BuiltHub

DELIVERABLE D3.4: Platform services development

Project acronym	BuiltHub
Full title	Deliverable 3.4: Platform services development
GA no	957026
WP, Deliverable #	3, D3.4
Version	2
Date	23.02.2023
Dissemination Level	Public
Deliverable lead	EURAC
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Keywords	BuiltHub Platform, data, data representation, functionalities, features

This project has received funding from the EU's Horizon 2020 programme under grant agreement no 957026.

Disclaimer

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List of abbreviations

API	Application Programming Interface
BSO	Building Stock Observatory
CSV	Comma-Separated Values
D	Deliverable
EC	European Commission
EPBD	Energy Performance of Buildings Directive
EU	European Union
FAIR	Findability, Accessibility, Interoperability, and Reusability
GA	Grant Agreement
NUTS	Nomenclature of Territorial Units for Statistics
SPARQL	SPARQL Protocol and RDF Query Language
T	Task

1. Executive summary

The present deliverable D3.4 of the Horizon 2020 BuiltHub project has the main objective to clarify the basic development idea behind the creation of the BuiltHub platform, describing the main features that characterize platform services. The main features and graphical designs are shown reflecting the current version of the platform as of February 2024, allowing the possibility to improve and expand throughout the rest of the project.

This deliverable has been developed in close collaboration with Task 3.3 (focus group). Starting from the platform features and functioning described in D3.4, and through the testing of the alpha-version of the BuiltHub platform, this focus group gave the consortium partners feedback and contributions regarding the platform features and amelioration. Deliverables D3.4 and then D3.3 “Focus group report” are part of a continuous self-amelioration process of the BuiltHub platform bringing it as close as possible to the stakeholders’ requirements.

The Building Stock Observatory (BSO) [1] was the starting point for the development of the BuiltHub platform, as already mentioned in Deliverable D3.1 [2]. However, the BSO presented several limitations in need to be ameliorated. The BSO functionalities were included and restructured in the BuiltHub platform itself. Next, further functionalities were added to offer additional services to the final users and to better meet the requirements of the stakeholders in the BuiltHub community.

2. Introduction

The main basic functionalities of the BuiltHub platform are deepened in this deliverable. The aim is to show readers how the current version of the BuiltHub platform looks like and which main functionalities and features it offers. These were developed using a continuous self-amelioration process carried out in Task 3.3 through the involvement and consultation of a focus group. The focus group provided ideas for better meeting the needs of the end-users, to increase the efficacy of the platform itself, and to provide a better final service to the BuiltHub community, see WP2. The services are under continuous IT development in WP5. The BuiltHub platform used as a starting point for its development the Building Stock Observatory (BSO) [1] platform and its features and functionalities, restructuring them and increasing their efficacy. It not only improves the already implemented features in the BSO but also presents further functionalities not implemented in the BSO itself, which could however provide an important added value to the stakeholders in the BuiltHub community and represent novel, innovative features not available in other free databases on buildings in Europe.

The deliverable is organized so to describe the main features related to the sections in which the BuiltHub platform is divided:

- **Data library** with:
    - Ontology Viewer
    - Data Catalog
    - SPARQL for data querying
    - Data Upload
- **Dashboards** section
- **Analytics/stories** section

In the mentioned sections, which are deepened in the next chapters, a number of the basic functionalities of the BSO platform are included and ameliorated. Among them it is worth mentioning the

(i) indicators description
(ii) metadata provision
(iii) visualization options for the data
(iv) the download possibilities
(v) comparison options
(vi) higher-granularity data display
(vii) download and upload possibilities
(viii) analytics generation
(ix) the forum discussion function [3].

This process of clarification of the main features and functionalities of BuiltHub is of high importance to continue the development of the platform itself meeting the expectations of its

main stakeholders. This means developing a product able to satisfy the needs of several types of final users in the BuiltHub community, among which, see also D2.1 “Stakeholder mapping”[1]:

(a) researchers
(b) real estate developers
(c) policy makers
(d) citizens
(e) local and national authorities
(f) etc.

The results in terms of efficacy of the BuiltHub platform are related to meeting the needs of the stakeholders, which are central to the BuiltHub Consortium.

[1] https://builthub.eu/resource?uid=661. Accessed February 14, 2024

3. BuiltHub platform main structure and services

As mentioned in chapter 2, the BuiltHub platform is developed to improve the service provided by the Building Stock Observatory (BSO) data platform [1]. It was decided to keep useful features, functionalities and services provided by the BSO platform as a starting point for the development of the BuiltHub platform, aiming for a further amelioration of these services and implementing new functionalities for adding value to the new platform itself. The main impacts of the BuiltHub platform are related to the accessibility of the platform and added value for the stakeholders mentioned in chapter 2. The actual structure of the BSO was indeed modified and ameliorated. As of November 2022, the BSO platform consisted of three separate sections:

- Database
- Data-mapper
- National/Thematic factsheets

A brief definition provided by the BSO itself of these three sections is presented next:

- **Database:** The Database is a collection of data/information organized according to the spatial and temporal clustering available. The data are in this case organized according to different thematic areas and represented in tabular form, ready to be consulted or

> "There are 250 indicators feeding into the BSO database. The indicators are organized according to ten thematic areas:
>
> - building stock characteristics
> - building shell performance
> - technical building systems
> - Nearly Zero-Energy Buildings
> - building renovation
> - energy consumption
> - certification
> - financing
> - energy poverty
> - energy market
>
> Every set of data can be viewed per topic, year and country, or the EU as a whole. Once you have selected the indicators, the data is presented in summary tables and graphs, with references to every data source. The sources come from EUROSTAT, the European Commission's Joint Research Centre (JRC), EU funded projects, data from national and official statistics in the EU countries, databases on energy performance certificates and data from market providers, among others."

Box 1: Database definition according to the BSO description [1].

downloaded by the final users. The following Box 1 reports the description of the database provided by the BSO [1].

The initial subdivision between database and data-mapper is a structure that the BuiltHub platform aimed to overcome by creating instead a single user experience for accessing, visualizing, and analyzing building stock data bringing together different datasets in a standardized data model. This aspect is an innovation that is not yet available in other European building stock databases and will be better explained and illustrated in sub-chapters 3.1 and 3.3.

- **Data-mapper:** The data-mapper is a fundamental tool allowing final users to visualize the data in a graphical format instead of the tabular one provided by the database. This results in a better comprehension of the analyzed data and allows a better and easier distribution to the final users. The BSO as of November 2022 [1] provides a data-mapper, which is based on a map at NUTS0 (Nomenclature of Territorial Units for Statistics) level allowing the selection of the countries in which the end user is interested in. Through a drop-down menu it is possible to select the desired indicator and time period. The two maps/graphs provided are a colored gradient geographical map at NUTS0 and a bar chart. A basic description of the data-mapper provided by the BSO platform itself is reported in Box 2.

> **Data-Mapper according to the BSO description**
>
> "The BSO data-mapper is using maps and graphs to present indicators and allows users to compare the related information and data between EU countries."

Box 2: Data-Mapper definition according to the BSO description [1].

As already mentioned, concerning the BSO database, the data-mapper and the database are united in the BuiltHub platform in a single section with several dashboards, in which data in different formats can be filtered, visualized, and downloaded. Furthermore, some more features and functionalities for data analysis are implemented in the analytics/stories section, see sub-chapter 3.4, to offer a more extensive service to the end-users.

- **National/Thematic factsheets:** National factsheets are specific collections of data provided by the platform, which are elaborated and shown to provide the final users with a clearer view both on a specific thematic area and on a specific country. This means that the user has the possibility to choose among the different indicators or among the different geographic areas represented in the platform itself. The platform thus provides specific graphs, plots, maps and comments about the selected indicators or areas. This is exactly what the BSO provides to its users [1]. A definition of the BSO national factsheets is provided in Box 3. A specific section for national or thematic factsheets is not integrated in the BuiltHub platform since the new selection structure for the items to visualize already entails a similar function. This will be explained in more detail in sub-chapter 3.3.

National factsheets according to the BSO description

"To promote and publish the results from the database, the BSO produces both thematic and country-specific factsheets that address the most relevant issues, present results in charts and tables, and provides customized descriptions of the data.

The factsheets present the most important features, including indicators and recommendations, in relation to implementation of EU buildings legislation. They also present key statistics, analysis, and policy context. The country-specific factsheets also provide a national policy context."

Box 3: National factsheets definition according to the BSO description [1].

National and thematic factsheets are not relevant anymore, given the new indicators selection system implemented in the BuiltHub platform. Indeed, through the new selection system it is possible to visualize the indicators available for a certain nation/geographic area, or vice-versa, all geographic areas available for a specifically selected indicator. This aspect is explained in more detail in sub-chapter 3.1.

3.1. Main structure of the BuiltHub platform

The main structure of the BuiltHub platform was developed and implemented to target the most pressing needs expressed by the BuiltHub community. The research for specific indicators is facilitated through a new "search system", which offers a clear view on which data is available and for which geographic area. This "search system" is discussed and detailed in sub-chapter 3.3.

The BuiltHub platform is structured in several main sections, providing different services to the end-users who can freely access the platform after registration. More details concerning the registration modalities and use are provided in sub-chapter 3.2. The main sections in which the BuiltHub platform is subdivided are the following:

- Data library with:
    - Ontology Viewer
    - Data Catalog
    - SPARQL for data querying
    - Data Upload
- Dashboards section
- Analytics/stories section

The aforementioned sections are shown in a schematic representation in Figure 1. More information concerning the sections can be found in the following sub-chapters in this document.

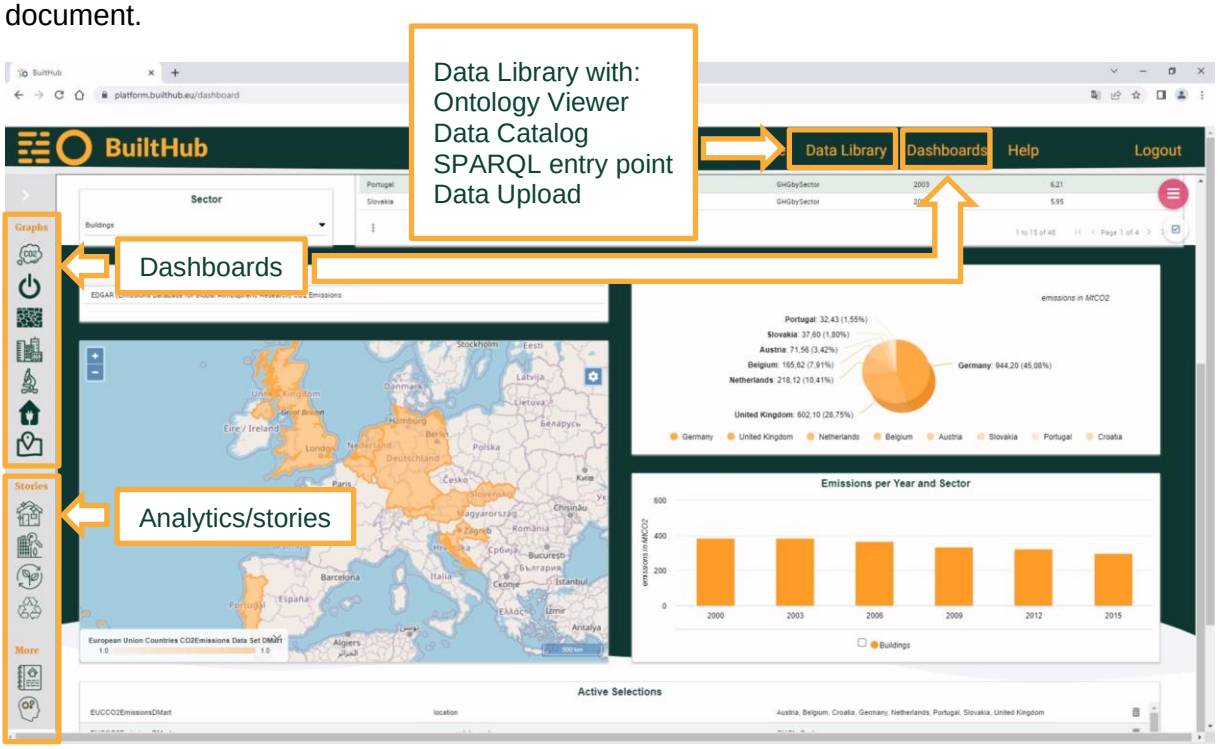


Figure 1: Main sections accessible by the BuiltHub platform: Data Library with Ontology Viewer, Data Catalog, SPARQL entry point, and Upload facility, Dashboards with data tables and visuals (shown in the figure), and Analytics/stories section.

The **Data Library** provides data space professionals (data scientists, engineers, analysts, architects, etc.), researchers, and software developers with several tools to understand the underlying data model, among which:

- **Ontology viewer**, see Figure 2.

