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A Data Structure for Digital Building Logbooks: Achieving Energy Efficiency, Sustainability, and Smartness in Buildings across the EU

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Abstract: The European Commission has mandated the use of digital building logbooks (DBL) to encourage deep energy renovations and overcome barriers in building renovations. The current energy performance certificates (EPCs) focus on operational energy consumption, whereas the DBL will cover the entire life cycle of buildings and provide a more comprehensive evaluation of buildings, through providing a passport rating in three domains: energy performance, sustainability, and smartness. This paper defines the digital building logbook (DBL) data structure within the context of the EUB SuperHub, a three-year project financed by the European Union under the Horizon 2020 program. The creation of the EUB SuperHub DBL data structure involved an extensive review of relevant literature, including existing DBL data structures developed in previous EU projects (iBRoad, ALDREN, BIM4EEB, X-tendo), recommendations from the "Study on the Development of an EU Framework for Buildings' Digital Logbook", requirements specified in the grant agreement, existing EU legislation, and anticipated future legislation. The proposed digital building logbook data structure for the EUB SuperHub project comprises eight primary categories and is designed to provide all the essential input data needed throughout the building's life cycle to compute the passport rating across three domains: energy efficiency, sustainability, and smartness. With the requirements stipulated in existing and soon-to-be-adopted EU legislation, the introduction of a digital building logbook has become a necessity. Though the undertaking is a formidable task and will require considerable effort, its benefits are numerous and promising, including the potential to enhance energy renovation rates.

Keywords: digital building logbook data structure; one-stop shop; digitalisation; building passport

Citation: Malinovec Puček, M.; Khoja, A.; Bazzan, E.; Gyuris, P. A Data Structure for Digital Building Logbooks: Achieving Energy Efficiency, Sustainability, and Smartness in Buildings across the EU. *Buildings* **2023**, *13*, 1082. https://doi.org/10.3390/buildings13041082

Academic Editor: Antonio Caggiano

Received: 27 March 2023
Revised: 10 April 2023
Accepted: 16 April 2023
Published: 20 April 2023

1. Introduction

In the era of developed digitalisation, it is obvious that digitalisation in the construction sector is still lagging behind other sectors. There are already many different databases in EU countries, which focus primarily on one topic area. A database that covers the entire building life cycle, from the design phase through the construction, operation, performance, maintenance, and deterioration is needed, to consolidate all relevant building data across the EU. A digital building logbook is becoming a necessity in the era of digitalisation, containing all relevant building-related data over the whole life cycle of a building, providing different types of stakeholders with different information for different purposes at the right time.

One practice guide on building logbooks [1] was published 20 years ago, in June 2003. The building logbooks aimed to improve access to information for facilities managers or others responsible for managing buildings, enabling them to improve the energy efficiency of their buildings. It was expected that using logbooks would improve the understanding, management, and operation of buildings, resulting in lower running costs and reduced carbon emissions to the atmosphere. A building logbook was defined as a key source of information for anyone involved in the daily management or operation of the building.

The concept of a digital building logbook (DBL) was first introduced recently, through EU legislation with the European strategy "Renovation Wave", published by the European Commission in 2020 [2]. To break some of the key barriers in building renovations and foster deep energy renovations by creating better conditions for renovation, the European Commission has been obliged to introduce digital building logbooks that integrate all building-related data. In the proposal for the third revision of the Energy Performance of Buildings Directive (EPBD), published in December 2021 [3], a digital building logbook is defined as a "common repository for all relevant building data, including data related to energy performance such as energy performance certificates, renovation passports and smart readiness indicators, which facilitates informed decision making and information sharing within the construction sector, among building owners and occupants, financial institutions and public authorities". Article 19 of this EPBD proposal refers to a database for energy performance of buildings. The last paragraph of this article states that "Member States shall ensure that the national database for energy performance of buildings is interoperable and integrated with other administrative databases containing information on buildings, such as the national building cadastres and digital building logbooks". This sentence within article 19 paves the way for mandatory linking of the national EPC databases to digital building logbooks.

A digital building logbook, serving as a repository for a building's information throughout its life cycle, is crucial not only for the construction sector but also for the real estate sector. Building-related information plays a vital role in investment and financial decision making, as well as in adequate risk assessment. Decision makers in the construction and real estate sectors require high-quality data and assessment results to finance, construct, and renovate sustainable, low-carbon buildings [4].

