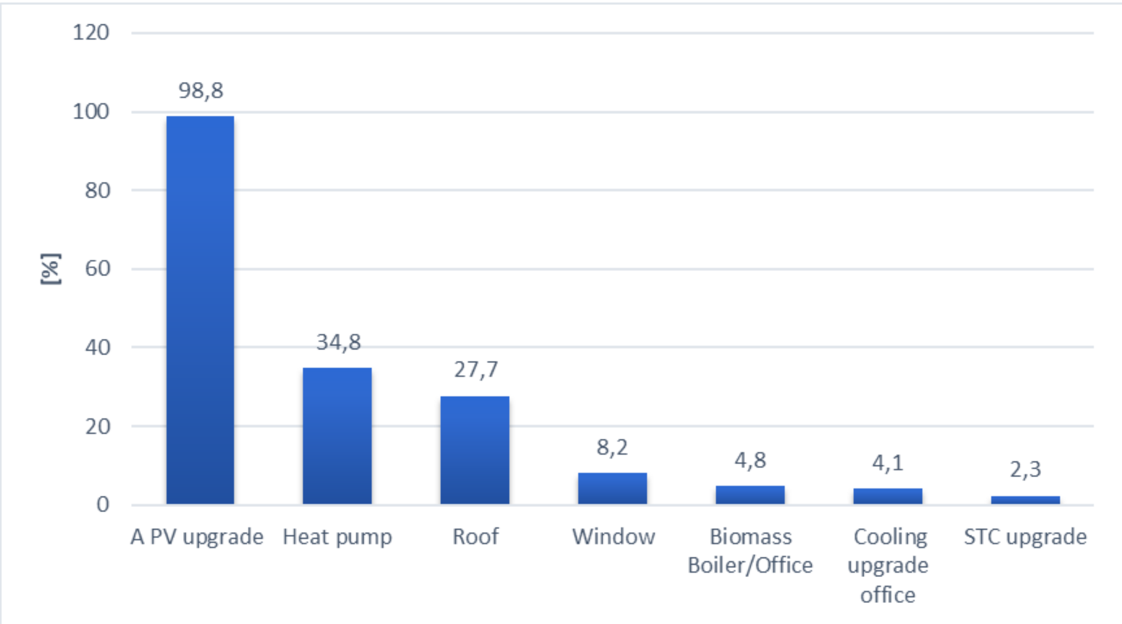


Figure 6: Primary energy saving

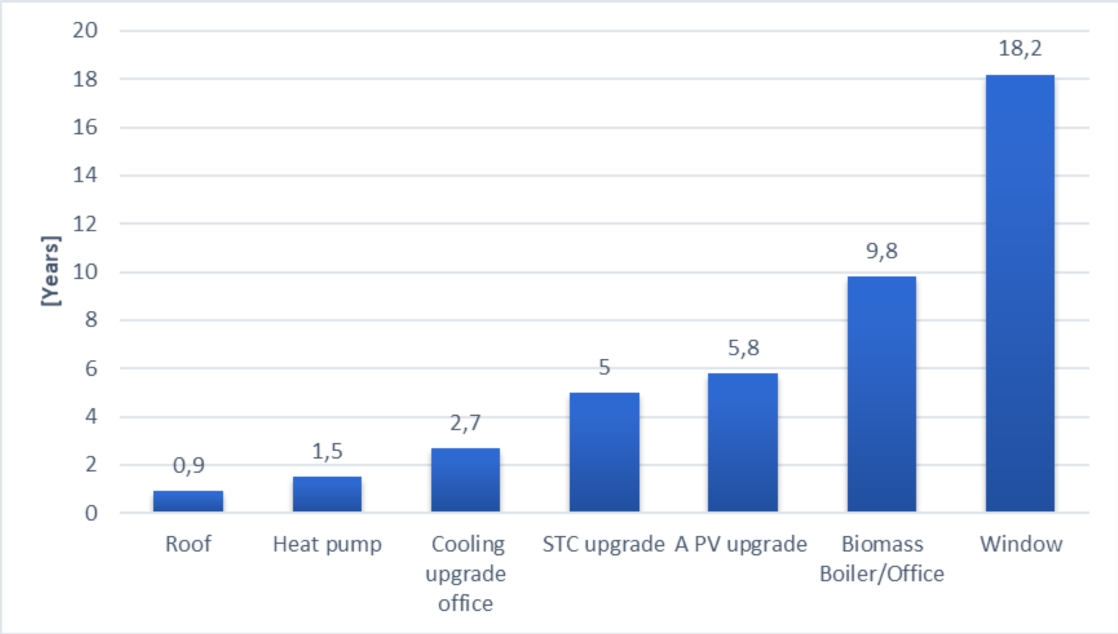


Figure 7 Payback years

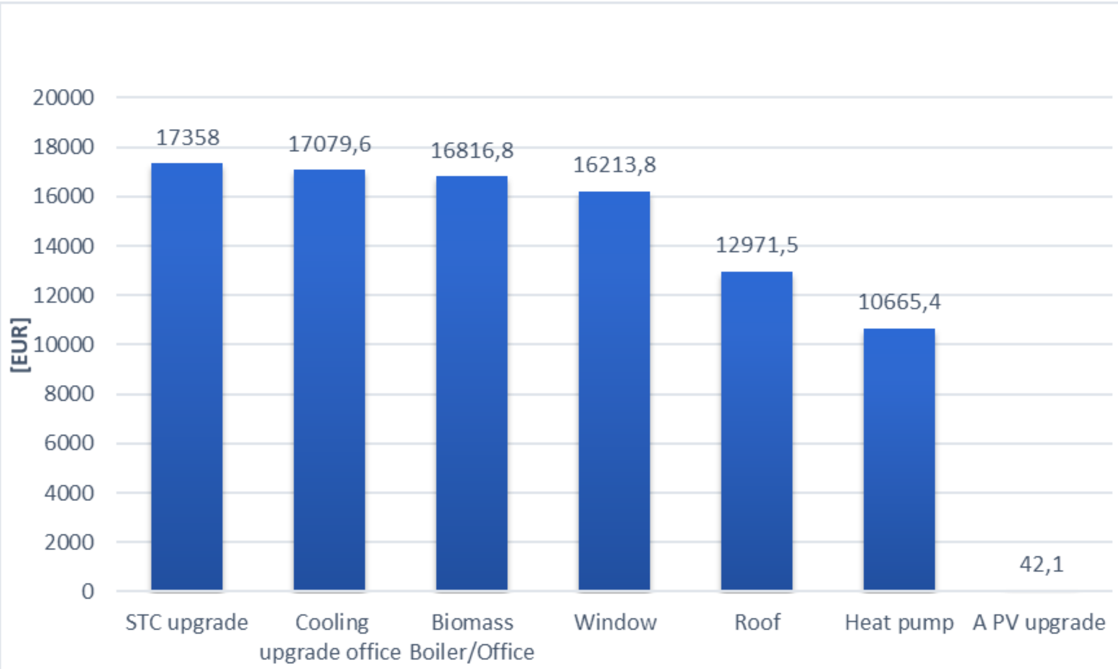


Figure 8 : Annual cost for energy bills

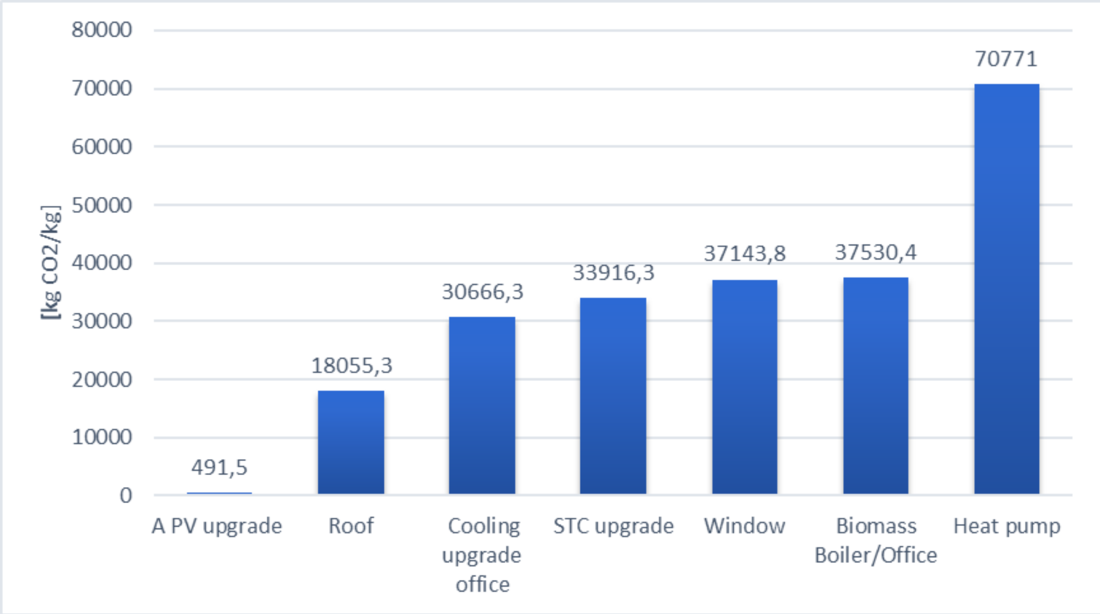


Figure 9: CO2 emissions

The end-user can choose the bubble graph visualization. In bubble graph the user must define a set of parameters that will refer to the values of x-axis, y-axis and the diameter of the bubble. In Figure 10, the x-axis depicts the renovation cost, the y-axis refers to payback years and the diameter of the bubble represents the energy saving.

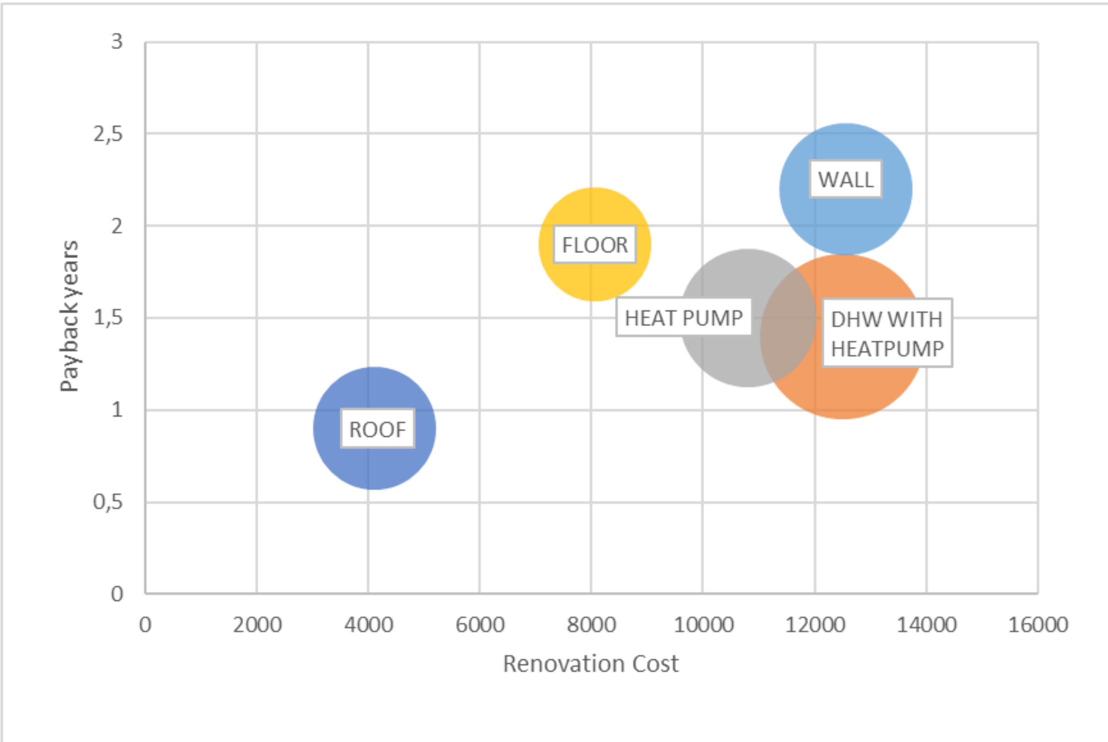


Figure 10: Bubble graph for renovation depiction

For owners of several buildings, the ranking according ROI might span several buildings. For avoiding energy poverty, it must be checked however that heating cost is acceptable for buildings having low-ROI measures.