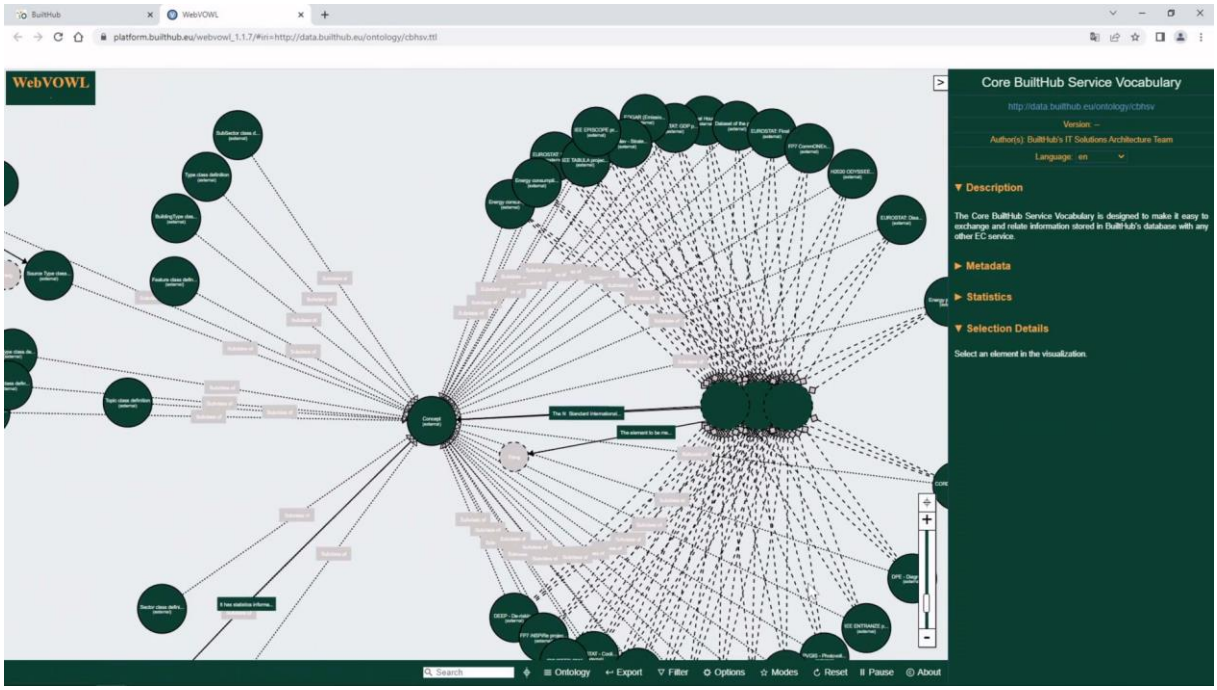


Figure 2: Ontology viewer for the BuiltHub ontology

The ontology viewer provides an interactive visualization of ontologies, making it easier for users to understand the structure and relationships of the BuiltHub datasets along with their classes and properties. This allows developers and ontology engineers to debug and validate ontologies, ensuring consistency and correctness in the ontology design. The WebVOWL visualization tool employed on the BuiltHub platform can be used to generate visual documentation for ontologies, making it easier for stakeholders to understand and collaborate on ontology development projects. Integration with other semantic web applications is possible.

- **Data Catalog,** see Figure 3.

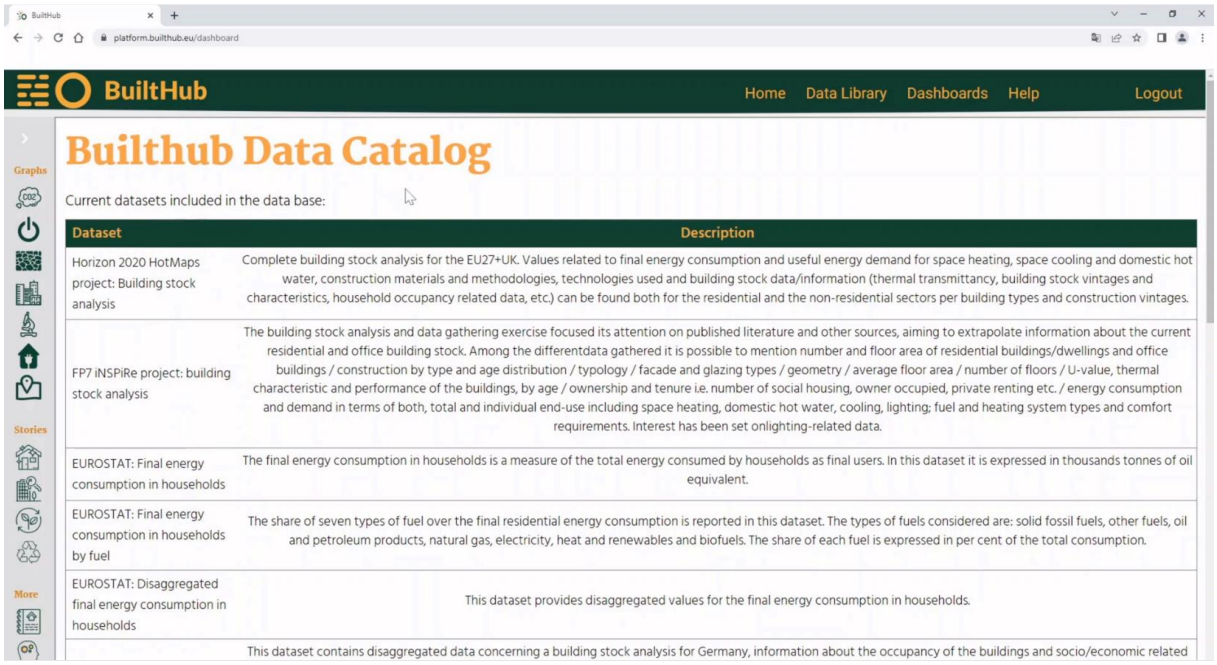


Figure 3: BuiltHub data catalog

The data catalog shows all datasets included in the BuiltHub database. It provides a description of the contents of each dataset. When clicking on the name of a dataset, a page opens providing further details, such as the covered NUTS level, sectors (residential/services), subsectors/building types (single-family houses, offices, etc.), time ranges (e.g., for construction periods), and “predicates” (conditions for filtering), with standardized validation possibilities such as data type, allowed range, and cardinality, see Figure 4.

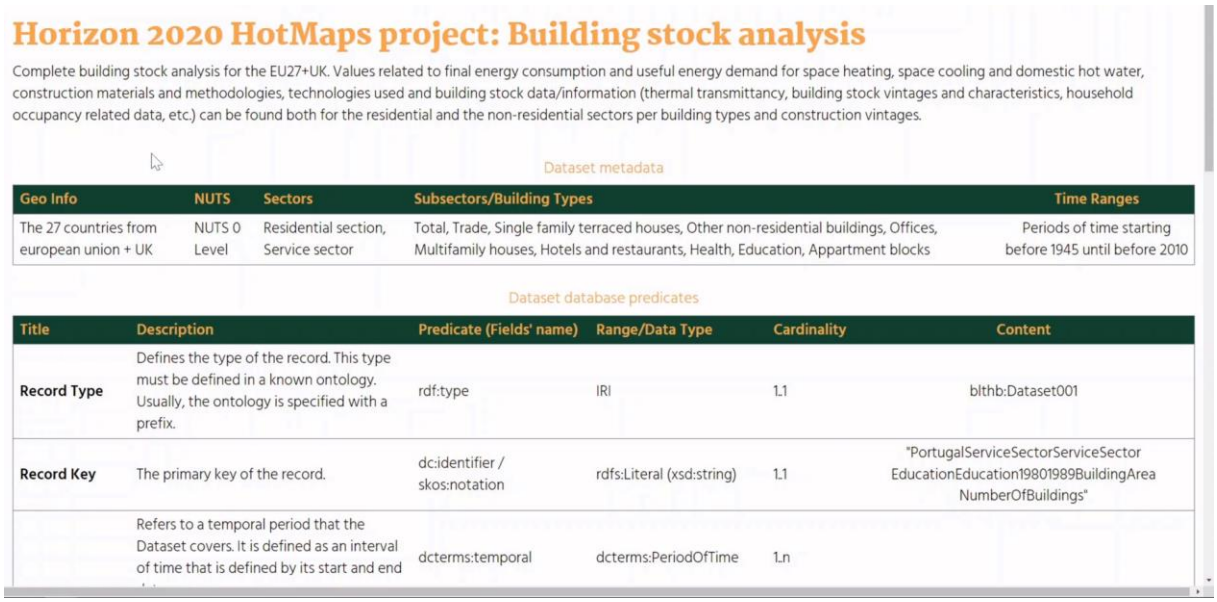


Figure 4: Description and metadata for a BuiltHub dataset

- **SPARQL entry point**

It is indicated for advanced end-users, such as professionals and researchers (data scientists, engineers, analysts, etc.), real estate developers, and authorities. The platform will give experts the possibility to code and launch their own queries, as shown in Figure 5. Users with less expertise can leverage pre-coded queries offered as sample queries, copying them over and adapting them if needed. An example of application related to the SPARQL entry point is the possibility to create a search for multiple data types across multiple datasets in one go within the BuiltHub platform itself. This is an innovative feature building upon state-of-art developments in graph databases. While graph databases are common in other domains[2], the BuiltHub platform is the only platform currently providing such a feature for free in relation with building sector data. More information concerning this section is provided in sub-chapter 3.5.

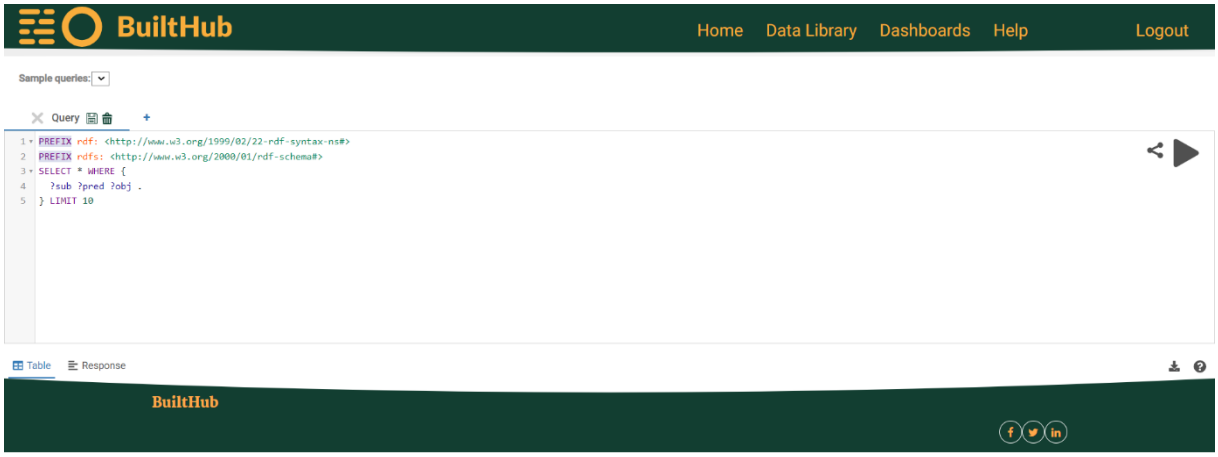


Figure 5: BuiltHub SPARQL entry point with the query editing window

- BuiltHub **data upload** facility (Figure 6)

It allows users such as authorities, energy agencies, and statistics institutions to extend the data on the platform choosing the appropriate data model from a drop-down list. This allows a sustained data flow over time.

- BuiltHub **integration services**

They are not graphically visible on the platform itself, but accessible from external applications such as MS Excel, as explained in the platform guidelines and videos under the “Help” menu. They offer **several types of APIs** (Application Programming Interfaces) for programmatic or enhanced data download, including a REST API and an OData feed allowing interoperability with MS Excel and other office applications. This is a unique feature of the BuiltHub platform not yet available on other free platforms informing about the European building stock. It proposes a method for Member States to comply with the future requirement to periodically

[2] An example is the Internet Movie Database (IMDB), https://www.imdb.com/. Accessed February 15, 2024.

send data about their building stocks to the European BSO. Member States could thus use the BuiltHub platform as playground to first analyze their data, before committing it to the EU BSO.

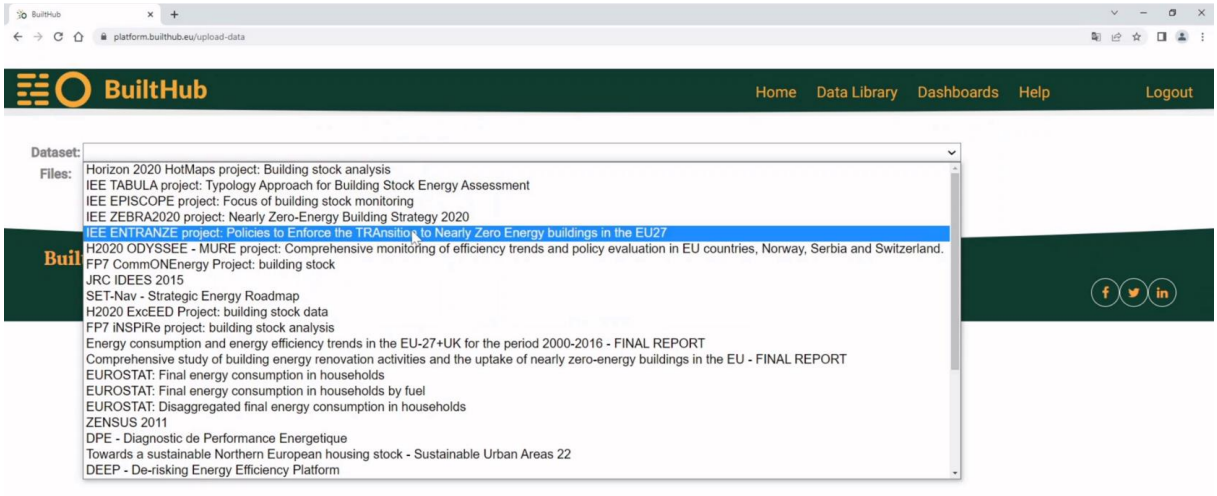


Figure 6: Data upload facility

Currently, access to this upload facility is free for all users. Some restrictions related to the users' rights to access its functionalities may be implemented in the future, see sub-chapter 3.2. In this section, it will be possible to upload raw data in a specific format and structure according to the underlying data model, allowing for extensions and updates to the data on the platform. The raw data will then be processed according to the platform data pipeline.