A significant shortage of information regarding real estate assets, ranging from individual buildings to neighbourhoods and cities, has been identified in Italy. Dejaco et al. [5] have proposed building and district logbooks as tools for collecting, organising, and managing information, with the aim of streamlining the real estate management process. The proposed logbooks, conceived as tools for risk management, could be intended as rigid control tools. The performed analysis of the literature on the defined DBL data structure revealed that only four EU-funded projects, namely iBRoad [6], ALDREN [7,8], BIM4EEB [9,10], and X-tendo [11,12], have suggested a DBL data structure. The digital building logbook developed within the iBRoad project covers single-family houses, while the one developed within the ALDREN project covers office buildings and hotels. In July 2020, the European Commission published Report 1 of the "Study on the Development of a European Union Framework for Buildings' Digital Logbook" [13], which recommended a DBL data structure containing eight main categories and emphasized the importance of having a common DBL for the entire building stock. Therefore, the consortium teams working on the EUB SuperHub project developed a digital building logbook data structure, that covers the entire building stock throughout the building life cycle.

Many papers on digital building logbooks have been found to not provide the DBL data structure but to cover other important aspects.

In May 2021, the EU-funded ePANCEA project team published a report [14] to incentivise energy renovations and stimulate cost-effective deep building renovation in Europe. They conducted two surveys to collect information on the current state of energy performance certificates (EPCs) and to identify stakeholders' needs and expectations regarding a possible link between EPCs and the DBL. The authors concluded that EPCs could be

an important data source for a DBL, and that building descriptions, characteristics, and technical building systems are important data to include, without providing the exact DBL data structure. The authors emphasised that the EPC should automatically feed the DBL.

A review report on models for a European digital building logbook was published by Gómez-Gil et al. [15] in March 2022. The authors performed a comparison of the existing DBL data structure, namely iBRoad, ALDREN, X-tendo and the "Study on the Development of a European Union Framework for Buildings' Digital Logbook", according to seven parameters: references used as a starting point for the model definition, identification of the relevant stakeholders in the DBL, identified potential user needs, proposed structure, data sources, potential functionalities, and operation and use.

The same authors, Gómez-Gil et al. [16], analysed the contribution of new digital technologies (e.g., 3D scanning, smart monitoring, digital twins) to the digital building logbook, and new EU tools to support circularity and energy efficiency in buildings (e.g., SRI, responding to users' needs). The need to collect more real data on buildings, to foster the decarbonisation of the building stock, is stressed.

Mêda et al. [17] were the first to address and conceptualise a common framework considering a data template, digital building logbook, and digital twin construction. The results indicated that an improved understanding of integrating the data template building logbook and digital twin concept would boost implementation and innovation.

Mêda et al. [18] proposed a process-based DBL framework, that defines the activities, the data, and stakeholder involvement across the built asset life cycle, from early conception and feasibility, through design and construction, to use/operation. They developed and verified Business Process Modelling Notation (BPMN) maps.

The European Builders Confederation (EBC) [19] considers digital building logbooks and building renovation passports as interesting tools for enhancing knowledge about the EU building stock, which can lead to an increase in renovation rates. In a position paper released in January 2021, the EBC made several recommendations regarding the implementation of a DBL. One of the key points emphasised, was the need to ensure that all technical data about the building, such as its characteristics, design plans, equipment descriptions, and designs, are readily available in the logbook.

This paper defines the complete data structure of the digital building logbook developed as part of the EUB SuperHub project. This logbook will support the EUB SuperHub online platform and the EUB e-passport. The defined digital building logbook data structure is an essential layer within the developed online platform, and acts as a digital container that documents all input building-related data over the entire building life cycle. This information is used to calculate the passport rating in three domains: energy performance, sustainability, and smartness. The existing national databases in the seven EU countries involved in the EUB SuperHub project (Austria, Croatia, France, Germany, Hungary, Ireland, and Italy) are also discussed as potential data sources for the elaborated EUB SuperHub digital building logbook data structure.