The requirements for such a scheme are:

- The renovation roadmap must indicate the amount of energy saved/CO2 omitted and the return on investment, given an estimated increase of energy price

- The renovation roadmap must account for unchanged occupancy and weather
- The renovation road map shall account for shading if new buildings are already planned
- The renovation roadmap shall list the measures in their logical order
- The renovation roadmap must give alternatives (exchange insulating glazing, exchange of windows…)
- The renovation roadmap shall indicate trigger points like maintenance cost increase for heat exchangers, new funding, new legislation enforcing changes...
- The renovation roadmap must present a title of the measure and a brief description with quantification
- The renovation plan shall allow selecting measures not being linked and calculate the ROI
- After inputting an investment sum, the most economical measures fitting into that budget shall be presented (using the Knappsack algorithm (Martello und Toth 1990))

3.1.6 Performance forecast

Recently the energy prices soared and it makes sense to calculate the ROI based on different energy pricing scenarios. To judge economy of measures it also needs a performance forecast, with and without measures (from the renovation roadmap). If the prices for the measures (installation) increase, measures will have reduced ROI and performance will be improved later. For the energy price it is vice-verse. The last increase in energy price in 2022 should outperform them increase in renovation cost. The commission has published a document talking rising energy prices (European Comission 2021).

Given the existing increase in global temperatures, there might be more cooling and less heating load in future. The performance forecast component might indicate the change during the lifetime of the building.

The CO_2 intensity of the power grid is also subject to changes, Natural gas is blended with biogas according to the decarbonisation plans in the EU. The tool shall indicate future CO2 intensity, based on those changes

The requirements for the component are:

- The tool shall indicate KPI for longer periods in time in future
- The representation should use figures
- KPI may be selected by the user from heating/cooling energy demand/$CO2_{eq}$

Figure 11 represents the results for the month ahead energy consumption for CERTH’s smart home. As stated in D4.2, this tool will aggregate the predicted values of each day and forward the summation to the Operational Rating Module.

In turn, the Operational Rating Module will estimate the change in the Operational Rating EPC based on the forecasted consumption. Figure 11: Predicted versus Actual Energy Consumption

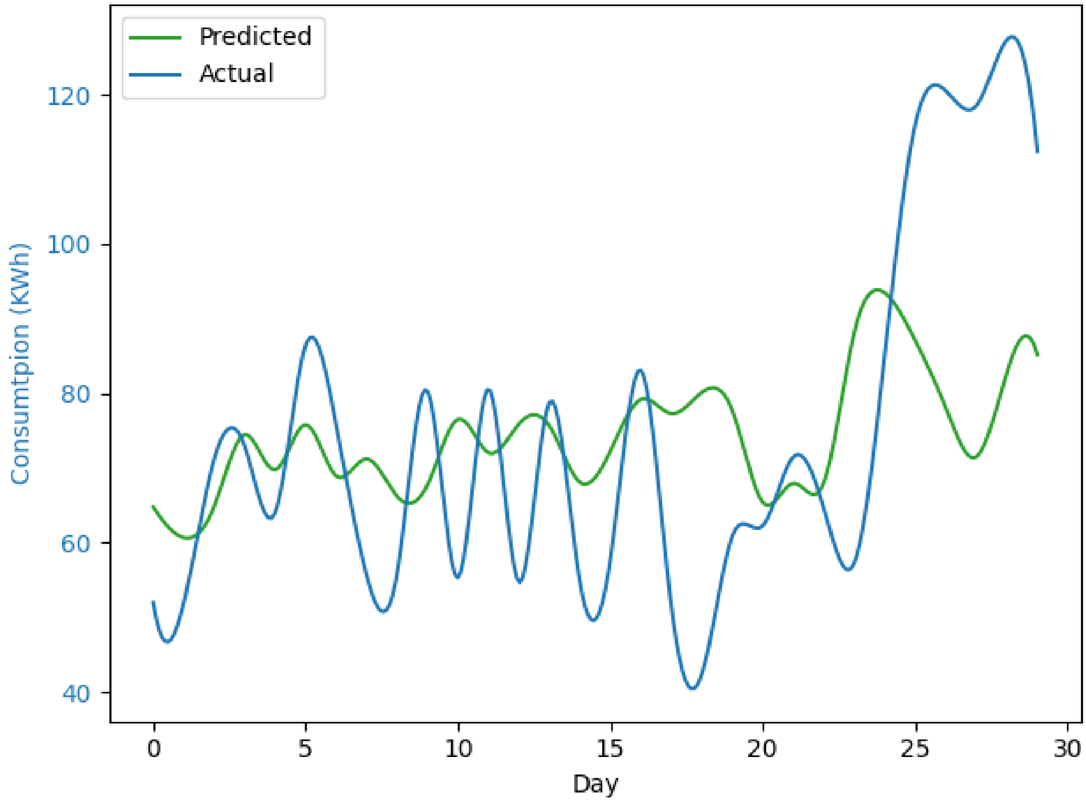


Figure 11: Predicted versus Actual Energy Consumption

Figure 11 compares the predicted with the actual energy consumption ex post, challenging the precision of the digital twin as well as of the weather forecast. Such comparison may be used to improve both or to alter the usage scenario (occupancy).

3.1.7 GIS Tool

For the webGIS visualisation tool the main system specifications, as also presented in D3.2, and are highlighted below. The webGIS tool shall

- produce EPC statistics per region by correlating EPCs issued by the D^2EPC framework with NUTS regions
- visualise the EPC statistics on a WebGIS map
- provide attribute and spatial querying tools
- provide an endpoint for data dissemination using OGC services
- visualise BIM models of Pilot Cases using 3D graphics for the buildings (public) as demonstration and BIM models of buildings/dwellings provided by users (only to authenticated users) on a map

The webGIS visualisation tool to this end, does not require any user authentication level, which entails open access to data demonstration and dissemination. However, in the future will be investigated the users' authentication access via credentials, providing dedicated access to specified functionalities of the webGIS.

3.1.8 Benchmarking Tool

Benchmarking is defined as process where you measure the performance of your building against the performance of similar other buildings. The benchmarking differs for owners of single buildings and multiple buildings or agencies responsible for energy policy in the region. Owners of single buildings shall be presented buildings with similar characteristics but better energy performance (see D4.1).

Apart from comparing the buildings performance with a renovated building, comparing the performance to a new building built according to actual standards is the second alternative. In Columbia the histograms and medians of the Energy Star Score are shown but also geolocated (Columbia 2022) to be able to compare to similar neighboring buildings .For owners of several buildings a comparison of energy demand in the categories and energy bought is valuable.

The requirements for a benchmarking service are:

- In operational EPC ratings the 100% value is a reference building, and no benchmark must be shown.
- For all ratings with absolute values, a histogram for the building category is shown, where the building's values are located.
- The reference is to be given for all ratings energy used, primary energy and $CO2_{eq}$.
- Other KPI like energy per volume and resident may be compared to similar buildings and similar climates, shown if this applies for the pilot buildings in the project

3.2 Implementation of UI for the portal

Three main service hosts are considered:

- The D^2EPC Main Platform services host (EPC issuance, indicators calculation etc.), which is developed and maintained in a server supported by CERTH. Additionally, SEC is contributing with a web based dummy for operational EPC, featuring a dynamic EPC visualization and comprising statistical analysis of KPI for existing EPC records.
- The WebGIS services host, which is developed and maintained in a server supported by GSH.
- The Verification and Credibility services host, which is developed and maintained in a cloud server supported by HYP.

3.2.1 Main Platform

The Main Platform services host is expected to provide access to the following services:

- Issuance of the Asset-based EPC (Asset Rating Calculation Engine Module)
- Issuance of the Operational-based EPC (Operational Rating Calculation Engine Module)
- Calculation of the D^2EPC set of indicators (Building Performance Module)
- Provision of the optimal recommendations for performance upgrade (Road mapping Module)
- Calculation of energy performance predictions (AI Performance Forecasts Module)
- Issuance of performance alerts and notifications (Performance Alerts & Notifications Module)
- Benchmarking of buildings' energy performance (Building Energy Performance Benchmarking Module)
- BIM and real-time building data management (Digital Twin)
- Other common services to support the different functionalities of the web platform and provide data input to the aforementioned services

Figure 12 depicts the up-to-date implemented services that are part of the Main Platform. As mentioned, dedicated services have been developed for the validation of BIM files provided for the buildings under study (parsing and identification of deficiencies), as well as for the calculation of the asset-based EPC. In order to support the operation of the aforementioned, additional services for the efficient management of BIM files have also been integrated.

All the components are being developed as Python packages and are integrated as imported modules in the Main Platform backend, while matched to a corresponding service. All the developed services can be accessed by the D^2EPC Web Platform through a common API.