In the future, this section may be made accessible only to data providers and users authorized to update the raw data, to prevent unauthorized tampering, which would potentially undermine the reliability of the data shown. Then, unauthorized end-users would only be able to access some (if not all) of the elaborated data provided in the Dashboards and Analytics/stories sections. Data providers and premium users may be granted access to exclusive dashboards.

Authorized data providers, when uploading their data, must pass the data model conformity and ETL (Extract, Transform, Load) processes of the BuiltHub platform to allow the integration into the BuiltHub database.

The **Dashboards** section is the main entry point for most end users of the platform and especially suitable for citizens, policy makers, real estate developers, and local and national authorities. It is the part of the platform where all datasets can be queried and shown in tabular format and through graphs. One of the limits of the BSO platform is the division between the database and the data-mapper, which does not allow a smooth navigation through the available data and data representation formats for the end-users. This subdivision is eliminated by the BuiltHub platform, in which a single section for the access to all the data types and formats is present. This section of the platform will be deepened in sub-chapter 3.3.

The **Analytics/Stories** section is dedicated to analytics services and visualization of "stories", i.e., insights from datasets with interactive features for data exploration and recommendations. This section allows more advanced users and professionals such as real estate developers and authorities to analyze the available data but can also serve as support for basic data science and research tasks. This section of the platform will be deepened in sub-chapter 3.4.

3.2. Access modalities

While in the current version of the platform as of February 2024 any registered user has free access to all sections, different levels of access may be granted to end-users in the future. This allows distinguishing simple data users from those who also provide data and from users with more technical skills capable to fully exploit the integration services and create more advanced queries with the SPARQL entry point. This distinction can be done through an access portal. End-users would need to register to a specific service and thus get access to different specific areas according to their credentials.

Figure 7 shows the current access page of the BuiltHub platform.

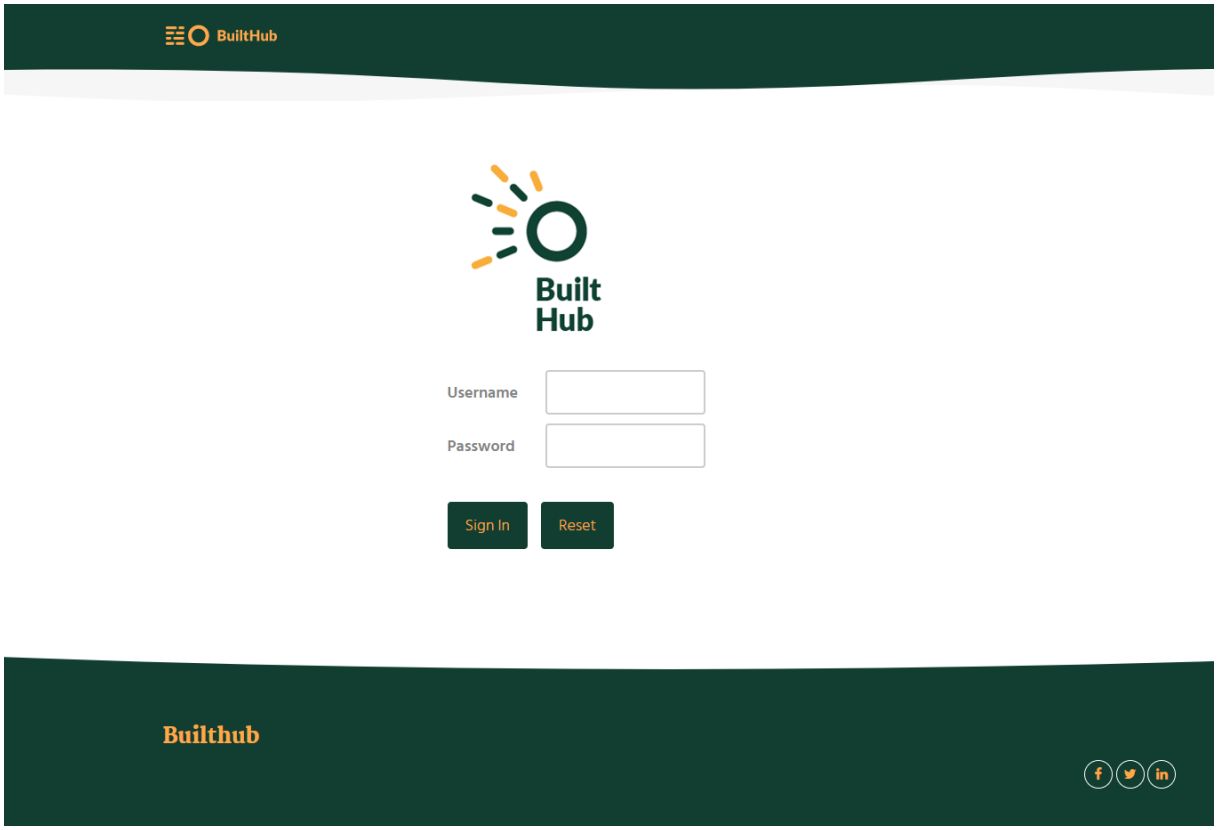


Figure 7: Access page to the BuiltHub platform

The use of such a registration system allows platform administrators to monitor the use of the platform and understand which services are most used and appreciated by the end-users, guiding future improvements.

Such a registration system can further serve to provide added services or functionalities to a subset of (e.g., premium or official) end-users sharing data and not only downloading/using the data already present in the platform. This could indeed be an incentive for data providers to share their knowledge and upload their data/information to the platform, contributing in this way to the development of the BuiltHub community itself.

3.3. Dashboards section

In this chapter, the most relevant ameliorations and focus points of the dashboards as suggested by the BuiltHub community through the stakeholder engagement actions (surveys, focus groups, dialogues, workshops, webinars, third-party events; see WP2) are listed and described in each paragraph following the list item.

- **Improved smoothness of navigation and data mining, showing map, tables, graphs, and action buttons (filtering, downloading) on a single page.**

The BSO as of November 2022 presents a clear and well-defined distinction between the database and the data-mapper, not allowing the end-users to smoothly move from one to the other [1]. This distinction represents an obstacle to the user friendliness of the platform, and thus it has been decided to remove it by creating a single section where users can set filters on the whole dataset and then see a map of the regions the filtered data pertains to and the filtered data itself, both in tabular format and in graphs. Users can also directly download the data. It is thus possible to explore the data in all types of formats without changing the section used, contrary to the handling on the BSO platform where users have to switch between Database and Data-mapper.[3] This section will allow the end-users to easily navigate through the available data in the platform choosing which type of data to visualize or download and in which visual representation. This important, unique aspect of the BuiltHub platform can be resumed in an improved smoothness of navigation and data exploration. Figure 8 shows as example of this integration the dashboard on CO_2 emissions from EDGAR (Emissions Database for Global Atmospheric Research) filtering from the whole dataset for countries France, Germany, Italy, and Spain, and for the years from 2015 to 2018. The map and diagrams update accordingly on-the-fly, and the user can hover with the mouse over parts of the diagrams to get more information including the numerical values provided in the table for cross-checking.

[3] Update: in February 2024, the BSO is undergoing heavy changes, many of which are in line with BuiltHub's platform and suggestions.

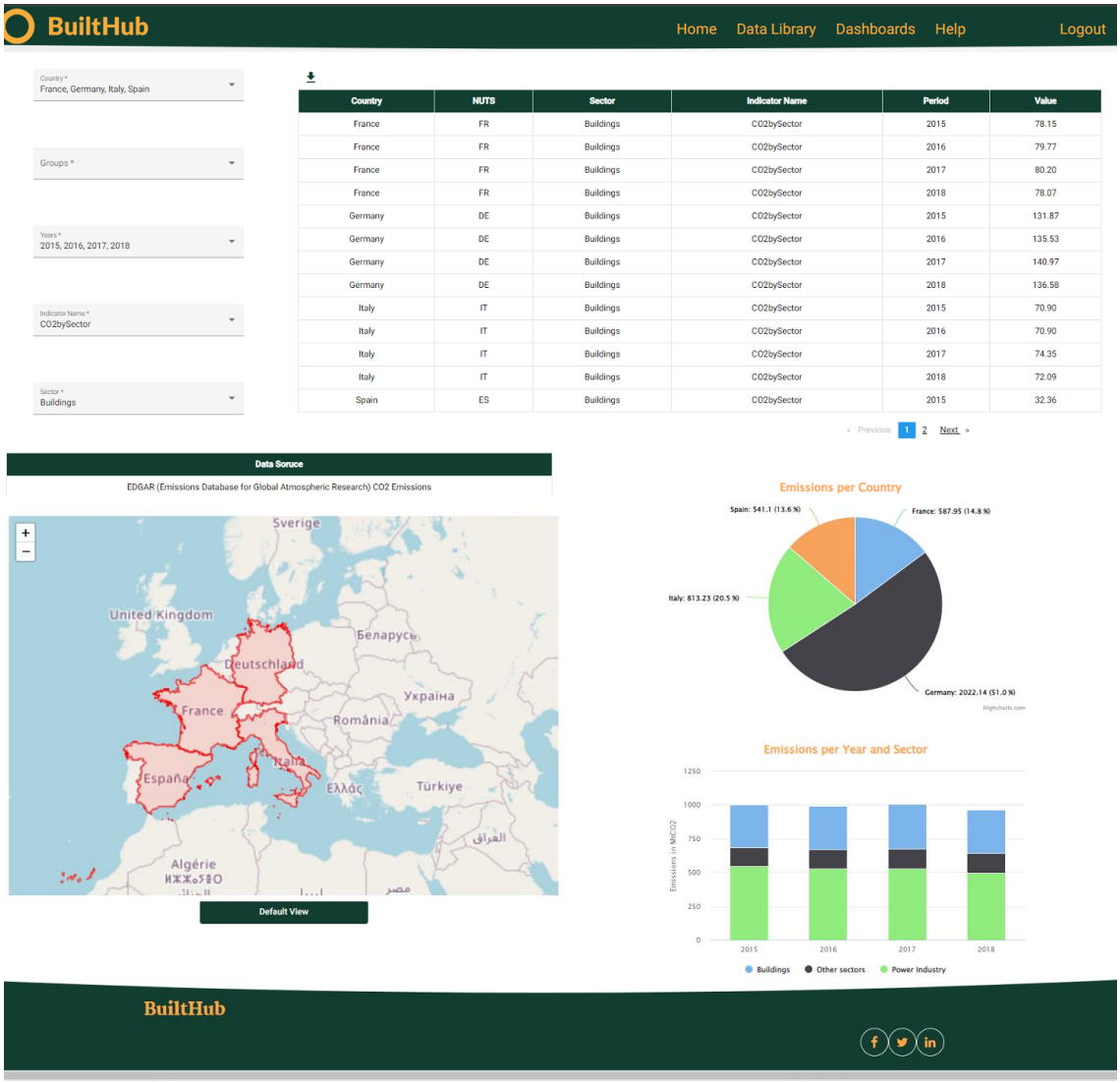


Figure 8: Emissions dashboard

- **New “search system” for the selection of indicators**

End users have numerous possibilities to navigate to the information they are looking for. Most users, such as citizens, administrators, building stock managers, and policy makers, are expected to use the dashboards and filters provided on the dashboards. Expert users, such as data scientists and researchers, can additionally make use of the SPARQL entry point and integration services.

- **Display only available information**

This aspect is also sustained by the development of the filtering mechanism in the search system, allowing the end-users to have a better navigation through the available indicators. This new mechanism is not based as the one of the BSO on the visualization of all indicators/nations but on gradual filtering. A selection in one filter dynamically determines the options in other filters such that the end-user can only request data effectively available. For instance, the selection of a geographic area filters the indicators down to those available for that area. The same approach can be used the other way round, by letting the end-user

selecting an indicator and then only allowing filtering the nations/geographic area this indicator is available for. In this way it will not happen as it was for the BSO to search for an indicator and get a message that no results were found. These aspects can be resumed in the two aforementioned bullet points.

- **New indicators with respect to the BSO and detailed description thereof**

The indicators provided by the BSO differ from the ones provided by the BuiltHub platform. The latter consist indeed of a selection of the most relevant ones provided by the BSO and a set of newly selected ones by the BuiltHub Consortium according to the feedback from the BuiltHub community and developments at European level such as the EPBD recast. The thematic building stock areas available in the BuiltHub platform in the version as of August 2023 concern emissions, energy, census data, and energy renovation. Furthermore, the description of the displayed indicators has been improved with respect to the BSO (version August 2023), which does not provide any information concerning the indicator but only the name of the indicator itself. The BuiltHub platform provides instead a detailed description and metadata through the Data Catalog.