The structure of this paper is as follows: Section 1 outlines the origin of the digital building logbook, with a particular emphasis on its data structure. Section 2 briefly describes the research methodology followed in this paper. Section 3 provides a literature review, which concludes with a list of requirements that must be addressed by the DBL data structure. Section 4 is dedicated to the existing national databases in the EU countries involved in the EUB SuperHub project, which could serve as a reliable data source for the elaborated DBL data structure. In Section 5, a brief description of the developed EUB SuperHub online platform is provided, which is supported by the elaborated EUB SuperHub digital building logbook data structure. The most significant section is Section 6, which presents the elaborated EUB SuperHub digital building logbook data structure and describes each of the eight main categories. Finally, Section 7 concludes the paper.

2. Research Methodology

The research methodology employed in this study involves three primary steps:

1. Analysis:
   (a) Examination of three European Commission reports published in 2020 [13,20,21], with a particular focus on the proposed DBL data structure in Report 1 [13].
   (b) Analysis of the DBL data structure suggested by EU-funded projects, such as iBRoad, ALDREN, BIM4EEB, and X-tendo [6–12].
   (c) Evaluation of all the requirements stipulated in existing EU legislation [22], as well as future legislation expected to be adopted soon (e.g., the proposal for the EPBD recast, published in December 2021 [3]).
   (d) Consideration of all the requirements outlined in grant agreement no. 101033916—EUB SuperHub [23], regarding building-related data that must be provided throughout the building life cycle.
2. Compilation:

   Listing all the requirements identified in the analysis that need to be satisfied.
3. Development:

Creation of the EUB SuperHub digital building logbook data structure based on the list of requirements.

3. Literature Review on Building Logbooks and Initiatives across Europe

The first step to define the logbook data structure is the definition of all the requirements.

3.1. European Commission Documents Referring to Digital Building Logbooks

In the year 2020, the European Commission carried out a study on the "EU-wide Framework for a Digital Building Logbook (DBL)" and published the following three reports, with the main aim being to support the widespread use of digital building logbooks across Europe and to encourage data transparency and increased data availability to a broad range of market players, including property owners, tenants, investors, financial institutions, and public administrations:

- Definition of the digital building logbook—Report 1 of the "Study on the development of a European Union Framework for Buildings' Digital Logbook", July 2020 [13];
- Building logbook state of play—Report 2 of the "Study on the development of a European Union Framework for Buildings' Digital Logbook", July 2020 [20];
- "Study on the Development of a European Union Framework for Digital Building Logbooks", final report, December 2020 [21].

Report 1 [13] presented a definition of a DBL, building on a state-of-play analysis and stakeholder input from across Europe. The report outlined the potential role and scope of an EU-supported DBL, including the central features of the instrument, as well as data handling and governance issues. Based on the desk research and mapping initiatives, Report 1 suggested the DBL data fields (categories and subcategories) be structured into eight information categories: 1. Administrative Information, 2. General Information, 3. Building Descriptions and Characteristics, 4. Building Operation and Use, 5. Building Performance, 6. Building Material Inventory, 7. Smart Readiness, 8. Finance.

Report 2 [20] aimed to present the results of the analysis of 40 building logbook initiatives in different countries. The report provided an overview of the initiatives and highlighted key success factors and barriers to the implementation of building logbooks.

The final report [21] identified the list of 15 actions, and the following three priority actions for the European Commission to consider, and potentially carry out, in support of the widespread use and efficient functioning of digital building logbooks across the EU:

Priority action 1: Development of a standardised approach for data collection, data management, and interoperability and its legal framework. Priority action 2: Development of guidelines for linking existing databases. Priority action 3: Launch of public funded R&I projects to further explore the digital building logbook concept and its implementation.

All of the key findings from those three reports were of the utmost importance when elaborating the EUB SuperHub digital building logbook data structure. They provided input data and guidelines for defining the DBL structure within the EUB SuperHub project, covering the entire life cycle of buildings and comprising all relevant building information, to a broader range of stakeholders.

3.2. Overview of Digital Building Logbook Data Structure Elaborated within EU Projects

The following, already defined, digital building logbook data structures within EU-funded projects were analysed in more detail (Table 1):

- a DBL data structure named iBRoad-Log, defined within the iBRoad (individual building renovation roadmaps) project [6];
- a DBL data structure named ALDREN BuildLog, defined within the ALDREN (alliance for deep renovation in buildings) project [7,8];
- a DBL data structure named BIM4EEB Building Log-book, defined within the BIM4EEB project [9,10];
- a DBL data structure named X-tendo logbook, defined within the X-tendo (extending the energy performance assessment and certification schemes via a modular approach) project [11,12].