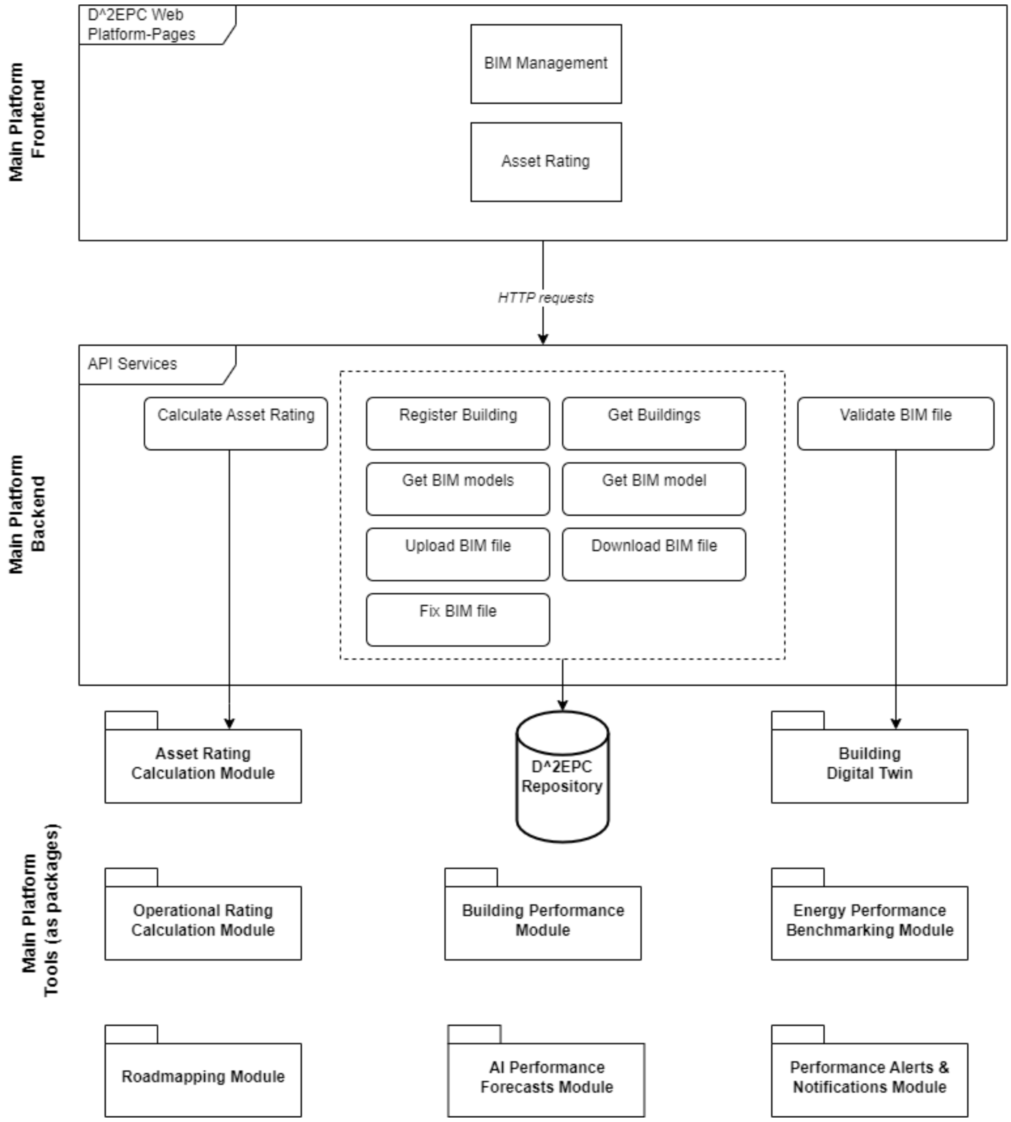


Figure 12 Main Platform Architecture

3.2.1.1 BIM Parser (Digital Twin)

The user interface for the BIM parser comprises BIM Management, the validation of the BIM file and input of missing information. Starting with the BIM Management page, the end user is provided with an environment that allows them to upload and validate the static information of any building included in a BIM file. The process of uploading an IFC file is analyzed below. Firstly, the user uploads the BIM file in IFC format, through the main field on the top of the page (Figure 13). By the time the upload of the IFC file is complete, the platform will inform the user about the success of the process with an indication in the top right corner (Figure 14).

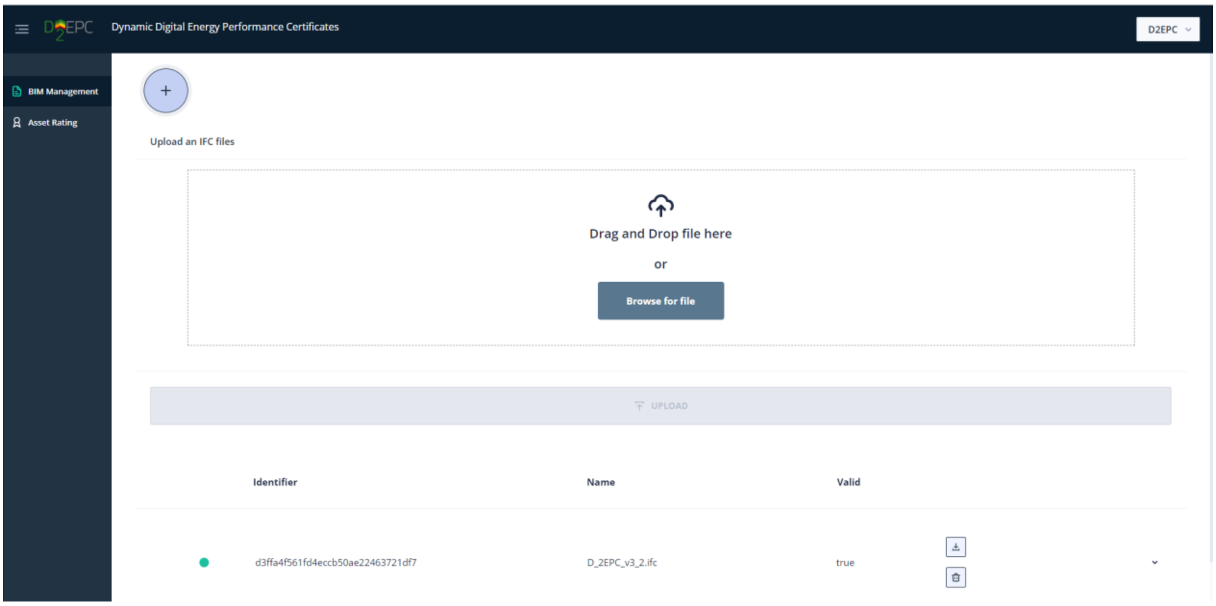


Figure 13: IFC file upload

The next step is to validate the IFC file so the resulting building model will be compatible with the platform's requirements and deliver accurate results. The "Valid" field indicates the file's status. When the value is "False", the user shall use the "Validate" button (Figure 15) to add any missing values or assess the doubtful values in the file. Figure 15 presents the Validation page, where the user performs all the necessary modifications to the building information. After the "Valid" field contains the value "True", the user is able to request the EPC calculation by pressing the "Asset Rating" button (Figure 17).