This aspect is also shown in Figure 9.

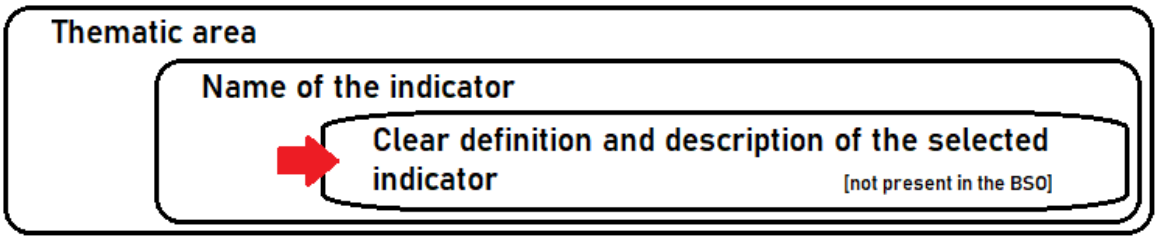


Figure 9: Definition scheme of the available indicators in the BuiltHub platform

- **Improved metadata provision**

One of the most critical points of the BSO is the poor provision of metadata [1]. Often referred to as data that describes other data, metadata is structured reference data that helps to sort and identify attributes of the information it describes. Metadata are indeed fundamental for guaranteeing a high-quality level service to the end-users. As explained in deliverables D3.1 and D3.2 of the BuiltHub project, metadata need to guarantee the FAIRness of the provided data (Findability, Accessibility, Interoperability, and Reusability) [4]. For end-users it is fundamental to have the possibility to clearly trace the displayed data back to their original source. In order to achieve this target, the Data-Cite [5] and Schema.org [6] schemas have been used as a basis for the creation of a list of fundamental metadata to be collected. More specifically, the metadata collected are the following: Name, Content, Author/s, Dataset URL, Reference and publication year, Spatial extension, Granularity, Methodology URL, Methodology description, Accuracy, Completeness, Source, Access, License, Terms of Use, Source type. The visualization possibilities of the metadata are related to the possible visual representations of the data themselves (tabular, plot, map, etc.). The Data Catalog is the technical solution created for the BuiltHub platform to link the data to the metadata. The provision of improved metadata is a relevant added value of the BuiltHub platform.

- **Higher granularity than NUTS0**

The BSO stops at the NUTS0 level, which is the national, EU country level. BuiltHub showcases in several dashboards data exploration at higher spatial granularity, up to NUTS3. For instance, Figure 10 shows the Census data dashboard. The Census data was used since it is one of the few datasets available on buildings with such a level of detail.

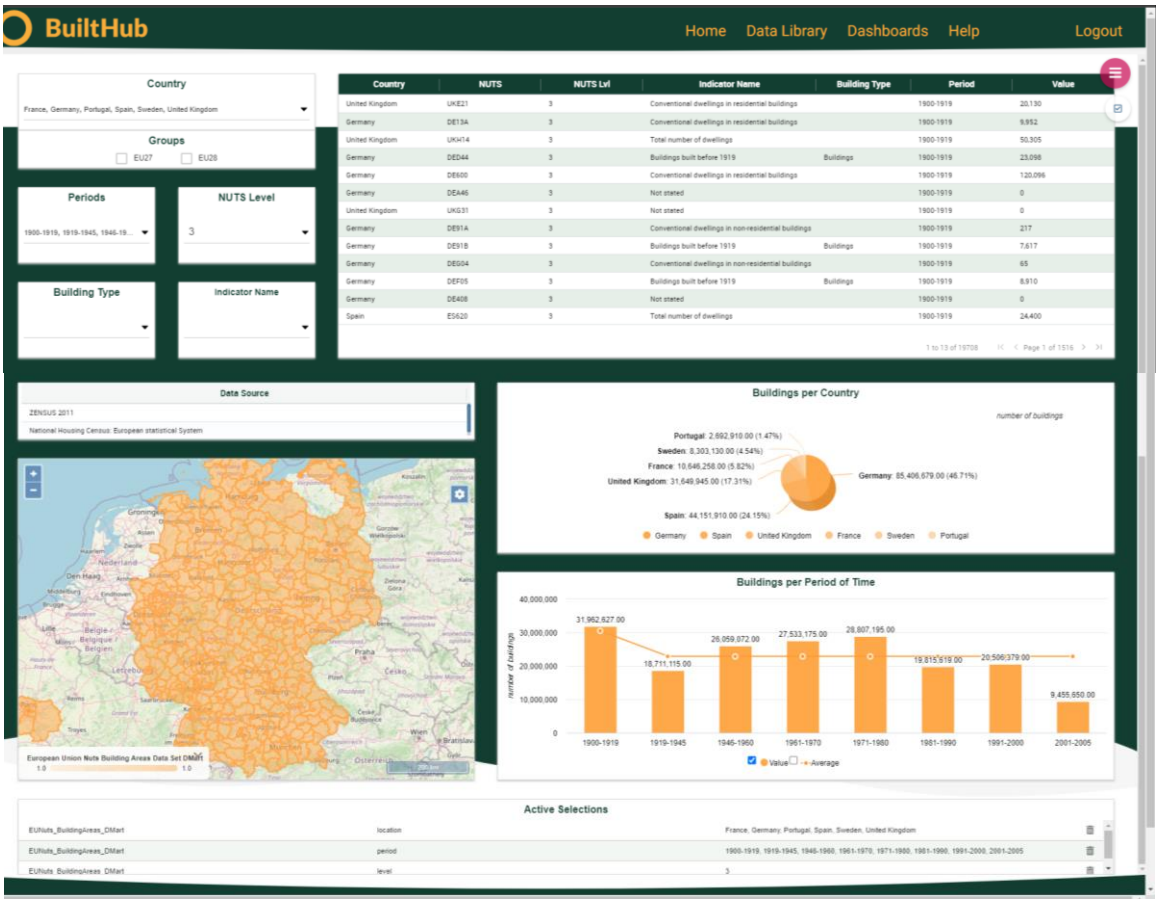


Figure 10: Census dashboard showcasing data exploration at different NUTS levels up to NUTS3

As another example to showcase this functionality and business case, the BuiltHub platform has integrated a dataset on energy consumption characteristics and their energy savings potential for several districts in Belgium, see sub-chapter 3.4.

Another page on the platform providing data at different NUTS levels is the “Territorial-Unit Consumption” story, see sub-chapter 3.4.

Integrating data at higher-than-national granularity is one of the most useful and recommended features according to the BuiltHub community’s feedback since it allows much more targeted and detailed building stock monitoring and planning of actions. It is therefore of particular use to local authorities (e.g., municipalities), policy makers, energy agencies, and researchers.

Representing more granular data for the building sector, combining filtering, tables, a map, and visuals in one dashboard, is an innovative feature that is unique to the BuiltHub platform.

- **Updated visual geographical representation**

A further visual representation option is related to the use of color gradient geographical maps. The geographical maps allow end-users to explore granularities at much higher resolution than a fixed NUTS level. The demonstration of this feature on the BuiltHub platform is given through the “Geo Information” dashboard, see Figure 11. This dashboard allows authorities, citizens, and policy makers access to contextual information such as the climatic conditions and renewable energy potential of a region.

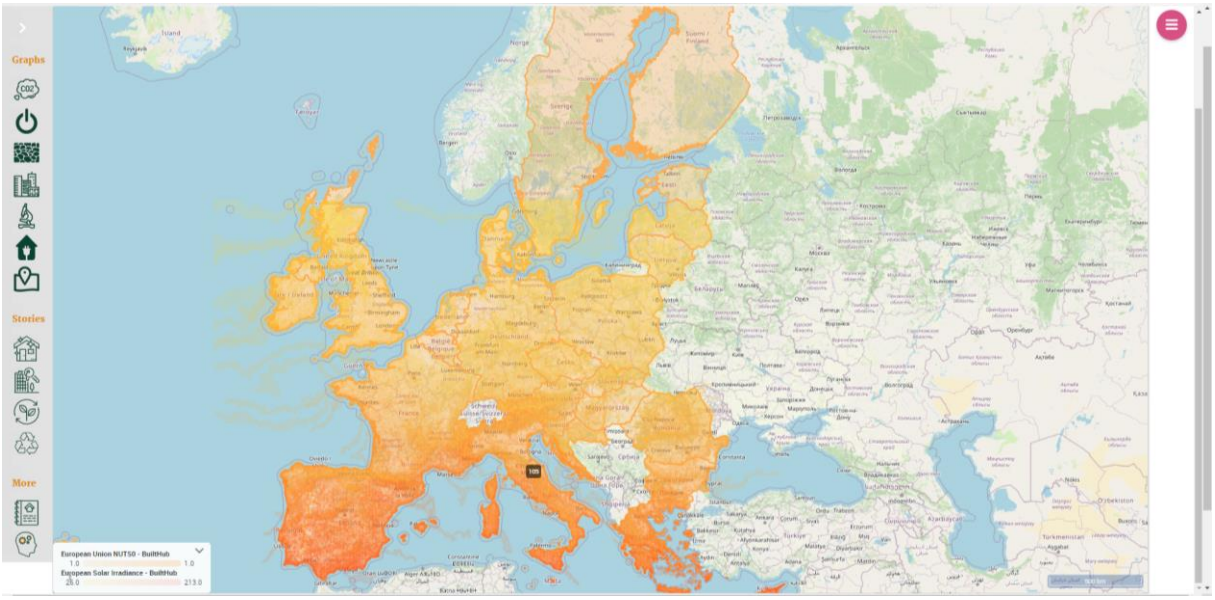


Figure 11: Geo Information dashboard with solar irradiance layer shown

- **Integration of totals, shares, and averages for the selected data**

The BuiltHub platform shows totals, averages, and shares (percentages) in the dashboard visuals calculated from the raw data uploaded to the platform. Grouping (e.g., selecting data at NUTS0 or for the whole EU-27 rather than for single Member States) automatically updates the calculation of respective totals, averages, and shares. The presented parameters depend on the type of graphical representation chosen by the end-users. For instance, some bar charts have overlay lines representing averages. Furthermore, there are stacked bar charts showing shares.

- **Free download of all data**

As for the BSO, all raw and transformed data on the BuiltHub platform can also be downloaded for offline use or further elaborations.

Table 1 summarizes all the added values and functionalities. They cover a wide range of aspects, starting from the user interface of the platform to more technical aspects such as download, visualization, and integration options.

Note that this deliverable provides a view of the current state of progress of the platform. The platform is built to scale up and allow for further improvements and extensions as needed.

Table 1: Summary of the main added values and functionalities integrated in the dashboards section of the BuiltHub platform

Added values and functionalities integrated in the dashboards section of the BuiltHub platform
Improved smoothness of navigation and data mining
New “search system” for the selection of indicators
Display only available information
New indicators provision with detailed description and metadata provision thereof
Higher granularity than NUTS0 (Nomenclature of Territorial Units for Statistics)
Updated visual geographical representation
Integration of totals, shares, and averages for the selected data
Free download of all data

This dashboard section together with the analytics/stories section are envisaged as the most utilized parts of the platform by end-users. The sections allow download, dynamic exploration, and analysis of all collected data.

3.4. Data analytics and stories section

The data analytics and stories section provides end-users with additional services and insights going beyond the collection and diffusion of data/information. While the current version of the platform offers free public access to all sections, the platform architecture allows the creation of new analytics/stories for business clients related to the type of license and with access strictly reserved to a single customer. This feature is important to be able to build business models enabling economic viability of the platform in the long run, see also the deliverables of WP6.

These analytics/stories represent a fundamental added value provided by the BuiltHub platform otherwise not available in building data platforms freely open to the public.