Table 1. List of European projects addressing the structure of a digital building logbook.

Project Acronym	Project Title	Project Duration	Project Home Page	DBL Name	Type of Buildings Addressed
iBRoad	Individual building renovation roadmaps	1 June 2017–31 December 2020	https://ibroad-project.eu/ (accessed on 18 March 2022)	iBRoad-Log	Residential buildings (single-family houses)
ALDREN	Alliance for deep renovation in buildings	1 November 2017–30 September 2020	https://aldren.eu/ (accessed on 5 May 2022)	ALDREN BuildLog	Non-residential buildings (office and hotel buildings)
BIM4EEB	BIM based fast toolkit for efficient renovation in buildings	1 January 2019–30 June 2022	https://www.bim4eeb-project.eu/ (accessed on 8 April 2023)	BIM4EEB Building Logbook	–
X-tendo	Extending the energy performance assessment and certification schemes via a modular approach	1 September 2019–31 August 2022	https://x-tendo.eu/ (accessed on 11 May 2022)	X-tendo logbook	Private (residential, offices) and public buildings (schools, hospitals, etc.)

Table 1 lists three EU-funded projects addressing digital building logbooks.

The four listed EU projects, in their deliverables [6–12], defined a digital building logbook data structure (main categories and subcategories). Table 2 gives an overview of the main categories of DBL defined within those four EU projects and the main categories suggested in Report 1 of the "Study on the development of a European Union Framework for Buildings' Digital Logbook", published by the European Commission in July 2020 [13].

It is noteworthy that iBRoad-Log covers single-family houses, whereas ALDREN BuildLog covers office buildings and hotels. Report 1 of the "Study on the development of a European Union Framework for Buildings' Digital Logbook" [13] stresses that a common DBL for the entire building stock is desirable and would avoid fragmentation. A separate DBL for different building typologies should not be pursued.

Table 2. Comparison of different elaborated existing DBL data structures.

	IBRoad-Log July 2018	**ALDREN BuildLog April 2019**	**BIM4EEB Building Log-Book June 2019**	**Study EU DBL July 2020**	**X-Tendo Logbook November 2020**
1	General and administrative information	Building picture	General and administrative information	Administrative information	Administrative information
2	Building construction information	Energy rating & target	Building construction information	General information	General information
3	Building energy performance	Energy verification	Building energy performance	Building descriptions and characteristics	Building descriptions and characteristics
4	Building operation and use	Comfort & well-being	Building operation and use	Building operation and use	Building operation and use
5	Smart information	Cost value risk	IoT information	Building performance	Building performance
6	–	Documentation—BIM	–	Building material inventory	Building material inventory
7	–	–	–	Smart readiness	Smart readiness
8	–	–	–	Finance	Finance

Each analysed DBL structure contains the following same main categories:

- General and administrative information (called "building picture" within the ALDREN BuildLog);
- Building performance (called "energy rating & target" within the ALDREN BuildLog);
- Building operation and use (called "energy verification" within the ALDREN BuildLog).

Smart readiness, as a main category, is present in all of the analysed DBLs except in the ALDREN BuildLog. Finance (or "cost value risk" within the ALDREN BuildLog), as another important category, is present in all analysed DBLs except in the iBRoad-Log. Documentation is a separate main category within the ALDREN BuildLog, whereas in all other analysed DBLs, different types of documents are part of already defined main categories. There is no separate category used only for storing building documentation. The X-tendo logbook follows the structure defined by the European Commission in Report 1 [13].

To improve buildings' performances across the building life cycle, development of the European digital building logbook has had strong attention from the European Parliament and European Commission. One of the three identified priority actions for the European Commission is to develop an EU Framework for DBL. Furthermore, to further explore the digital building logbook concept and its implementation, publicly funded research and innovation (R&I) projects need to be launched (priority action 3) [21].

The DBL data structure developed within the BIM4EEB project will be stored and assessed inside the BIM management system.