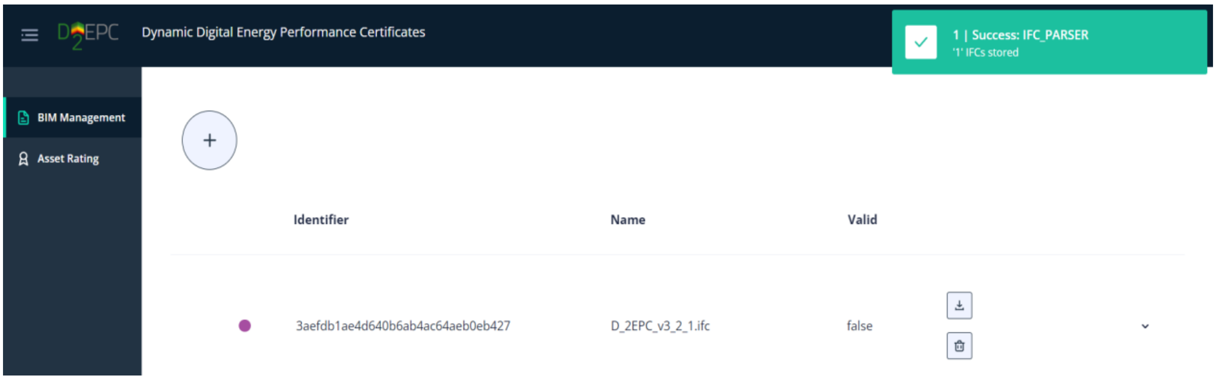


Figure 14: Successful upload of IFC file

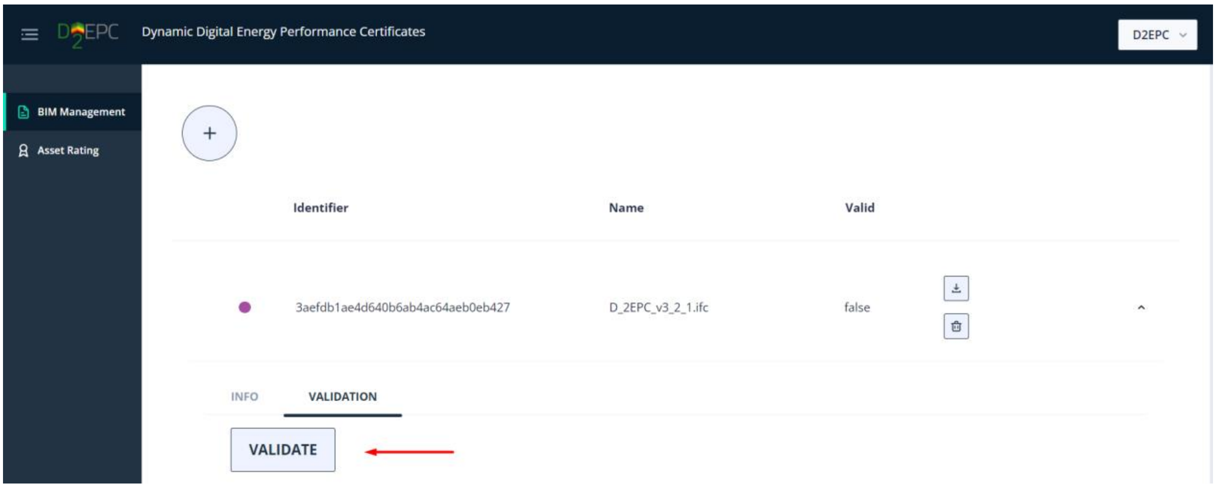


Figure 15: Validation button

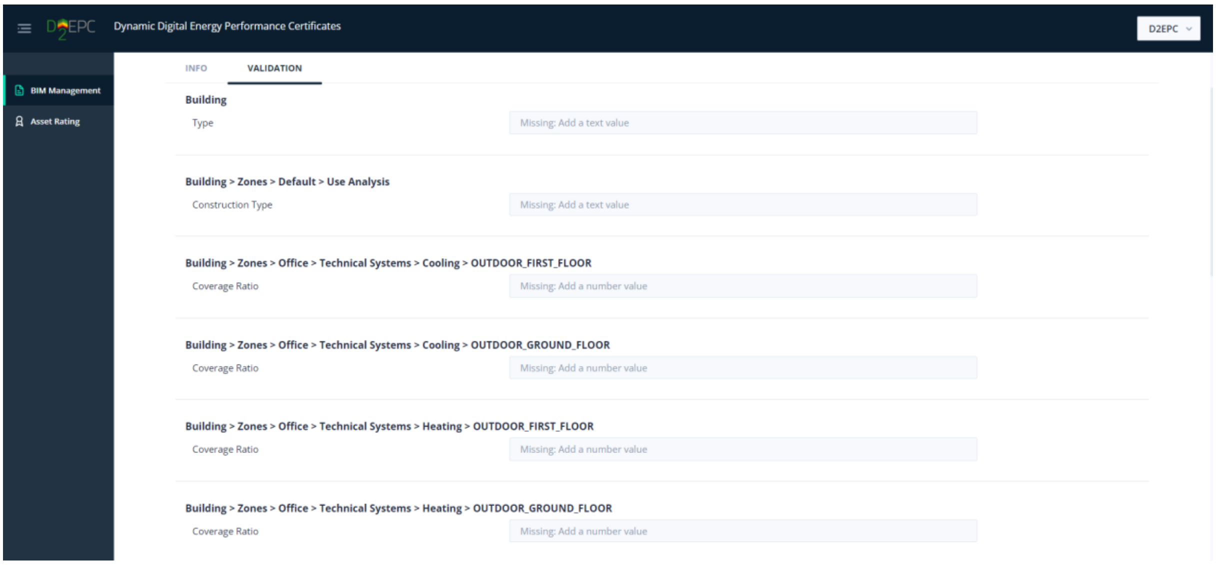


Figure 16: Missing values

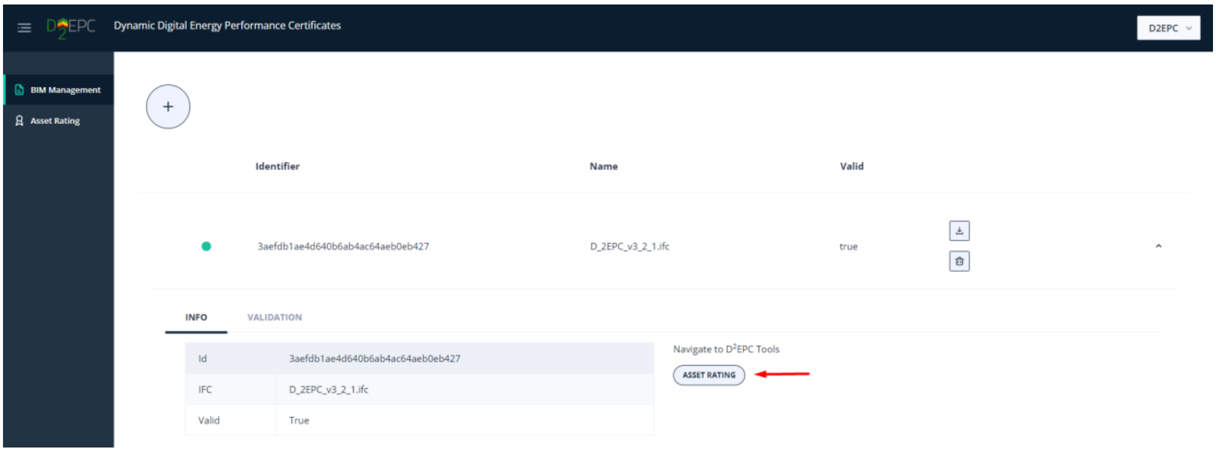


Figure 17: Successful validation

With the successful validation of the BIM file, all the information is available to start the asset-based EPC rating.

3.2.1.2 Asset Rating (asset based EPC)

The web page for the Asset Rating has been meticulously designed to effectively communicate as much information as possible to the EPC assessor, so they will be able to validate the result of the Asset Rating Module in an effective and easy way.

To begin with, the page demonstrates the monthly variance of the building's energy consumption at the three stages of energy calculations: Energy Demand; Final Energy; and Primary Energy (Figure 19). The energy values for each month can be presented as a total or disaggregated per energy service. The monthly energy values can be extracted either in a bar-chart format or as numerical values in a table format (Figure 21). In the bar chart, the user can isolate a desired time period (Figure 20) or download a particular time period as an image, for all three sets of energy results. It is worth mentioning that each result can be exported either as absolute energy values [kWh] or normalized values per area [kWh/m^2] (Figure 22). The described representation has been chosen to enhance the end-user experience and understanding of the building's energy performance.

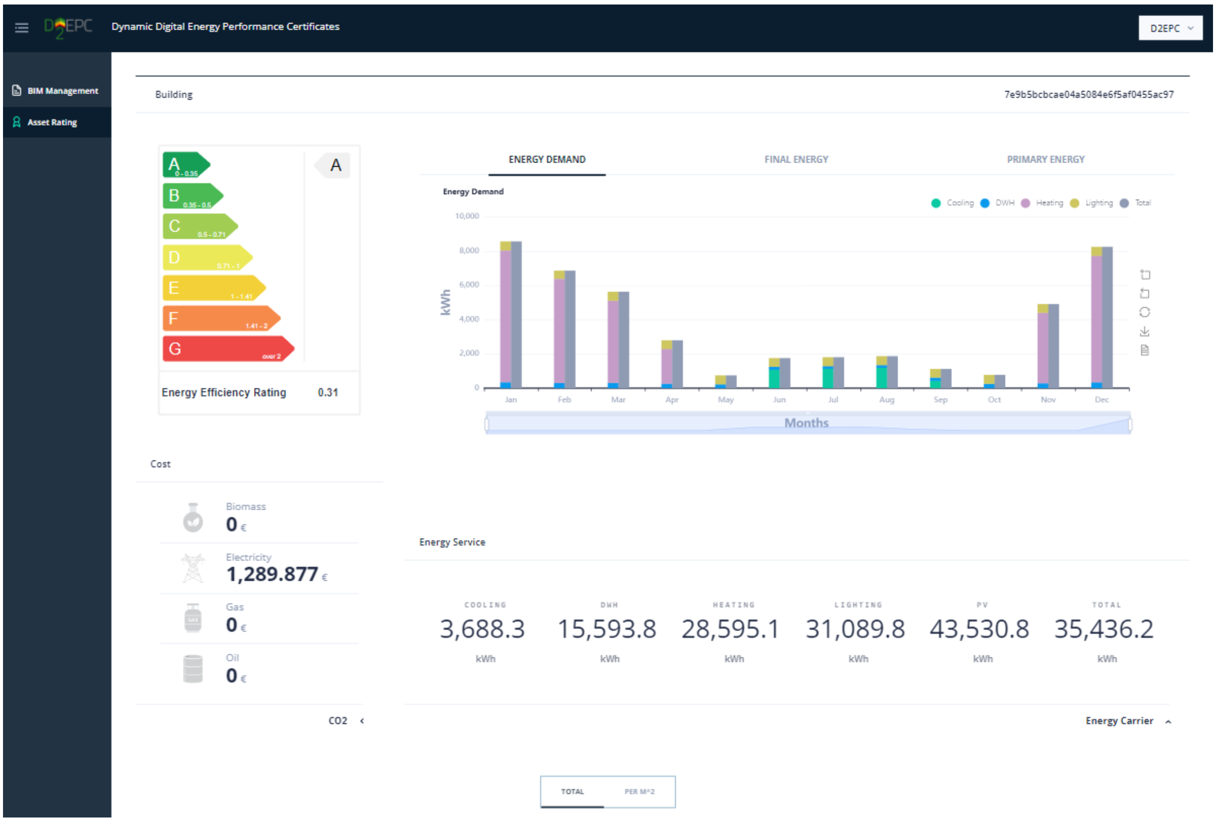


Figure 18: Asset Rating page

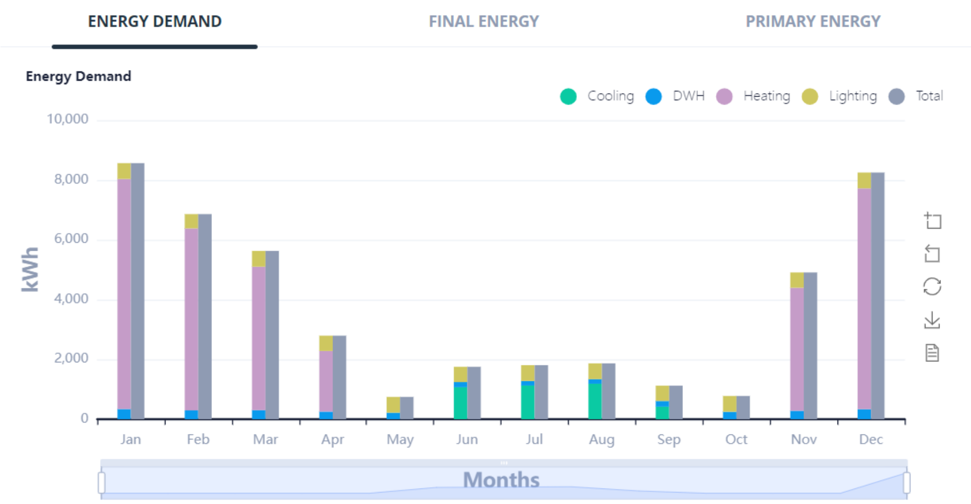


Figure 19: Energy Demand diagram [kWh] – Absolute values

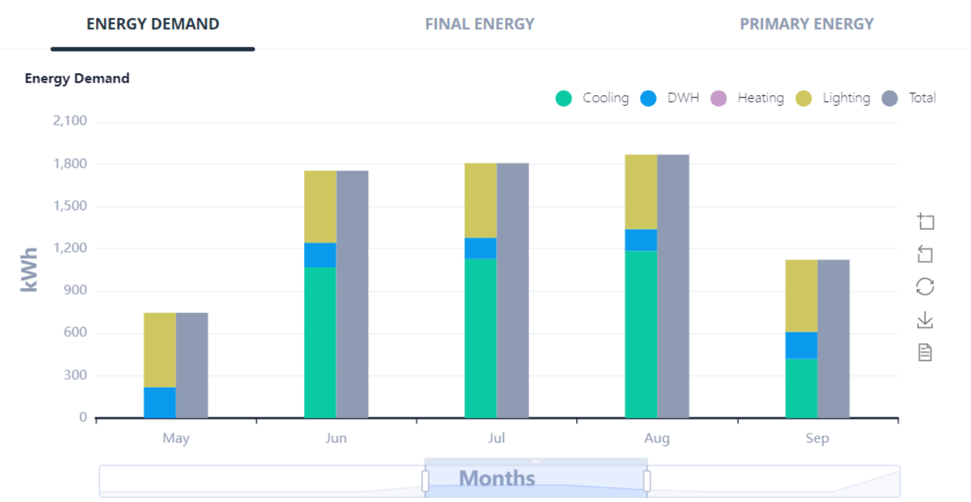


Figure 20: Energy Demand diagram [kWh] - Monthly isolation

ENERGY DEMAND | FINAL ENERGY | PRIMARY ENERGY

Data View

Months:	Cooling	DWH	Heating	Lighting	Total
Jan	0	341	7698.98	528.1	8568.08
Feb	0	295.72	6089.97	476.99	6862.68
Mar	0	302.29	4801.65	528.1	5632.04
Apr	0	254.59	2030.13	511.07	2795.79
May	0	218.86	0	528.1	746.96
Jun	1069.89	173.56	0	511.07	1754.52
Jul	1127.5	152.32	0	528.1	1807.92
Aug	1186.4	154.23	0	528.1	1868.73
Sep	418.55	193.25	0	511.07	1122.87
Oct	0	249.49	0	528.1	777.59
Nov	0	282.52	4116.48	511.07	4910.07
Dec	0	336.15	7389.04	528.1	8253.29

Figure 21: Energy demand [kWh] - Data view format

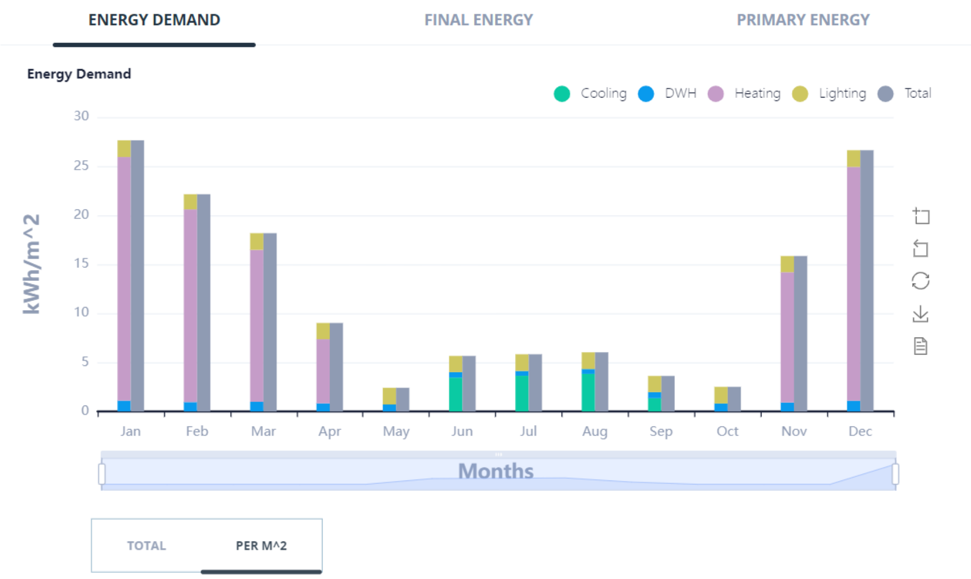


Figure 22: Energy Demand Diagram – Normalized values [kWh/ m2]

Proceeding to the bottom of the page of the UI, the end-user can access the annual values for energy use on the KPIs section. Figure 23 and Figure 24 demonstrate the annual energy usage per energy service and per each energy carrier, respectively.