Analytics/stories currently implemented on the platform include:

- **Comparison of a single indicator available in two different datasets**, see Figure 12**.**

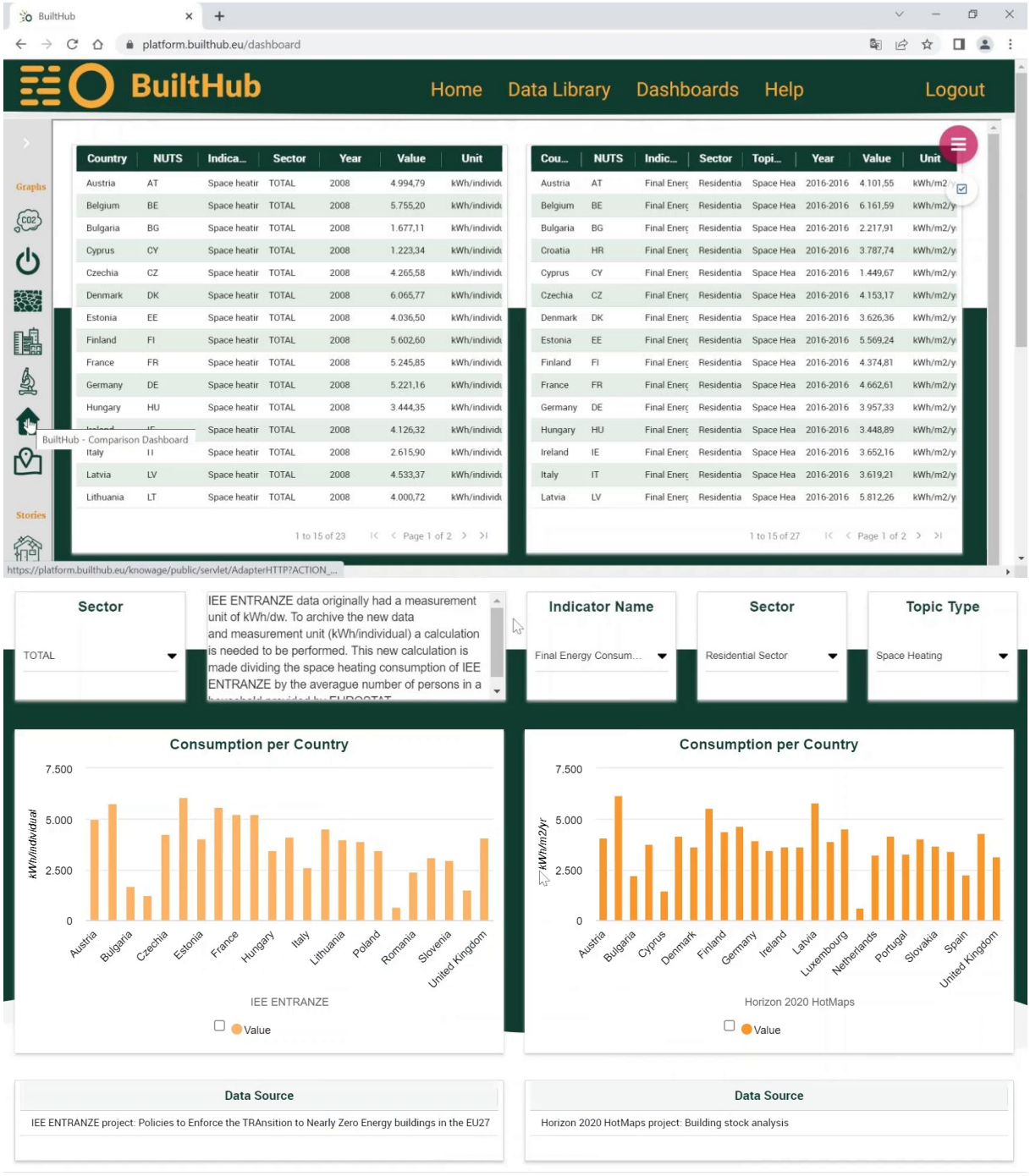


Figure 12: Comparison dashboard

One of the additional services the BuiltHub platform provides is the possibility to compare data from different sources. For a specific indicator/year/granularity, there could be multiple values depending on the data source used. Stakeholders in the BuiltHub community, among which researchers, consultants, and energy agencies, stated their high interest in a service allowing them to compare those values for quality checking and validation purposes. For this reason, BuiltHub created this comparison dashboard.

The end-users will be supported in comparing and choosing among the provided data the dataset they consider best for their purposes. BuiltHub will not comment on the provided data quality. Instead, end-users are encouraged to use the Openmode forum to discuss the provided data [4]. The Openmode forum allows end-users to discuss and provide added value to the community through their comments. The possibility to have interactions among the different end-users of the BuiltHub platform represents a requested added value.

- **Indicators derived from a combination of several datasets**

End-users in the BuiltHub community have expressed high interest in tables and visuals showing key performance indicators derived from combining several datasets in a meaningful way. While researchers and data scientists would typically download the raw data and then proceed with the creation of their own transformation and visualization processes, visualizing on a platform such derived indicators can be of great value to end-users working in other fields than data science such as authorities, administrations, policy makers, and real estate managers.

Figure 13 shows an example. In the figure, the Hotmaps project dataset was combined with Eurostat data to calculate the final energy consumption in residential buildings per energy carrier and inhabitant. Different end-users have best familiarity and judgment with different types of indicators. Hence, providing end-users directly with the indicators most suitable to them is an important support. To the knowledge of the consortium, this is a novel, innovative feature not yet offered on other free platforms informing about the European building stock.

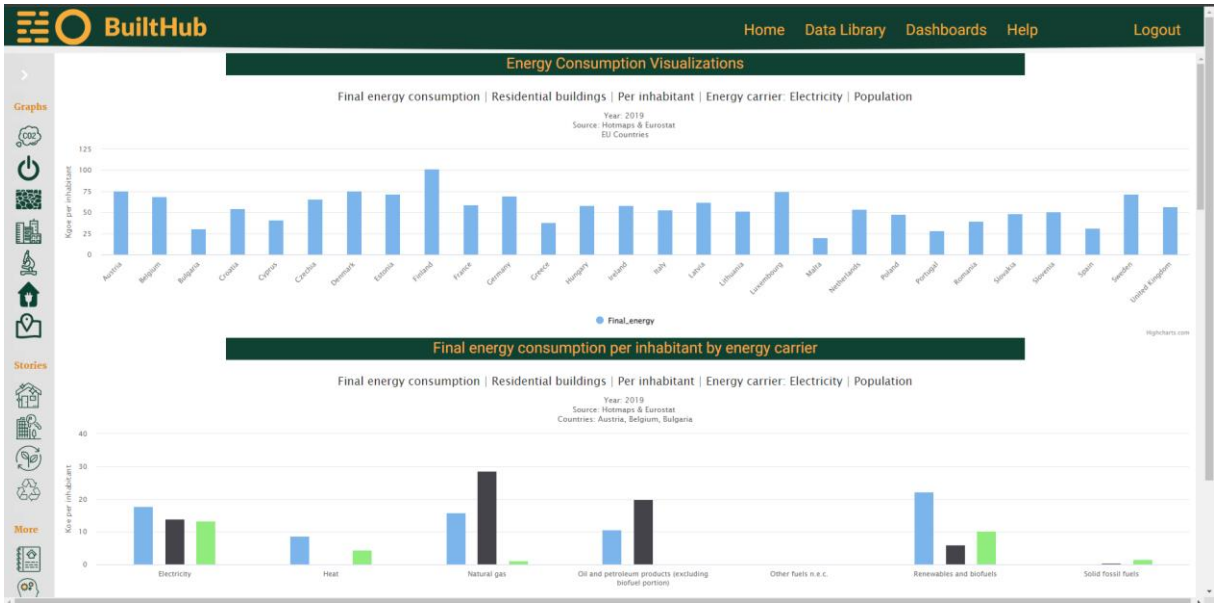


Figure 13: Final energy consumption per energy carrier and inhabitant

- **Comparison of regional data up to NUTS3 (small regions)**

The BuiltHub platform shows the integration of regional data at different NUTS levels provided by single projects into dedicated dashboards. This data is then compared in tables and visuals that the end-user

can generate and explore dynamically and interactively with the filters, drop-down menus, and by hovering with the mouse over the data.

Figure 14 shows the **BE REEL! district renovation story**, i.e., how the BuiltHub platform has integrated and transformed data on energy consumption on energy saving potential for three municipalities in Belgium as provided by the BE REEL! project.[4]

Period	Terraced	Semi-detached	Detached	Apartments	Others	Total
Before 1900	271	145	128	26	4	574
1900-1918	363	71	25	24	3	486
1919-1930	620	161	17	31	7	836
1931-1945	786	161	31	44	6	1028
1946-1960	957	796	123	46	7	1929
1961-1970	439	679	330	216	3	1667
1971-1980	260	606	605	411	5	1887
1981-1990	147	323	494	272	2	1238
1991-2000	72	284	436	308	7	1107
2001-2010	224	278	157	550	8	1217
2011-2020	192	241	87	611	2	1133
Unknown			1	14	16	31
Total	**4331**	**3745**	**2434**	**2553**	**70**	**13133**

District	Houses	Average floor area (m2)	Total floor area (m2)	Specific energy consumption (kWh/m2)	Total adjusted energy consumption (MWh/yr)	Total calibrated energy consumption (MWh/yr)	Reduction potential (MWh/yr)
BAVIKHOVE	1631	157	270431	142	36936	48385	9931
HULSTE	1496	156	233212	145	32890	47476	9618
HARELBEKE	10006	144	1372744	138	182914	222587	46064
Total	**13133**	**148**	**1876387**	**140**	**252740**	**318448**	**65613**

[4] https://www.be-reel.be/. Accessed February 15, 2024.

1.3 Energy consumption and reduction potential by district (cartographic representation)

Select sectors or districts to visualize them on the map

Sectors Districts

Default View

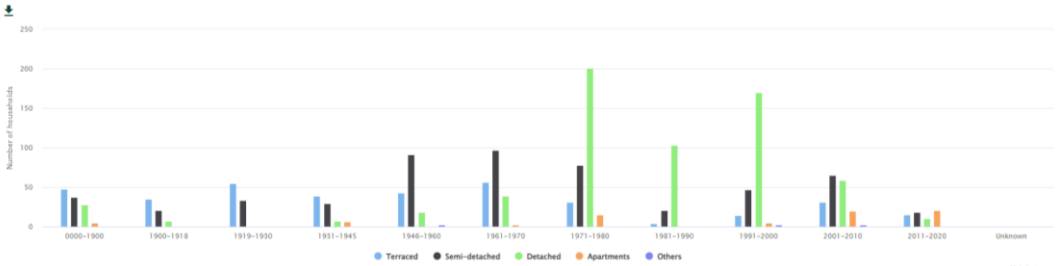
2. Overview at the level of the district

Here you can filter by districts. If you select more than one district, the results will be accumulated

Table * 2.1 Typology of the build...

Districts BAVIKHOVE

2.1 Typology of the building stock at district level (number of households)



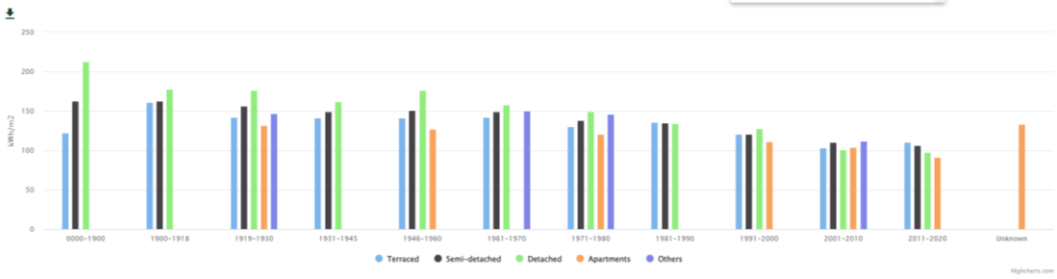
Period	Terraced	Semi-detached	Detached	Apartments	Others	Total
Before 1900	48	37	28	5	1	119
1900-1918	35	21	7	0	0	63
1919-1930	55	33	0	0	0	88
1931-1945	39	29	7	6	0	81
1946-1960	43	91	18	0	2	154
1961-1970	56	97	39	2	0	194
1971-1980	31	78	201	15	0	325
1981-1990	4	21	103	0	0	128
1991-2000	14	47	170	5	2	238
2001-2010	31	65	59	20	2	177
2011-2020	15	18	10	21	0	64
Unknown	0	0	0	0	0	0
Total	**371**	**537**	**642**	**74**	**7**	**1631**

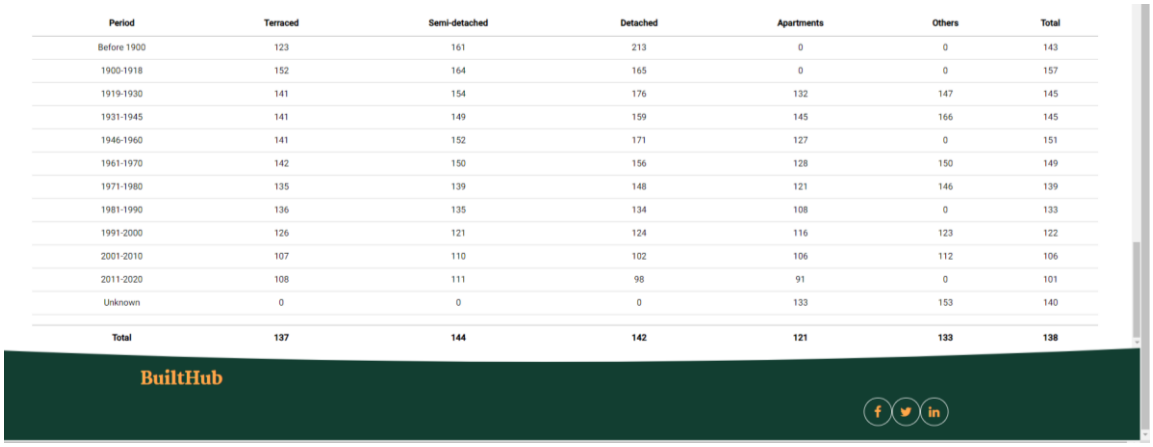
3. Overview at statistical sector level

Here you can filter by sectors. If you select more than one sector, the results will be accumulated

Table * 3.3 Average specific ene...