On 12 October 2021, the European Commission launched the HORIZON-IA (HORIZON innovation actions) call for proposals (climate neutral, circular and digitised production 2022), with several topics. One of the topics, entitled "HORIZON-CL4-2022-TWIN-TRANSITION-01-09—Demonstrate the use of Digital Logbook for buildings", relates entirely to digital building logbooks. The following three projects, addressing digital building logbooks, are funded under the topic: BUILDCHAIN, Demo-Blog, and openDBL. All three projects started in January 2023.

3.3. Brief Overview of Building Logbooks and Initiatives across Europe

Across Europe, there are numerous building logbooks and initiatives at varying stages of development, each with its own distinct scope and focus. Report 2 of the "Study on the development of a European Union Framework for Buildings' Digital Logbook", published by the European Commission in July 2020 [20], presented the results of the analysis of 40 building logbook initiatives in different countries, indicating DBL name, name of organization/ministry/company responsible, mandatory/voluntary, paper/digital, public/private, type of building covered, and maturity level. Two of the detected building logbooks have been discontinued: ImmoPass, from Germany, and home information pack (HIP), from the UK.

These logbooks and initiatives differ in terms of:

- Focus or area covered (e.g., Energy Management Information System in Croatia and Energiamonitor in Estonia are primarily intended to be used for energy monitoring, Madaster in the Netherlands records all materials and products that are incorporated in a real estate, Woningpas in Flanders (Belgium) features information on energy performance, renovation advice, the housing quality, and data on the environment);
- Types of buildings covered (e.g., Woningpas in Belgium covers only individual houses and multi-apartment buildings, whereas Eigenheim Manager in Germany, Madaster in the Netherlands, Basta Logbook in Sweden, and Produktkolen in Sweden cover all types of buildings);
- Initiative type (voluntary/mandatory, public/private, paper/digital);
- Maturity level (UD—under development, IP—in place, D—discontinued).

Table 3 gives an overview of building logbooks and initiatives across project partner countries involved in the EUB SuperHub project.

Table 3. Overview of building logbooks and initiatives across project partner countries involved in the EUB SuperHub project.

Project Partner Country	DBL Name	Name of Organisation/Ministry/Company Responsible	Mandatory/Voluntary	Maturity Level: IP—in Place, D—Discontinued
Croatia	Energy Management Information System	Croatian Government Real Estate Agency	Mandatory for all public buildings	IP
France	CLEA Mon Carnet Logement Passeport Efficacité Énergétique (P2E) Wiki Habitat	QUALITEL Digilogement EDF Novabuilt	Mandatory since January 2023	IP
Germany	Eigenheim Manager	Leipziger Eigenheim Manager GmbH	Voluntary	IP
	Gëbaudepass	Bundesminister für Verkehr, Bau- und Wohnungswesen (BMBBW)	Voluntary	IP
	Hausakte	Bundesminister für Verkehr, Bau- und Wohnungswesen (BMBBW)	Voluntary	IP
	ImmoPass	HypoVereinsbank and Dekra	–	D
	QDF Hausakte	Bundesverband Deutscher Fertigbau e.V.	Mandatory	IP
Italy	Fascicolo del Fabbricato	Regional government based on national requirement	Voluntary	IP

The mandatory Croatian Energy Management Information System is a web application primarily used for monitoring and analysing energy and water consumption in public buildings.

The national authorities in France have launched a testing phase of different logbook concepts, organised in the framework of the PTNB—Plan de Transition Numérique du Bâtiment (Building Digital Transition Plan), launched in December 2014 by the Housing Ministry. It is important to point out, that digital building logbooks have been mandatory in France since January 2023.

There are several digital building logbooks in place in Germany, such as Eigenheim Manager, Gëbaudepass, Hausakte, and QDF Hausakte, mostly intended for individual houses. ImmoPass was a quality assurance system providing prospective real estate buyers with information about the sustainability and energy performance of the building, launched in 2001 by HypoVereinsbank. However, ImmoPass is currently discounted in Germany for unknown reasons.

In Italy, there is a voluntary building logbook called "Fascicolo del Fabbricato", which serves as a repository for all relevant information related to a building's safety, stability, plant engineering, usability status, and maintenance plan.

More details about existing building logbooks and initiatives across Europe can be found in [24].