Figure 23: Annual energy consumption per energy service [kWh/ m²]

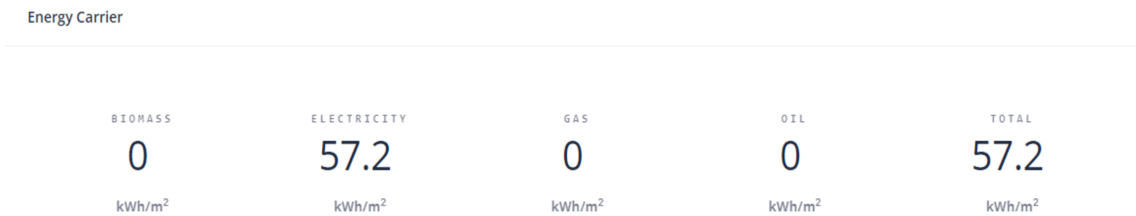


Figure 24: Annual energy consumption per energy carrier [kWh/ m²]

On the bottom left of the page, there is a set of economic and environmental indicators. Figure 25 and Figure 26 present the annual CO_2 emissions per energy carrier and the annual cost of the building's energy use, respectively. Each set of KPIs is able to be presented as absolute energy consumption or normalized values per area.

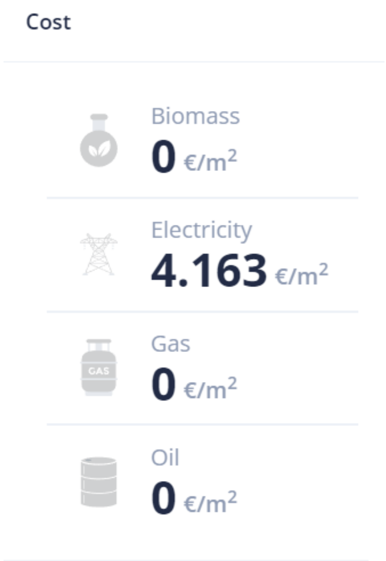


Figure 25: Financial Indicators per m²

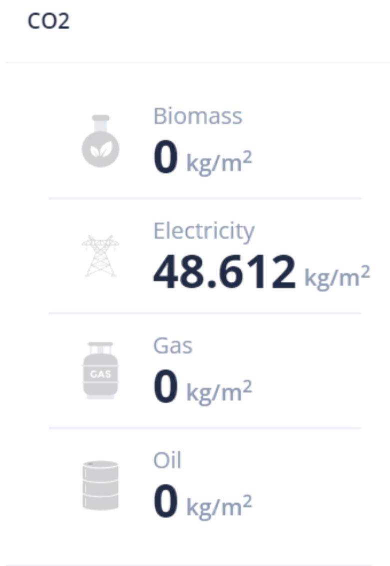


Figure 26: Environmental Indicators per m²

Finally, the building's energy class is the main indicator derived by the D^2EPC Asset Rating methodology, and thus it is located in the top left corner of the Asset Rating page. Figure 27 presents in detail all the displayed information in this field. The "Energy Efficiency Rating" value at the bottom represents the ratio between the energy performance of the building under examination and the building used as a reference. The classification is performed according to the limit values included in each of the seven energy classes.

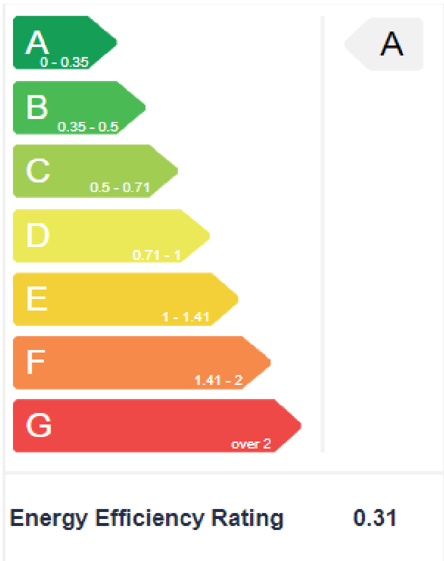


Figure 27: Energy Class

3.2.1.3 Operational EPC

3.2.1.3.1 Structure of Input

The operational EPC is produced out of meter readings for the energy streams. Depending on instrumentation meters the energy delivered, and the energy used can be shown, although only the energy delivered, the primary energy and the greenhouse gas emission expressed as CO_2 mass are rated. Additionally, the non-renewable and renewable primary energy use shall be shown (European Commission 2021). This however is only possible if it is metered, not if decentral renewable energy appliances are in place. Here the same problem like with decentral domestic hot water producers occur. The solar yield could be estimated based on the orientation, inclination and Peak power of the solar panels or aperture for solar thermal. Ambient energy is excluded both for heat recovery in venting as well as for heat pumps.

So, the implementation needs a structure to input the meters at the different levels. In Pilot 5 we have solar thermal energy, electric energy and natural gas flowing into the energy system of the building and heat delivered to the two parts of the building. The meter data will be collected via API as soon it is available, now csv files are used. Since the quality checked degree day data is not available immediately the user interface can only show non weather normalized KPI during the time the quality assured degree days are not available. Figure 28 shows the first screen, where the user inputs the data source for the end energy used and the heat supplied to the building (for uses case 5, this is possible).

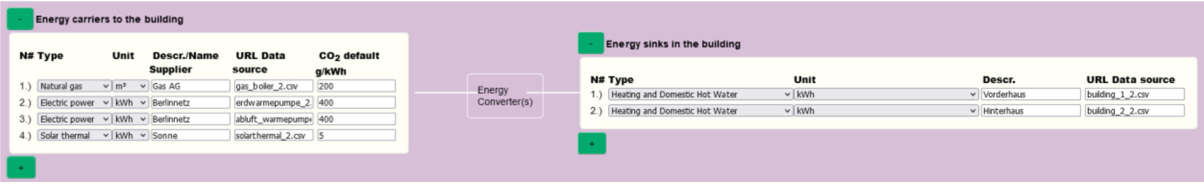
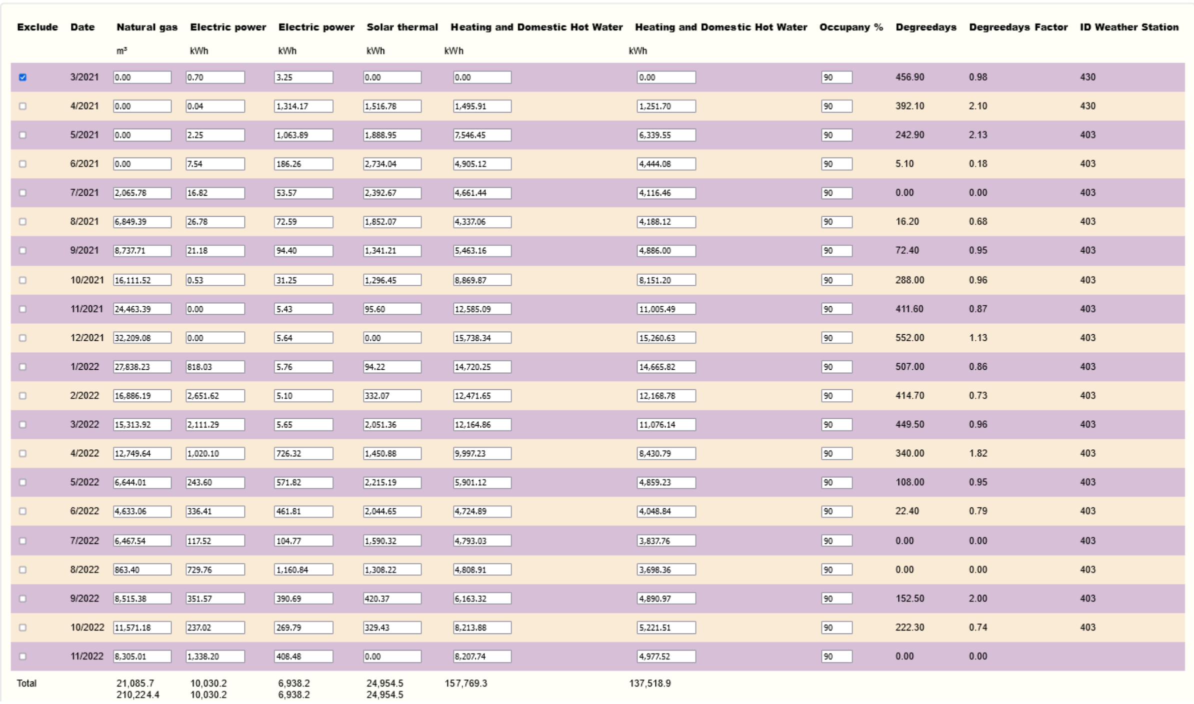


Figure 28 Input for energy streams

Energy sinks might be left blank, if not metered. After filling in, data is shown for every month, adding retrieved data for Degree Days. Meter data will be taken from the D^2EPC data repository once it exists, or from meter operators via API. Figure 29 shows the exemplary data retrieved for the pilot 5, and in parallel degree day data from the identified neared weather station.