3.3 Average specific energy consumption, by building type and construction period



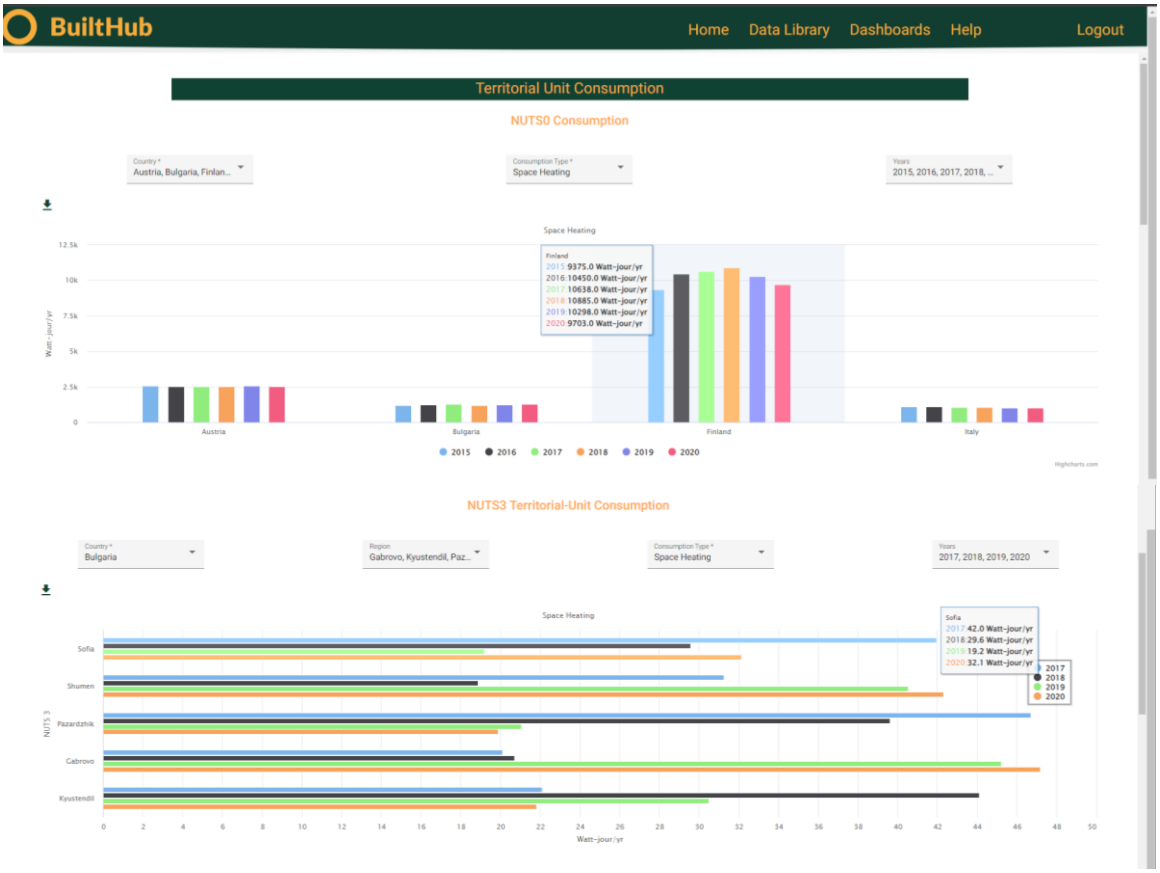


Period	Terraced	Semi-detached	Detached	Apartments	Others	Total
Before 1900	123	161	213	0	0	143
1900-1918	152	164	165	0	0	157
1919-1930	141	154	176	132	147	145
1931-1945	141	149	159	145	166	145
1946-1960	141	152	171	127	0	151
1961-1970	142	150	156	128	150	149
1971-1980	135	139	148	121	146	139
1981-1990	136	135	134	108	0	133
1991-2000	126	121	124	116	123	122
2001-2010	107	110	102	106	112	106
2011-2020	108	111	98	91	0	101
Unknown	0	0	0	133	153	140
Total	**137**	**144**	**142**	**121**	**133**	**138**

Figure 14: Integration of regional data at different NUTS levels into a dedicated interactive dashboard. The BE REEL! project provided BuiltHub with the data.

In the tables and visuals, the number of households by building type (terraced, semi-detached, etc.) and construction period at municipal level can be explored. This allows end-users to assess the size of each building segment analyzed in subsequent tables and visuals. It follows an overview of average floor area (m^2), total floor area (m^2), specific energy consumption (kWh/(m^2 a)), total energy consumption (MWh/a), and reduction (energy saving) potential (MWh/a) in tabular and graphical format and in a map. The end-user can choose which single districts to compare, which will dynamically fetch/re-calculate the new absolute values, averages, and totals, and update the map, tables, and graphs. A dedicated filter allows end-users to choose the key performance indicator and reference unit (building or dwelling).

Figure 15 shows the **Territorial-Unit Consumption story** on the BuiltHub platform, which allows end-users to choose specific countries and regions within countries at different NUTS level to compare final energy consumption per energy use (space heating, space cooling, domestic hot water, electricity, etc.) across regions and across several years, to explore the development over time. This allows a first assessment of the degree of decarbonization and is thus of high added value to policy makers, energy agencies, and local and national authorities. The story can be interactively composed by the end-users, allowing them to independently choose a set of specific countries in the first part of the story, final energy uses, and years. In the second part of the story, end-users can choose a specific country and then, within that country, a subset of regions to compare data against. The map, tables, and visuals update dynamically according to the filtering done by the user. Details can be explored hovering over the data with the mouse.


BuiltHub
Home
Data Library
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Help
Logout
Territorial Unit Consumption
NUTS0 Consumption
Country *
Austria, Bulgaria, Finlan...
Consumption Type *
Space Heating
Years
2015, 2016, 2017, 2018, ...
Space Heating
Finland
2015: 9375.0 Watt-jour/yr
2016: 10450.0 Watt-jour/yr
2017: 10638.0 Watt-jour/yr
2018: 10885.0 Watt-jour/yr
2019: 10298.0 Watt-jour/yr
2020: 9703.0 Watt-jour/yr
Watt-jour/yr
Austria
Bulgaria
Finland
Italy
2015
2016
2017
2018
2019
2020
NUTS3 Territorial-Unit Consumption
Country *
Bulgaria
Region
Gabrovo, Kyustendil, Paz...
Consumption Type *
Space Heating
Years
2017, 2018, 2019, 2020
Space Heating
Sofia
2017: 42.0 Watt-jour/yr
2018: 29.6 Watt-jour/yr
2019: 19.2 Watt-jour/yr
2020: 32.1 Watt-jour/yr
Sofia
Shumen
Pazardzhik
Gabrovo
Kyustendil
NUTS 3
Watt-jour/yr

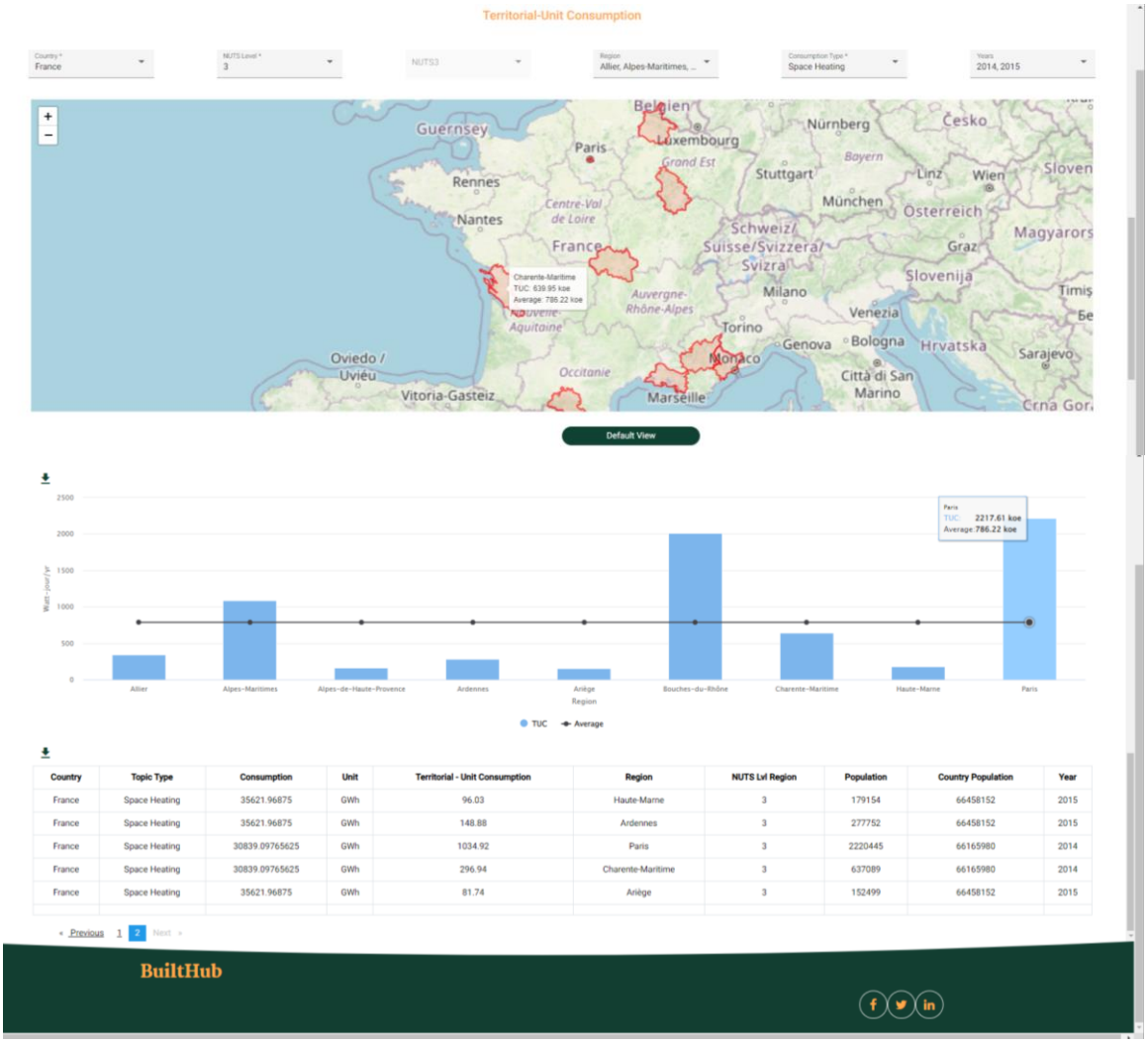

Figure 15: Territorial-Unit Consumption story

- **Machine-Learning (ML) story**

Figure 16 shows the ML analysis for Swedish renovation strategies as featured on the BuiltHub platform. Such analyses, typically carried out by research institutions or other institutions specialised in energy renovation scenarios, are of vital importance to national and local authorities and energy agencies because they guide in the decision which renovation packages should be applied to which types of buildings, considering associated energy savings and costs.

The story shows how ML techniques such as clustering, classification, and leveraging imagery of buildings can be applied to the development of targeted energy retrofits. Featuring this story on the BuiltHub platform allows other countries or regions in Europe to replicate this best practice, adapting it to their specific needs.


BuiltHub
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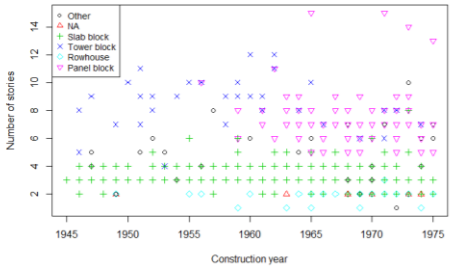
Machine Learning Analysis for Swedish Renovation Strategies
Energy used in buildings accounts for 40% of total energy use in the European Union (EU). Following the decarbonization process set out in the European Green Deal, all Member States established long-term renovation strategies to facilitate the transformation of existing buildings into nearly zero-energy buildings. In Sweden, a significant part of the multifamily building stock was built between 1945 and 1975, and many of these buildings are facing significant renovation needs today. To facilitate these needs, machine learning (ML) methods can be used. Several studies have focused on using ML to enrich building databases with various building features and Google Street View to collect data. This dashboard visualizes how ML algorithms were applied to support the Swedish long-term renovation strategy.
Google Street View observations
Machine learning
Building database enrichment
Share of the multifamily building stock 1945–1975 in each EPC rating A–G
A 0.0364%
B 0.386%
C 2.41%
D 15.3%
E 46.1%
F 29.7%
G 6.13%
The Swedish government initiated the construction of new buildings of high quality in the 1940s with the aim to provide adequate housing for all. The construction peaked between 1965–1975 when more than 100,000 dwellings, apartments as well as single-family houses were built per year. However, buildings from this period are now facing increasing needs for refurbishment and improvements in energy efficiency. The EPC ratings of the multifamily building stock 1945–1975 can be seen in the image, which shows that the majority of the buildings have an EPC rating of E or F.
Representative building types 1945–1975: (1st) slab block from 1945–1960; (2nd) slab block from 1960–1975; (3rd) panel block and (4th) tower block

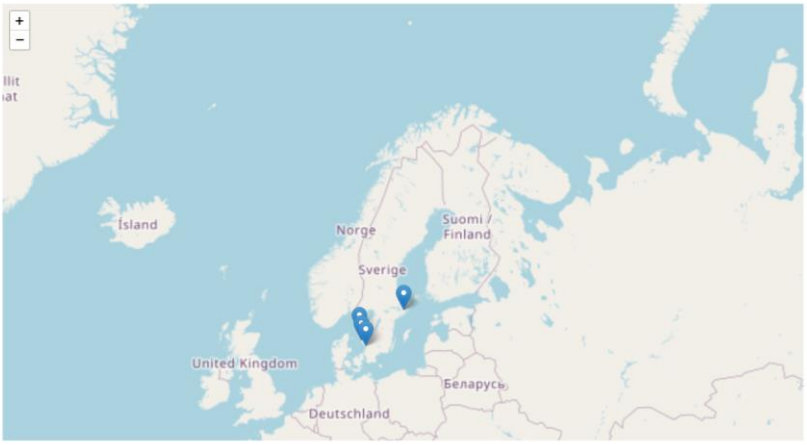
The main division of multi-family buildings of this period is based on the appearance and size of the building, where three main types of buildings are usually considered: slab blocks, panel blocks, and tower blocks. Ocular observations were made in Google Street View of 476 EPCs that were sampled from the total of 50,000 EPCs 1945-1975. Sampling was conducted as a weighted random sampling, where the probability of each EPC being selected was determined based on the area of the building that the EPC represented. In addition, due to the underrepresentation of certain building types (tower blocks) in the sample data, observations were made for an additional 41 manually selected EPCs. However, some observations were not possible due to lack of coverage in Google Street View. Thus, these EPCs were removed, resulting in a total of 514 observations broken down in the table.