3.4. Lessons Learned from the Literature Review about What Digital Building Logbooks Should Look Like

Based on the analysed existing DBL data structure and all the suggestions within the "Study on the Development of an EU Framework for Buildings' Digital Logbook" (Report 1, Report 2, final report) published by the European Commission [13,20,21], and bearing in mind all requirements within already existing EU legislation (e.g., directive (EU) 2018/844, [22]) and the future ones that will be soon adopted (e.g., [3]), there is a whole list of requirements (main findings) that need to be fulfilled when defining and implementing a digital building logbook.

The elaborated digital building logbook needs to:

1. Be applicable for the entire building stock (residential and non-residential buildings);
2. Collect and monitor all relevant building data within the entire building life cycle;
3. Be easy to use (simplicity, user friendly);
4. Be easily understandable and usable by different stakeholders, who have different information needs, and use data in different ways and for different purposes;
5. Become a common gateway to access data, and bring data from different data sources together by linking with other existing reliable building information databases (e.g., EPC database, property price/lease register, Energy Management Information System, as well as databases related to the smart readiness indicator, building renovation passports and the level(s) framework);
6. Use a hybrid approach to data storage—only common basic data and data that cannot be found in any other databases are entered and stored physically within a created digital building logbook; for all other building data, that are already stored in some other reliable databases that are regularly updated and maintained, data and information need to be linked via a unique building ID to DBL—this will ensure that the information is up to date whenever data is being updated at source—only, in that case, a DBL will become a dynamic tool providing up-to-date and reliable data;
7. Comprise at least the following data (elements, indicators) within the DBL data structure:
    - 7.1. Physical accessibility (design for all)—according to the new proposal of the EPBD directive (December 2021) [3], accessibility for persons with disabilities need to be addressed for all new buildings;
    - 7.2. A history of any major renovations or replacements—based on the task description [23];

7.3. Records about materials used (material passport)—traceability of materials and chemicals over the building's life cycle—based on the task description [23];
7.4. Energy efficiency classes (EU energy labels) of sources of energy for space heating/domestic hot water/space cooling and built-in light sources;
7.5. BACS efficiency class (EN 15232-1)—directive (EU) 2018/844 [22] introduced a new provision related to the building automation and control system (BACS): all new and existing non-residential buildings with an effective rated output for heating/cooling systems, or systems for combined space heating/cooling and ventilation, of over 290 kW need to be equipped with a building automation and control system (BACS), as of 31 December 2024; the intention is to lower this threshold from 290 to 70 kW as of 1 December 2030;
7.6. Building maintenance history—based on the task description [23];
7.7. Smart readiness indicator (SRI)—rating smart readiness of buildings based on an assessment of the capabilities of a building/building unit to adapt its operation to the needs of the occupant and the grid is becoming important, with the main goal being to improve energy efficiency and overall performance of a building/building unit; this is a new provision introduced by directive (EU) 2018/844 [22];
7.8. E-mobility—infrastructure for electric vehicle recharging. This is a new provision introduced by directive (EU) 2018/844 [22];
7.9. Operational costs—based on the task description [23];
7.10. Actual energy performance of the technical building system—based on the task description [23];
7.11. Life-cycle global warming potential (GWP)—according to the new proposal of EPBD directive (December 2021) [3], the life-cycle global warming potential of all new buildings will have to be calculated as of 2030; this obligation will start even earlier, from 2027, for all new buildings with a useful floor area larger than 2000 m^2.

8. To enable an automated generation of the LCA and LCC values of the building—based on the task description [23];
9. To act as the digital container containing all input values to calculate the passport rating in three domains (EPC, sustainability, and smartness)—based on the task description [23].

The elaborated DBL should be seen as a common gateway linked to existing databases [25], i.e., as a piece of networking that should be able to connect the existing heterogeneous databases on buildings, allowing the visualization of all the information available in the different sources through a single application. A digital building logbook will be applied to each building recognised by all other components of the platform, as well as any external software solutions.

A software intermediary that allows communication between two databases is called an application programming interface (API). To be able to communicate, those two databases need to work with compatible data interchange formats (e.g., XML, CSV).

The digital building logbook's purpose is to bring credible data sources together and become a common gateway to access data. Connecting all these data sources and users requires common languages—interfaces and protocols—to enable interoperability, data consistency, and information exchange.

On the announcement webinar "Digital Building Logbook", held online in June 2022, Michael Flickenschild, the project coordinator of Ecorys, highlighted that "DBL is not a self-contained library but links existing databases" [26]. Furthermore, he stressed the project's main aim: developing an EU model for digital building logbooks.