Exclude	Date	Natural gas	Electric power	Electric power	Solar thermal	Heating and Domestic Hot Water	Heating and Domestic Hot Water	Occupany %	Degreedays	Degreedays Factor	ID Weather Station
		m³	kWh	kWh	kWh	kWh	kWh				
☑	3/2021	0.00	0.70	3.25	0.00	0.00	0.00	90	456.90	0.98	430
☐	4/2021	0.00	0.04	1,314.17	1,516.78	1,495.91	1,251.70	90	392.10	2.10	430
☐	5/2021	0.00	2.25	1,063.89	1,888.95	7,546.45	6,339.55	90	242.90	2.13	403
☐	6/2021	0.00	7.54	186.26	2,734.04	4,905.12	4,444.08	90	5.10	0.18	403
☐	7/2021	2,065.78	16.82	53.57	2,392.67	4,661.44	4,116.46	90	0.00	0.00	403
☐	8/2021	6,849.39	26.78	72.59	1,852.07	4,337.06	4,188.12	90	16.20	0.68	403
☐	9/2021	8,737.71	21.18	94.40	1,341.21	5,463.16	4,886.00	90	72.40	0.95	403
☐	10/2021	16,111.52	0.53	31.25	1,296.45	8,869.87	8,151.20	90	288.00	0.96	403
☐	11/2021	24,463.39	0.00	5.43	95.60	12,585.09	11,005.49	90	411.60	0.87	403
☐	12/2021	32,209.08	0.00	5.64	0.00	15,738.34	15,260.63	90	552.00	1.13	403
☐	1/2022	27,838.23	818.03	5.76	94.22	14,720.25	14,665.82	90	507.00	0.86	403
☐	2/2022	16,886.19	2,651.62	5.10	332.07	12,471.65	12,168.78	90	414.70	0.73	403
☐	3/2022	15,313.92	2,111.29	5.65	2,051.36	12,164.86	11,076.14	90	449.50	0.96	403
☐	4/2022	12,749.64	1,020.10	726.32	1,450.88	9,997.23	8,430.79	90	340.00	1.82	403
☐	5/2022	6,644.01	243.60	571.82	2,215.19	5,901.12	4,859.23	90	108.00	0.95	403
☐	6/2022	4,633.06	336.41	461.81	2,044.65	4,724.89	4,048.84	90	22.40	0.79	403
☐	7/2022	6,467.54	117.52	104.77	1,590.32	4,793.03	3,837.76	90	0.00	0.00	403
☐	8/2022	863.40	729.76	1,160.84	1,308.22	4,808.91	3,698.36	90	0.00	0.00	403
☐	9/2022	8,515.38	351.57	390.69	420.37	6,163.32	4,890.97	90	152.50	2.00	403
☐	10/2022	11,571.18	237.02	269.79	329.43	8,213.88	5,221.51	90	222.30	0.74	403
☐	11/2022	8,305.01	1,338.20	408.48	0.00	8,207.74	4,977.52	90	0.00	0.00	
Total		21,085.7 210,224.4	10,030.2 10,030.2	6,938.2 6,938.2	24,954.5 24,954.5	157,769.3	137,518.9				

Figure 29 Input data from meters

Data is presented in input fields, so it can be changed or data tuple.

3.2.1.3.2 Energy Consumption Quality Check

In the next step of the operational EPC the assessor shall have a look

- whether correct weather stations were selected Figure 29 right column
- at the correlation with the degree days Figure 30
- Input/output analysis converted energy streams (m³, kWh…) Figure 28

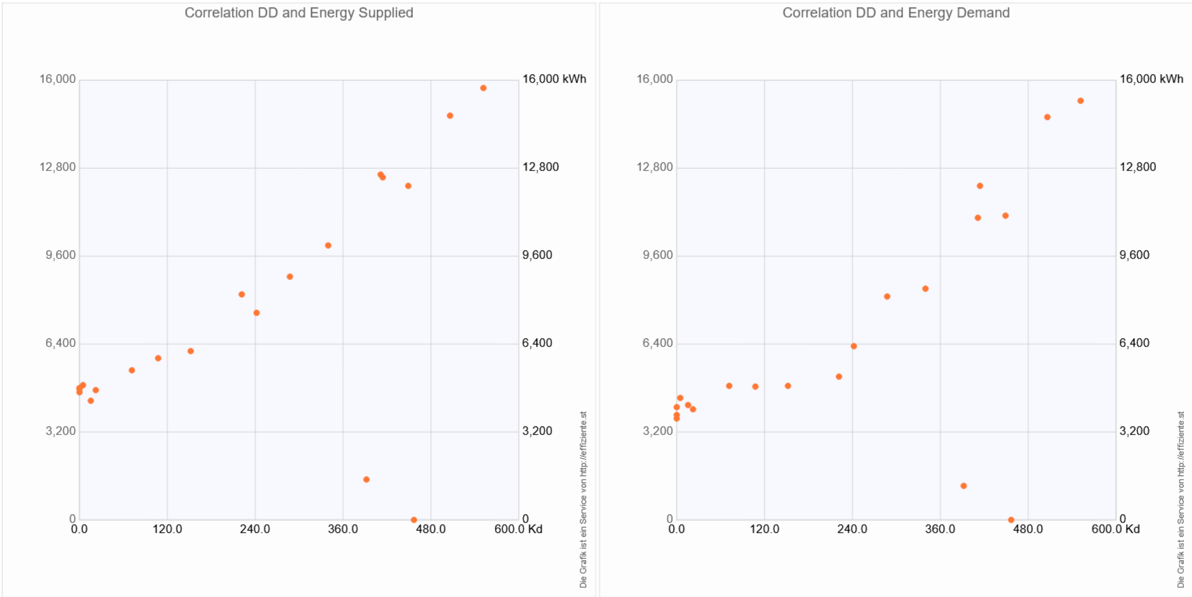


Figure 30 Correlation Energy-Degree-Days

Then he/she can exclude months with non-sufficient correlation of heat consumption and degree days. Also, the occupancy shall be entered for each of the months. Depending on the address of the building, the weather station is selected automatically. In Figure 31 the not normalized energy demand is also shown in pilot 5 for both building parts, so lacking correlation can be used to see whether part of the building had a different occupancy. Also the total energy input to the energy converter and the output is depicted. Not metered is the ambient energy for the heat pumps.

Total Input Streams: 252,147 kWh Output Streams: 295,288 kWh Factor 117 %

Figure 31 Energy utlilised per month

Finally, the results are shown for energy delivered, and the share of renewable energy in Figure 32.

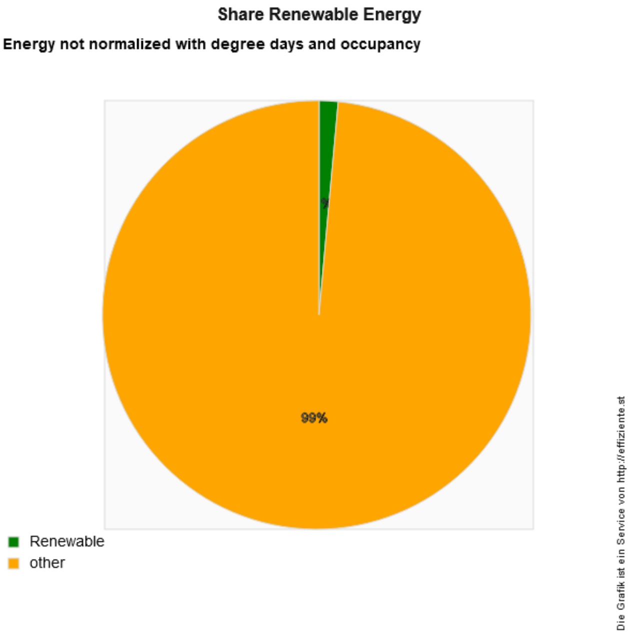


Figure 32 Results EPC, Share of RE

Because of the heat pumps utilized and RE in the power mix the real share of RE is higher.

The comments are summarized. Figure 33 shows an example for pilot 5:

Comments from quality control

- different weather stations used 403 vs. 430
- Please check energy converters, only condensing gas ovens and heat pumps might deliver more heat than end energy they consume!
- Check consumption for Vorderhaus: 4/2021, eventually excluding this month
- Check consumption for Hinterhaus: 4/2021, eventually excluding this month
- To few months covered (21)

Figure 33 Comments compiled by the automated quality control

3.2.1.3.3 Results

The results of the digital operational EPC as shown in Figure 34 will include performance indicators on the one side and an EPC rating on the other side:

Calculated indicators and EPCs

Building Type Multi Appartment Building

Average 0.024 kg CO_2/kWh

Share Renewable Energy 1.4 %

Energy related indicators with various reference

Total specific normalised	Months	Value
Used Energy kWh per m^2	20	99.5
Used Energy kWh per m^3	20	31.1
Used Energy kWh per Person	20	3,194.0
End Energy Demand kWh per m^2	20	5,162.2
End Energy Demand kWh per m^3	20	1,613.2
End Energy Demand kWh per Person	20	165,787.2
CO2 kg per m^2	20	122.1
CO2 kg per m^3	20	38.2
CO2 kg per Person	20	3,921.0

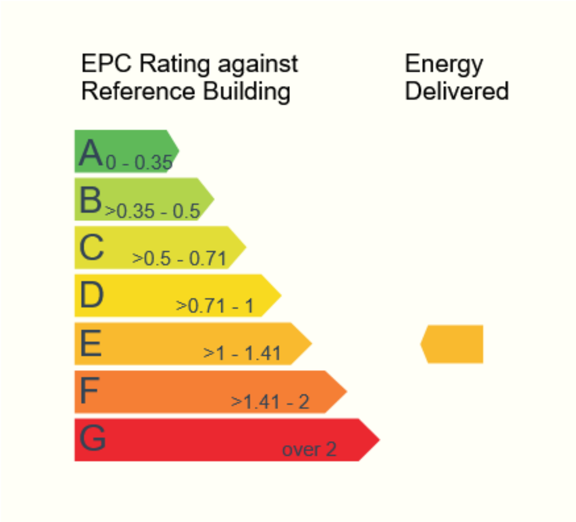


Figure 34 Key Performance Indicators and operational digital EPC

On an experimental level SEC also tried to implement a prototype with three categories, energy used, primary energy and CO2, having also a comparison to the statistical values. Figure 35 shows an experimental multi KPI dynamic operational EPC

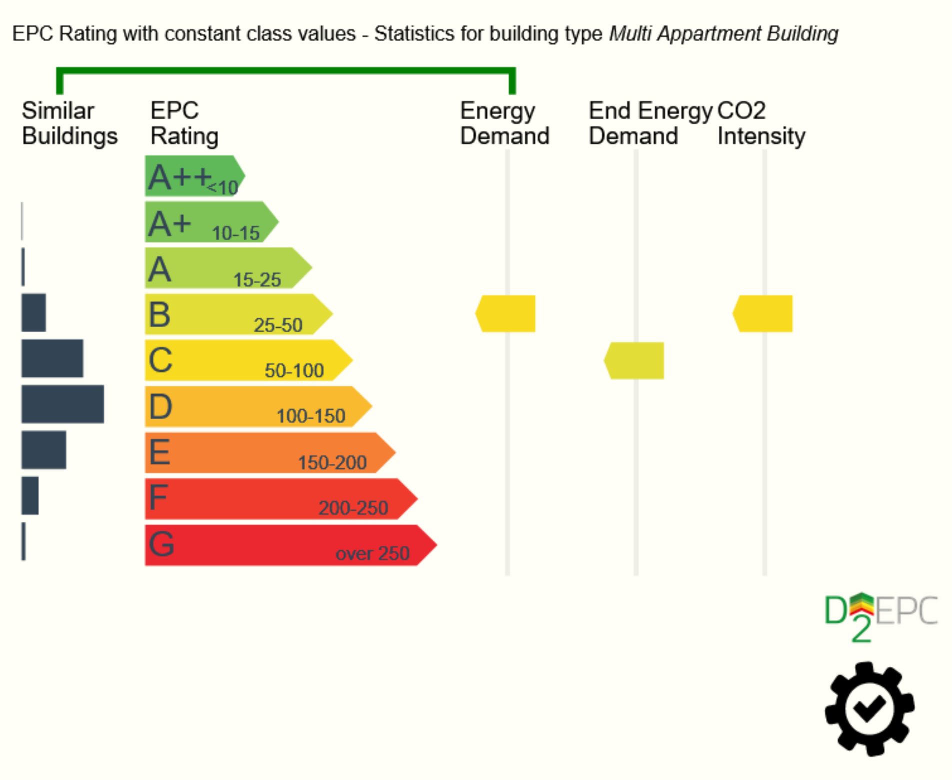


Figure 35 Proposal for a new dynamic interactive representation of the EPC label

The standardisation work for the operational EPC which is undertaken in parallel will show how much of this proposal will be used in the pilot services.