A specification of the classifications of the 514 observations conducted in Google Street View

Observed Building Characteristic	Number of Observations	Share of Observations
Building type		
Slab block	342	63.0%
Panel block	81	15.8%
Tower block	36	7.00%
Rowhouse	32	6.23%
Other	23	4.47%
Total	514	100%
Not brick façade	297	57.8%
Eaves overhang	215	41.8%

Visualisation of how construction year (x axis) and number of stories (y axis) correlate with building type.





The geographical distribution of the 514 observations is shown in the map. The dots show all multifamily buildings constructed between 1945 and 1975, whereas the black crosses mark the multifamily buildings that were observed in Google Street View. It can be seen that the studied multifamily building stock is distributed all across Sweden in a way that reflects the population density of the country. The observations show a similar pattern, indicating that they constitute a geographically representative sample.

Percental energy savings for each building type and energy retrofitting package according to the reference study

Building Type	Package 1 (%)	Package 2 (%)	Package 3 (%)
Slab block, 1945–1960	14.2	25.2	63.8
Slab block, 1960–1975	9.7	25.6	59.1
Tower block	17.6	25.4	63.6
Panel block	8.5	23.7	54.6

Marginal costs for each building type and energy retrofitting package according to the reference study

Building Type	Package 1 (€/m2)	Package 2 (€/m2)	Package 3 (€/m2)
Slab block, 1945–1960	6.0	115	398
Slab block, 1960–1975	5.1	147	426
Tower block	3.9	112	435
Panel block	2.5	120	437

For this study, a reference with tailored energy retrofitting packages for the Swedish multifamily building stock 1945–1975 have been used. For each building type there are three available packages (1–3) which entail different costs and energy savings (low to high). The packages must be applied in successive order, meaning that Package 2 requires Package 1 to have been conducted, and Package 3 requires both Package 1 and Package 2 to have been conducted.

- In Package 1, a number of measures that aim at optimising the operation of the building are undertaken.
- In Package 2, components such as pumps and fans are changed to more effective counterparts, and additional insulation is added in the attic and to existing windows.
- Package 3 contains the most extensive measures, including a new ventilation system with heat exchange from exhaust air, a change of windows, and 10 cm additional insulation on the building envelope.

The energy savings and the associated costs for each of the energy retrofitting packages can be seen in the tables above.

Details for four of the considered models for prediction of building type

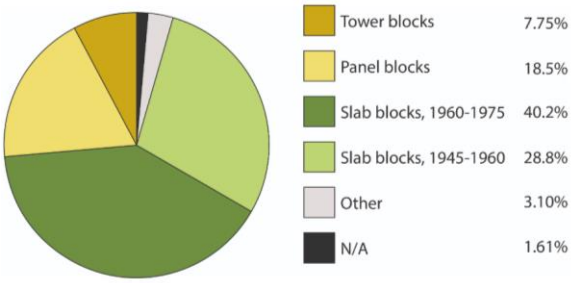
Model	Overall Accuracy (%)		Specific Accuracy (%)				
	Cross-Validation	Testing Data	Slab Blocks	Panel Blocks	Towe Blocks	Rowhouses	Other
SVM1 (Chosen model)	88.5	88.9	95.2	94.4	71.4	85.7	0
SVM2	89.3	87.9	98.4	88.9	71.4	57.1	0
LR1	88.0	87.9	93.7	88.9	85.7	85.7	0
LR2	85.7	87.9	95.2	88.9	85.7	71.4	0

Details for four of the considered models for prediction of building type

Building Characteristic	Features in Selected Mode	Machine Learning Model	Accuracy
Building type	Number of stories Construction year Heated space per story and address Number of apartments per address	SVM	88.9
Eaves overhang + not brick facade	Construction year Number of apartments Number of stairwells per apartment Area code	SVM	72.5

From the sample it is intended to create a model that predicts the type of building to know what type of rebruifshment package to be applied to it. In the search for the optimal model, two types of supervised ML models are considered for classification problems. The model types considered in this study were logistic regression (LR) and support vector machines (SVM). The table above (left) shows the four ML models that were considered for building type prediction, the results of which are shown for each building type. It can be seen from the table on the right that the building type can be predicted with an accuracy close to 90%. Facade material and eave overhang can be predicted with an accuracy of approximately 68%, but in combination, these features can be predicted with an accuracy of 72.5%. Therefore, apart from the model that predicts the building type from its characteristics, the combined model was chosen, as the two building characteristics were to be used to determine the suitability of the additional facade insulation. The validation showed an accuracy of 90.0% for the building type, which is close to the accuracy obtained in the tests. For the adequacy of additional facade insulation, the validation showed an accuracy of 63.2%, lower than that obtained in the tests. However, the relatively small size of the validation sample makes it difficult to draw important conclusions from these results.

The predicted distribution of building types in the multifamily building stock from 1945–1975. N/A values were generated if one or more of the features in the prediction model were mi



Based on the models shown before, building type and possibility for additional insulation could be predicted for the entire multifamily building stock built between 1945 and 1975. First of all, it can be seen in the predicted distribution of building types that almost all of the multifamily buildings from this era can be categorised as slab blocks (69%). N/A values were generated if one or more of the features in the prediction model were missing.

Decision tree showing how four building characteristics can help determine a tailored energy

This image provides an example of how enriched building databases can be applied to generate more accurate energy retrofitting strategies that can be used for policy purposes such as in the long-term renovation strategy, and also showcases how building-specific information can be used in decision trees for different energy retrofitting packages.
This decision tree is based on the notions that energy retrofitting should be carried out along with other planned refurbishment measures in a "window of opportunity", and that the overall objective is to transform existing buildings into nearly zero-energy buildings, in accordance with the objective of the long-term renovation strategy.
Based on these notions, it can be seen in the model that recently renovated buildings cases where the window of opportunity has been missed, are excluded from energy retrofitting. Likewise, buildings that already fulfil the requirements of nearly zero-energy buildings (EPC rating A–C) are also excluded from energy retrofitting. Buildings that have not been recently renovated and with the EPC rating D are allocated energy retrofitting package 1.
Finally, buildings that have not been recently renovated and with an EPC rating between E–G are allocated energy retrofitting package 2 or 3 depending on their suitability for additional facade insulation, which is part of energy retrofitting package 3.

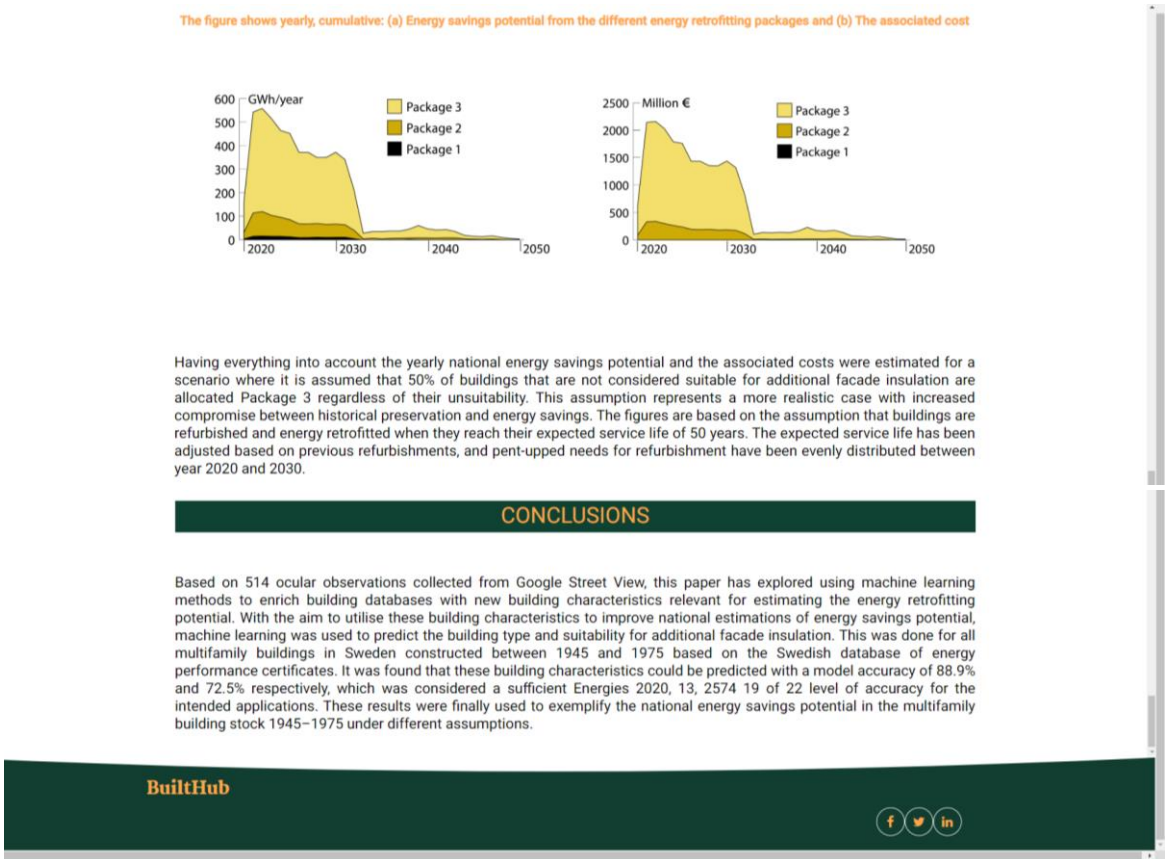


Figure 16: Machine-Learning Story

- **Machine-Learning guidelines**

The presented ML story is just one example of many where ML can be useful for building stock analyses. To illustrate the myriad of possibilities depending on the available data and goal, the BuiltHub platform features a dedicated section where users can pick the training dataset available to them from a dropdown list and then receive a recommendation on the type of algorithm they could use, with a reference to scientific literature, see Figure 17.

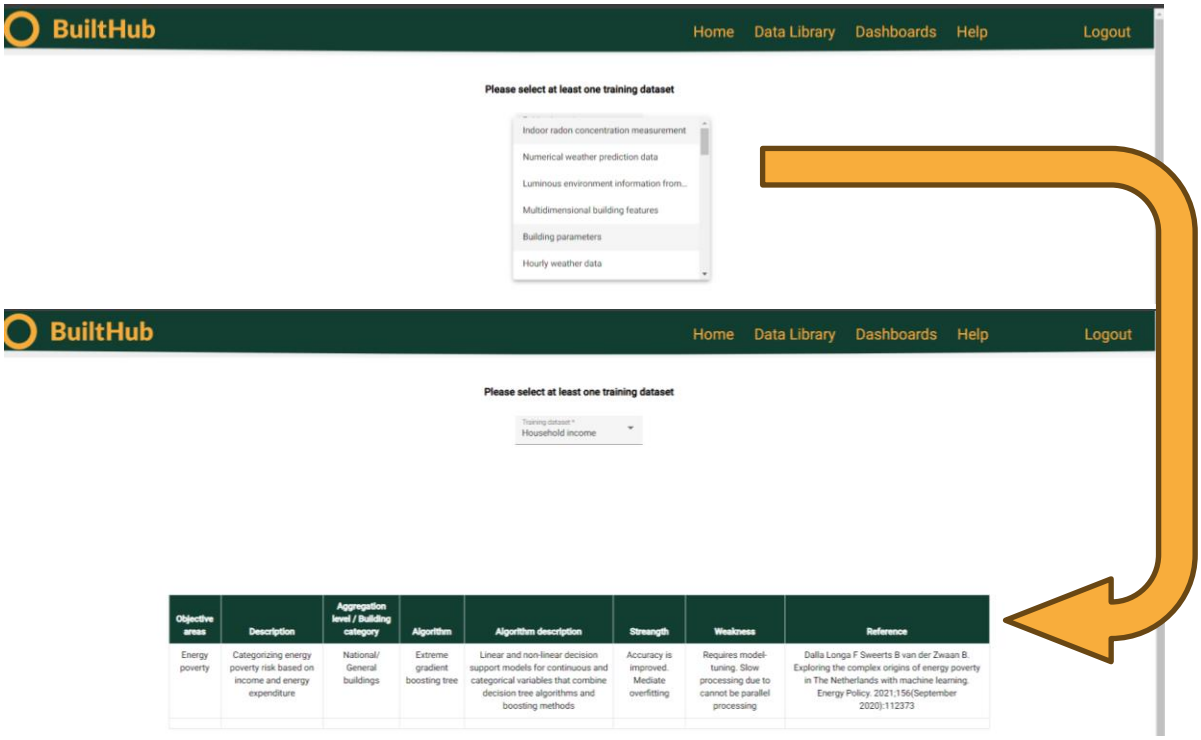


Figure 17: Machine-learning guidelines for the available dataset

In the figure, the example is given for a dataset on household income with the aim to combat energy poverty. The algorithm used in literature for this use case is shown along with the respective scientific paper. This supports expert users in the field such as ML engineers and researchers with expertise in ML in the choice of research material to study and apply to the use case but it also informs policy- and decision-makers about suitable ML techniques to tackle the objective at hand.