Report 1 of the "Study on the development of a European Union Framework for Buildings' Digital Logbook", published by the European Commission in July 2020 [13], discusses three approaches for storing data in the digital building logbook (DBL). The first approach involves physically storing all information related to the building in the

DBL database. The second approach uses a unique building ID as a digital gateway to link various sources of information related to the building. The third approach is a hybrid version, that combines the first two approaches. A combination of these approaches may be necessary to meet the diverse needs of stakeholders and to ensure the effectiveness of the DBL.

The EUB SuperHub team opted for a hybrid approach to data storage. Only common basic data and data that cannot be found in any other credible databases are entered and stored physically within a digital building logbook. For all other building data, that are already stored in some other credible interoperable databases regularly updated and maintained, data and information need to be linked via a universally unique building UUID to DBL. This will ensure that the information is up to date whenever data is being updated at source—only in that case, will a DBL become a dynamic tool providing up-to-date and reliable data.

On the second webinar, linking building and construction datasets at a national level, held online in October 2022, Michel Böhms from TNO (Organisation for Applied Scientific Research from the Netherlands), in his presentation entitled "Presentation on the review of existing datasets and the potential to link data", presented the most promising data for DBL, and stated that DBL data structure needs to be kept simple but not too simple. In the section "Open floor for Q&A on results of database review, linked data approach and connecting databases", Michael Flickenschild, the project coordinator of Ecorys, continued by stating that, there are many data sources around and that is important to start very small and slowly build this app ("start small, think big!") stressing Woningpas as a good example. In his opinion, one of the pitfalls is to make a DBL too complex.

4. State of Play of Existing National Databases in the EU Countries Involved in the EUB SuperHub Project as Potential Data Sources

Many building information databases are already in place in project partner countries (Austria, Croatia, France, Germany, Hungary, Ireland, and Italy) involved in the EUB SuperHub project, referring to building stock:

- National and regional EPC databases (e.g., national databases in all project partner countries, regional databases in Austria and Italy);
- Database on regular inspection of heating and air-conditioning systems;
- Cadastral databases;
- Property price register or real estate information system (register containing transaction values of sold properties);
- Leases register (register of rent payable in respect of property);
- Databases containing all life-cycle information about the construction/building products (e.g., Baubook in Austria, Ökobaudat in Germany);
- Databases for monitoring energy and water consumption in public buildings (e.g., Energy Management Information System—EMIS, in Croatia), and so on.

Some of the national databases mentioned above may serve as reliable source of data for the digital building logbook (Figure 1).

It is noteworthy that the vast majority of those databases do not interconnect. When working on Task 1.4 (Impact of energy efficiency improvements and certifications on the value of buildings) within the EUB SuperHub project [27], it was concluded that there is no interconnection between EPC databases and property price and leases registers. For example, existing databases containing transaction values of sold properties and rent prices of rented properties do not contain EPC labels of buildings being sold or rented, or any other data related to building energy efficiency. In project partner countries, it was impossible to quantify the increase or decrease in property value linked to energy efficiency (e.g., EPC label). It is essential to be able to distinguish between efficient and inefficient buildings. If a building is inefficient, consuming too much energy and falling below standards, it should become less attractive and obsolete, and consequently, experience the so-called "brown discount". On the other hand, a building that achieves sustainability requirements and

other green features (such as solar panels, PVs, heat pumps, energy-efficient lighting, and automation) should experience a "green premium".