3.2.1.4 Benchmarking Tool

For the operational EPC SEC developed a benchmarking based on existing data for the same building type. Since we have three types of ratings. The user has to choose the category, before the histogram is shown.

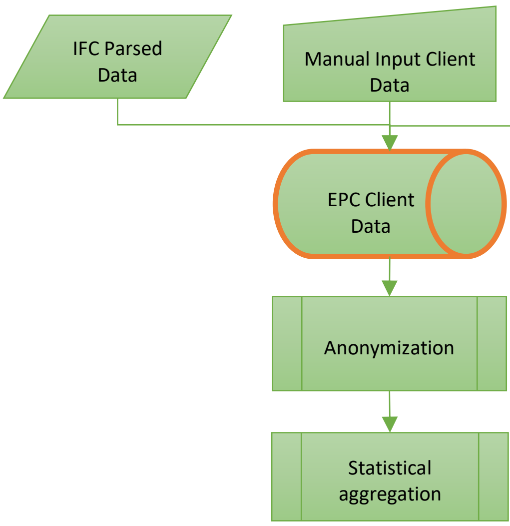


Figure 36 Deriving Statistics for relative ratings or including histograms

This method will be extended to other building types, where data is available to calculate the histograms. Also, the new scales for primary energy demand and CO2 will be added.

3.2.2 Verification and Credibility Tool

The Energy Performance Verification & Credibility Tool is a composite component that undertakes the device monitoring and data quality assessment. It comprises two separate modules that interact with each other.

- The Data Quality Tool is designed to perform tailored checks on the streaming datasets regarding the accuracy, completeness, and their overall credibility. The tool communicates directly with the Information Management Layer (IML), a cloud-based component which collects data from the pilot IoT infrastructure. Within the IML a first set of checks is performed on the timeseries datasets to detect extreme values and eliminate them prior to their streaming to other modules. The Data Quality Tool extends this preprocessing by adding extra checks specially designed to detect other inconsistencies specific to the ambient conditions and energy consumption data. The assessed data are further streamed to other components (i.e., the Digital Twin and the project's repository). For different types of errors, the tool generates the corresponding alerts that are streamed to the Performance Alerts and Notifications component and to the Credibility UI to be delivered to the end-users of the D^2EPC Web-Platform (Figure 37).
- The Network Monitoring Tool is responsible for monitoring the operational status of the IoT devices installed in the D^2EPC pilot. The tool steps on Hypertech's solution which has already developed a device monitoring service with a user-friendly UI to provide real-time insights on the overall network performance. Within D^2EPC, the service is aesthetically modified (same look-and-feel with the D^2EPC platform) and integrates the extra functionalities dictated by the project's architecture. Beyond the ONLINE/OFFLINE status of the deployed devices, the service is able to report information on bad quality datasets coming from the Data Quality assessment, (i.e., the alerts generated from the Data Quality Tool). The enhanced Credibility UI is deployed in a cloud-based server supported by HYP and can be accessed through the D^2EPC Web-platform.

In Figure 37 is included the functional diagram that highlights the Energy Performance Verification and Credibility interactions with other D^2EPC components. presents Hypertech's Monitoring Tool in its default view (prior to the modifications/extensions expected to be applied).

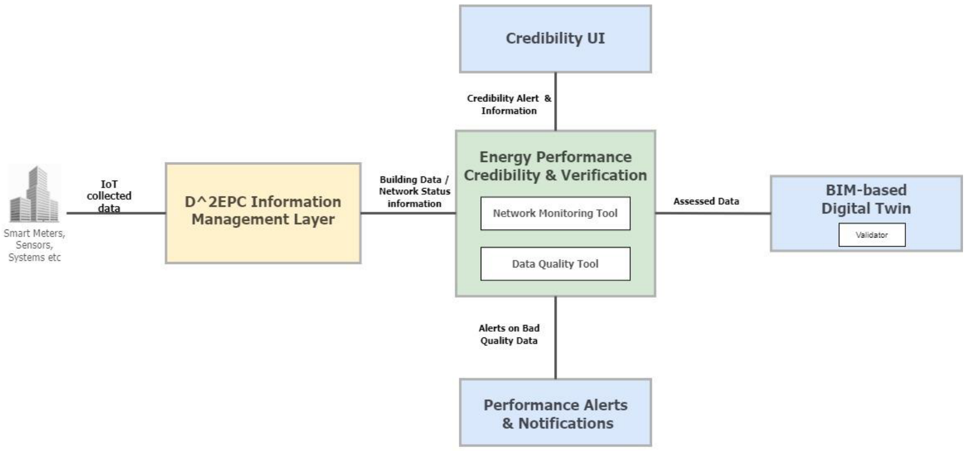


Figure 37 Energy Performance Verification & Credibility functional diagram

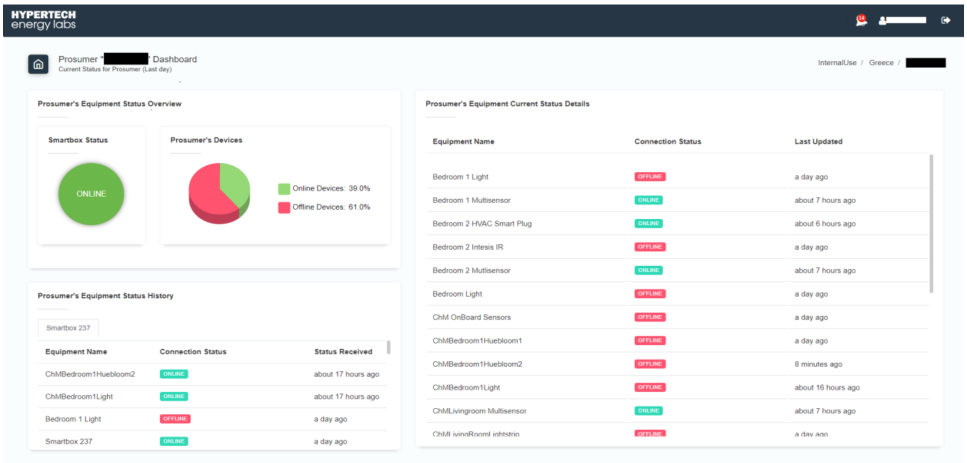


Figure 38 Network Monitoring Tool User-Interface

3.2.3 GIS Tool GSH

The webGIS visualisation tool consists of three main sub-components initializing the whole platform functionality:

- Geospatial database server, for the handling and the dynamic generation of the data regarding spatial information of issued EPCs as well as to enable the spatial functions required for storing, querying, and processing spatial features.
- OGC web server, which initialises an intermediate channel between the database and the application's main web server, disseminating stored datasets as OGC web services such as WFS and WMS.
- Web server, where the backend and the frontend environment of the webGIS visualisation tool deploying. The backend is mainly responsible for the interconnection between the frontend interface and the geospatial database via HTTP requests and the frontend is the web-based environment for the data visualization using 2D maps, charts and 3D graphics, providing also the querying structure for end users to engage with the database.

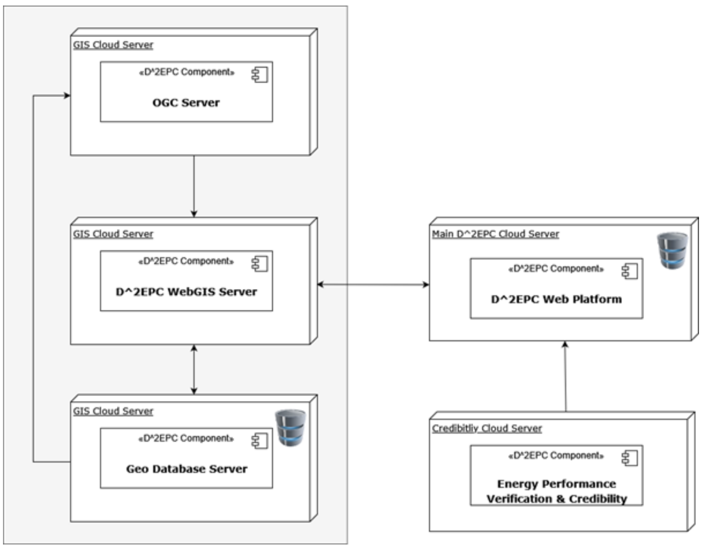


Figure 39 D^2EPC WebGIS Tool functional diagram.

The implementation of the webGIS based only on open-source libraries and tools. As depicted in Figure 39, each specific component has the following structure:

- GIS Cloud Server, implemented with the use of OGC Geoserver, an open-source server for sharing geospatial data, and the PostgreSQL database in combination with the PostGIS extension for the managing of spatial information.
- Back-end, implemented with Flask Py, a web framework which basically used for developing web applications.
- Frond-end, designed and developed with React framework and LeafletJS library for the needs of map visualization and user interaction with the spatial data. In addition, for the 3D graphical environment of the BIM demonstration used the open library ThreeJS, as well as ChartJS, for the chart demonstration of EPCs statistics.

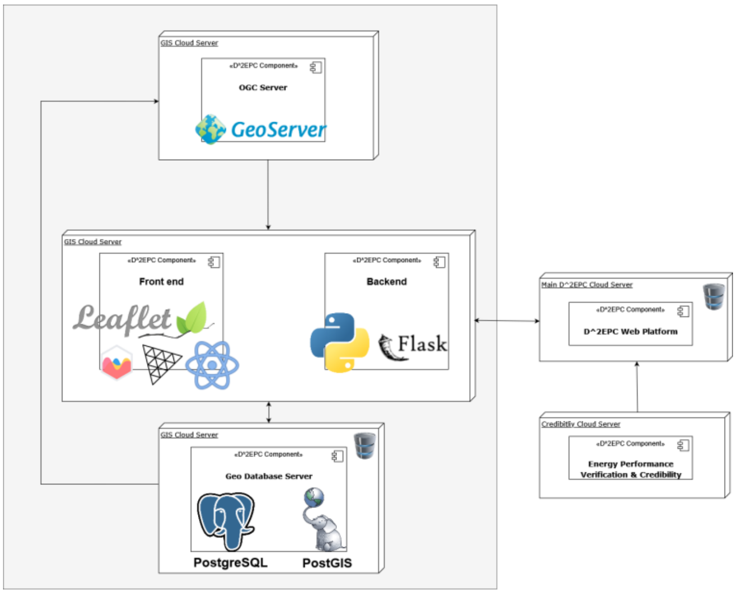


Figure 40 D^2EPC WebGIS Tool functional diagram.

The main user interface consists of several features expanding the user's capabilities and easy interaction with the several components and tools of the webGIS. Via the map frame, users can browse in the several European 4 NUTS levels, which appear in different zoom levels of the map, and have access to their EPC statistics with map and chart visualization tools.

Interacting with the vertical navigation bar, users are able to compose their own queries to the D^2EPC spatial database based on the European 4 NUTS levels, correlating them with the EPC's conditions, as demonstrated in Figure 41.

Figure 41 Example of attribute query and selection of region for visualising statistics.

Furthermore, the webGIS provides a comparison graphical tool for each of the four NUTS levels. In addition, the data dissemination tool, based on the Open Geospatial Consortium (OGC) standards, enables data downloading via a pre-specified link directly to the server side of webGIS, Figure 42.