3.5. SPARQL entry point section

The SPARQL entry point (Figure 18) is a section dedicated to technically experienced users, giving them the possibility to code personal queries accessing specific data. This allows automation and saving time and effort for the research of data, which would otherwise be done through the Dashboards section. Multiple queries can be done by the end users, and data can be downloaded in multiple formats, such as CSV and/or JSON. The possibility to download data in different formats represents an important added value provided to the end-users. Several pre-filled queries are available for adaptation by the end-user.

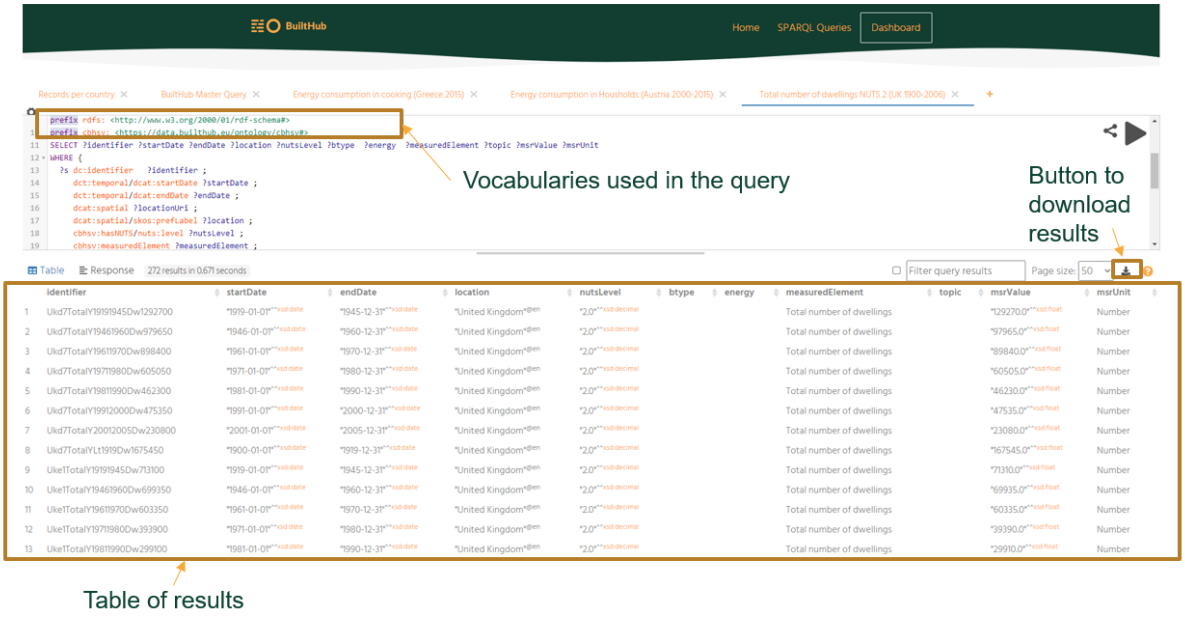


Figure 18: SPARQL entry point for custom advanced queries

4. Stakeholders' needs

This chapter entails the results of the stakeholders' dialogues carried out in WP2, relating them to the services and functionalities provided by the BuiltHub platform presented in this deliverable. This qualitative analysis has been carried out dividing the stakeholders in the following categories: i. Policy makers, ii. Researchers, iii. Utilities, iv. Designers, v. Real estate developers, and vi. Civil society. These categories of stakeholders have been analyzed, reported in the following paragraphs, and the BuiltHub sections and functionalities most interesting to them are summarized in a final table.

- **Policy makers (End user)**

Policy makers are among the most relevant stakeholders of the BuiltHub platform. Thus, the platform aims to provide them with an excellent service according to their needs, as done for all stakeholders. During the stakeholders' dialogues carried out in WP2, policy makers expressed their need for a user-friendly platform for data collection and analysis. For this reason, the BuiltHub platform aims to provide a range of extensible indicators according to data availability and expressed interest, organized in a clear and comprehensive way. Data is organized in tabular, graphical, and geographical (through maps) form, and all data are available for download. According to the stakeholders' consultations, the platform provides insights into building characteristics and, upon sharing of data, renovation and energy saving potential figures, see sub-chapter 3.4. Given the expressed desire of stakeholders to have higher spatial granularity data, the BuiltHub platform provides, where available, not only data at European and national level, but also at higher granularity up to the municipality level (NUTS3), through maps, tables, and visuals (charts). There is also a Geo Information dashboard showcasing the representation of high-resolution raster data. BuiltHub provides findability, accessibility, interoperability, and reusability (FAIRness) of the data collected in its

platform through the open access, BuiltHub ontology, and Data Catalog, as well as several interactive analytics and stories dynamically updating according to the filters and selections made, so that policy makers can assess the development of performance indicators over time and compare them across regions, to assess the impact of policies.

- **Researchers (Lead user):**

According to the stakeholder's dialogues carried out in WP2, researchers expressed a strong interest in community building of data providers and users, in exchange and collection of data via the platform and in developing connections with industry. The BuiltHub platform is accessible and of interest for several types of stakeholders providing and/or using data in the platform. Through the Openmode forum, see sub-chapter 3.4, stakeholders can exchange opinions and comments related to topics and data shown in the platform. For example, where the platform provides several data coming from different data sources for the same indicator, end-users can discuss about the quality of the provided data and which dataset in their opinion is better and for which purpose. The Comparison dashboard (Figure 12) gives the end-users the possibility to compare these datasets. The presence of FAIR data (through free access, BuiltHub ontology, and Data Catalog) allows researchers to check data reliability by studying the methodologies used at the source. Among the most relevant data for researchers there is CO_2 emissions, census, climatic, energy consumption, and renovation potential building stock data, which is present in the BuiltHub platform. The data collected in the platform is therefore used to support researchers in further analysis and in the creation of building stock transition reports and scenarios, as demonstrated by the scientific publications performed during BuiltHub's lifetime. The restriction of some areas and functionalities of the platform to only data providers could push researchers to decide to share their data on the BuiltHub platform. During the stakeholder's dialogues carried out in WP2, it emerged the willingness of researchers to share data when there is visibility for the organisation, privileged access, intellectual property protection/credit is given, and other services are reserved to data providers. According to researchers' requests, data is provided at higher granularity than NUTS0 where available and organized in meaningful tables and charts. All raw data is downloadable for individual analyses.

- **Designers (End user):**

According to the stakeholders' interviews carried out in WP2, designers ask for a single data platform and at the same time allowing the engagement with the data community. The BuiltHub platform entails in this regard a wide variety of indicators related to energy, CO_2 emissions, building stock, renovation etc., at different NUTS levels. The presence in the BuiltHub platform of cross-sectoral data and data coming from multiple sources allows designers to perform analyses, comparisons, and benchmarking regarding building energy, emissions, and retrofit performance. The engagement with the data community is offered in BuiltHub mainly through the stakeholder engagement activities in WPs 2 and 7, but also through the Openmode forum.

- **Real estate developers and administrations (Lead user):**

One of the main interests expressed by real estate developers and (local and national) administrations was to have a platform bringing together building stock related data from different sources and sectors, thereby facilitating their work. They also asked for engagement and relationships with other data users or providers. This first request is one of the main

objectives of the BuiltHub platform. The second request is fulfilled through the BuiltHub community. A connection between the two is offered by the Openmode forum, which gives the possibility to comment and discuss about the data/information and services provided by the platform. Functionalities such as visualisation and interactive inspection of uploaded datasets are very useful for real estate developers. According to the stakeholders' dialogues carried out in WP2, real estate developers are interested in data from the buildings and construction industry, EU, national and regional statistics. In terms of thematic areas, building stock characteristics, energy performance, renovation, and decarbonisation are important parameters to monitor. The data they could access through the platform would be used mainly for products and services development, benchmarking, decision-making, and evaluation. According to the WP2 stakeholders' dialogues, real estate developers would like to share data with provisions such as an agreement, intellectual property protection, and in return access to data. Further, they would prefer machine-readable and tabular data received through a RESTful API and browser. One of the most interesting services provided by the BuiltHub platform for them is the possibility to access data through the SPARQL entry point, where data can be downloaded in JSON format.

- **Civil society (End user):**

The BuiltHub consortium has developed a platform accessible by any registered end-user. The civil society ranges from non-experts to experts, with a common interest in data, community participation and partnerships, data analysis and processing, and insightful graphs. The BuiltHub platform offers dashboards for easier access to the data, but also more advanced features such as data upload, search through the SPARQL entry point, and data analytics. Members in the BuiltHub community pertaining to the Civil society category asked for benchmarking against national and municipality-level statistics. This functionality is offered by the Territorial-Unit Consumption story on the platform, see Figure 15. Further, the civil society expressed interest in the thematic areas offered, such as building stock characteristics, energy performance, and renovation. They can use the provided data for training and education, research and analysis, and to study the impact of policies and other societal changes affecting buildings (e.g., the Covid pandemic) they are interested in. The data provided should be related to reliable sources. Therefore, the BuiltHub platform provides in the Data Catalog metadata and descriptions for each dataset.

Table 2 summarises the platform functionalities implemented in the BuiltHub sections dedicated to the stakeholders identified in D2.1 "Stakeholder mapping".

Table 2: Mapping between the BuiltHub platform sections and the main stakeholders (light green rows indicate the three main BuiltHub sections, while the white ones refer to the Data library sub-sections)

BuiltHub section	Platform functionality	Stakeholders
Data library	To understand the underlying data model	(please, see rows for the data library items below)
- Ontology Viewer	To understand the structure and relationships of the datasets	Researchers (advanced users, such as data scientists, engineers, analysts, architects, and software developers)

- Data Catalog	To show and describe the included datasets	Researchers, real estate developers, local and national authorities
- SPARQL for data querying	To access the database by using a query language	Researchers, real estate developers, local and national authorities (advanced users, such as data scientists, engineers, analysts, architects)
- Data Upload	To appropriately upload external raw data to compare them with those already present	National authorities
Dashboards	To easily navigate through the datasets, choosing which data to view or download	Citizens, policy makers, real estate developers, local and national authorities
Analytics/stories	To deeply analyze the available data, e.g. by comparing different data sources	Real estate developers, researchers, local and national authorities (advanced users)

5. Conclusions

The BuiltHub platform aims to provide useful services to the community in the building sector, and specifically the BuiltHub community. It implemented and proposed changes for the BSO in its version as of November 2022, when this deliverable was structured and most BuiltHub tasks were ongoing, as well as introduced novel, innovative features reflecting state-of-art advancements in Europe's data strategy, the EPBD – in particular, the need for Member States to create national BSOs –, and data analytics/stories requested by the community. For this reason, the structure of the platform, compared to the BSO, has been completely rethought. A unified, state-of-art data search system, filtering, and interactive visualization across multiple datasets has been implemented. In addition to the data handling and interactive visualization, further services are provided by the platform. Among them, it is worth mentioning:

- Data upload to update and extend existing datasets.
- The possibility to compare multiple datasets for the same indicator.
- Improved provision of data model (standardized description of datasets, metadata, etc.).
- Exploration of derived indicators, calculated by combining information from several datasets.
- Browsing of data at different NUTS levels, from NUTS0 (national) to NUTS3 (local territorial units). Browsing of raster data.
- ML story and guidelines, to widen the application of ML techniques to building stocks.

Concerning the data research and download possibilities, relevant improvements have been proposed:

- The possibility to access the database through the SPARQL entry point, allowing to create own queries.
- On-site full raw data download in CSV and JSON format.
- Different APIs for download from external applications.

As mentioned in the introduction of this deliverable, the demonstrated functionalities represent the current state of progress of the platform. Future work intends to scale up, add datasets and services, and integrate with other platforms and their functionalities.

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Sources

[1] European Commission. Building Stock Observatory. https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/eu-bso_en

[2] Zambito A. et al. BuiltHub Deliverable D3.1. - Inventory structure and main feature and datasets. 2021

[3] Openmode. Open energy modelling initiative. https://openmod-initiative.org/

[4] Go FAIR. FAIR Principles. 2021. https://www.go-fair.org/fair-principles/

[5] DataCite metadata scheme. 2020.https://schema.datacite.org/

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