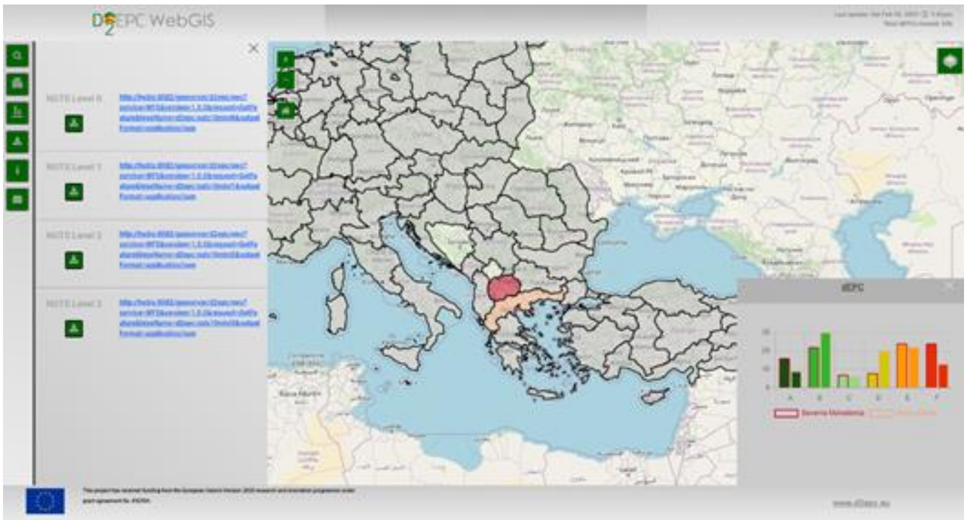


Figure 42 View of d2EPC comparison and dissemination tools.

In correlation with the above-mentioned information, a user-friendly 3D Building Information Model (BIM) graphical environment has also been developed to depict each of the six pilot cases. Complementary to the operational rating for the D2EPC 6 pilot case studies, the 3D visualization environment provides a fully interactive tool for the users to view various aspects of the building by clicking on them, Figure 43.

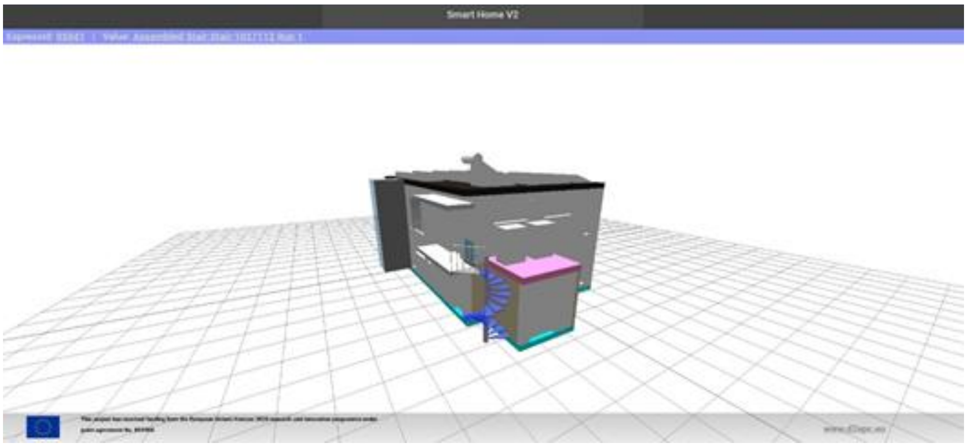


Figure 43 3D fully interactive visualisation of a pilot case building's BIM.

4 dEPC conceptual platform integration

4.1 System Architecture

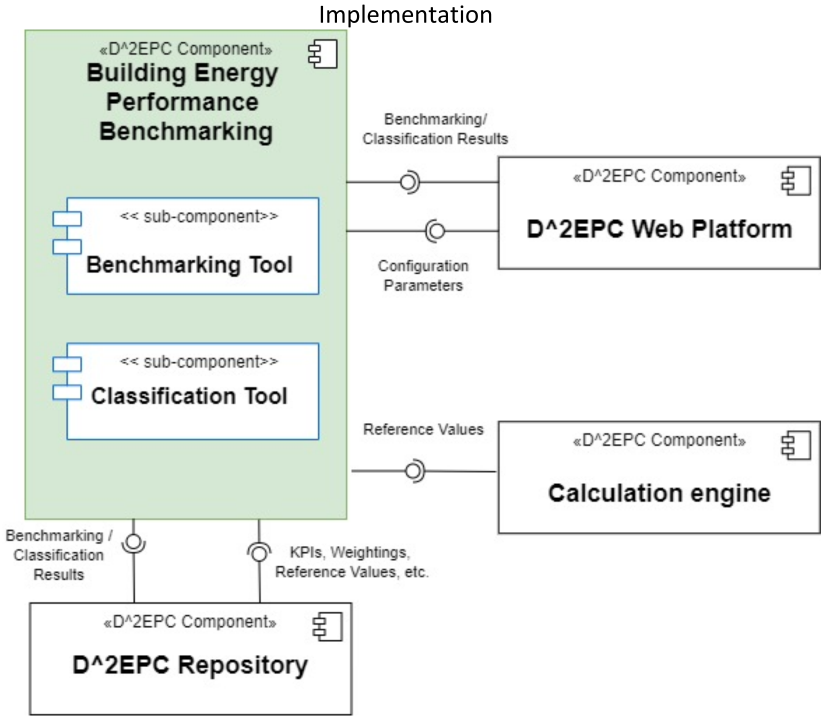


Figure 4445 Building Energy Performance Benchmarking Functional Diagram

4.2 Main User Interface Diverting for User Groups

For all user groups one common interface is made available before diverting to the user specific user interface. The user interface is different if a user group is

- Single building owner or facility manager having access to one EPC, anonymous benchmarking, renovation roadmap etc.
- Owner of a building stock having access to GIS or tabular presentation with benchmarking and same functionality with single buildings as the owner of one building
- Public administration having access to compliance on building level in GIS and street wise statistics
- Researchers having access only to aggregated data for quarters

Figure 46 shows a mock-up for the main menu, where the user classifies himself/herself into the categories.

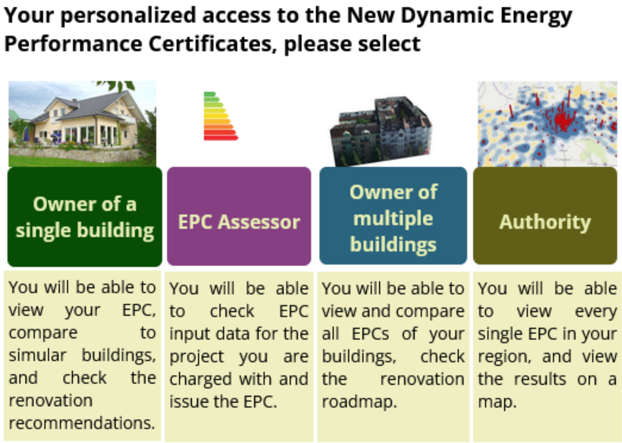


Figure 4647 Main Menu Portal

The main Portal menu allows to select the role of the uses. In the next phase the respective functions are offered. The first user group are owners of single buildings where the following functionality is offered, see Figure 48.

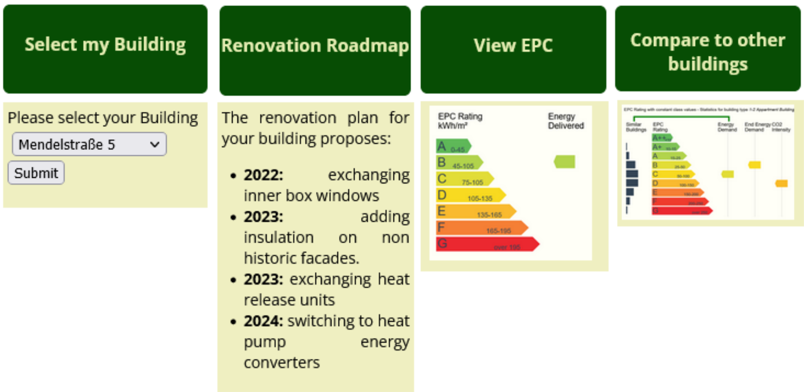


Figure 4849 Functionality for Building owners

After selection of the building (or attribution through authentication), the following information may be retrieved:

- Renovation plan
- EPC
- Benchmarking

The second user group are EPC assessors. After log-in they may check data and issue EPCs as depicted in Figure 50.

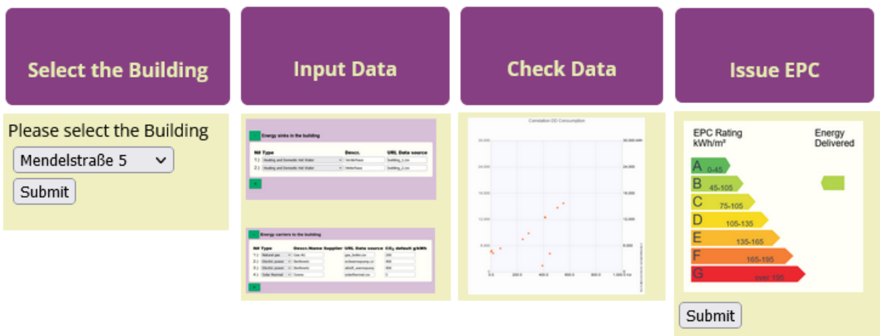


Figure 5051 Functionality for EPC assessors

The check of the input data is shown for operational EPC in Figure 52.

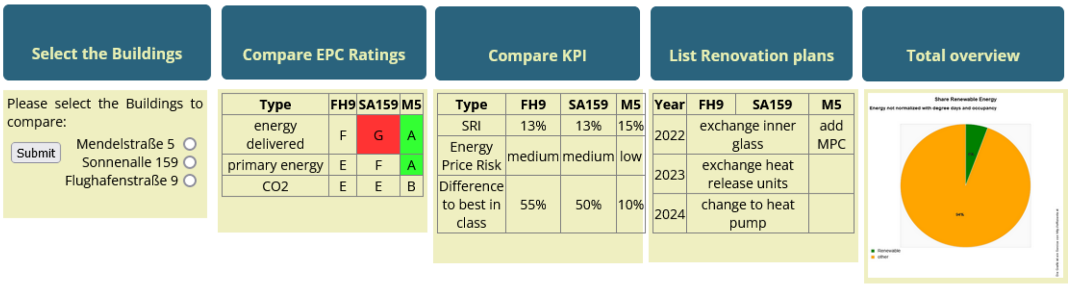


Figure 5253 Functionality for Owners of multiple buildings

The functionality for owners of multiple buildings comprises

- Selection of buildings to be compared
- Comparison of EPC rating
- Comparing KPI
- Consolidated list for renovation plans
- Total overview for renewable energy usage and CO_2 emission.

5 Conclusions

The deliverable depicts the up to date implementation of the D^2EPC Digital Platform. The main focus I placed on:

- Detailing and optimizing recommendations for renovation
- Giving an outlook about the future of the building energy demand and renewable energy share
- Reduce effort to collect data for issuing an EPC
- Allowing an overview over groups of buildings, visualizing them

The technical background is briefly described, based on which the different developed services are integrated into a common solution. The main requirements for each service/tool are listed, and the current implementation of the user interfaces is detailed. Finally, the conceptual platform integration of all services is analysed.

The challenge is to orchestrate the user interfaces with appropriate services for the user groups. In the next version of the deliverable, step services will be refined and integrating into the portal tested. In the next reporting period, the service API will be made available, so all of them can be integrated in the D^2EPC portal.

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