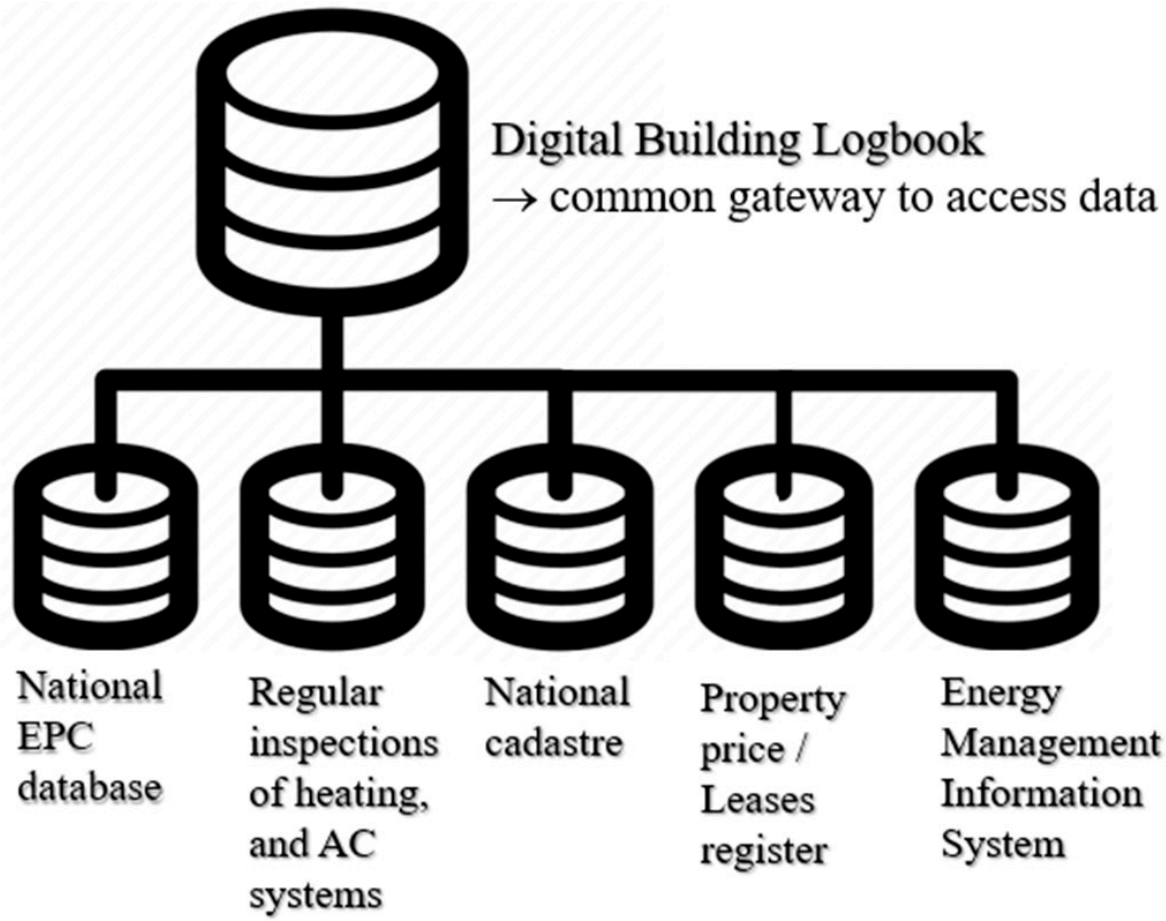


Figure 1. Linkage between digital building logbook and existing national databases.

All seven project partner countries involved in the EUB SuperHub project have national EPC databases in place. In addition, Austria and Italy also have in place regional EPC databases. Austria has 9 federal provinces (Länder), and Italy has a total of 20 regions. Statistics Austria set up a separate central energy performance certificate database in Austria (Energieausweisdatenbank EADB, https://www.statistik.at/datenbanken/adress-gebaeude-und-wohnungsregister/energieausweisdatenbank-eadb, accessed on 13 January 2023) as part of the buildings and dwellings register, for the electronic registration of energy performance certificates. It is up to the federal provinces to decide whether the registration by the issuers of energy performance certificates has to be carried out directly in the central energy performance certificate database (EADB) or in a separate federal province database. There is a national EPC database in Italy, named SIAPE (information system on energy performance certificates; Sistema Informativo sugli Attestati di Prestazione Energetica; https://siape.enea.it/, accessed on 13 January 2023), for the collection of the energy performance certificates of buildings and property units. It is noteworthy that the vast majority of EPC databases set up in the aforementioned EU countries are either only partly publicly accessible or not publicly accessible at all (Table 4).

Table 4. Overview of national EPC databases in EU countries involved in the EUB SuperHub project.

Project Partner Country		EPC Database	National EPC Database Name in the English Language	National EPC Database Name in the Original Language	National EPC Database Ownership in the English Language	Publicly Accessible (Yes/No/Partly)
1	Austria	Regional and National	Energy performance certificate database (EPCDB)	Energieausweis-datenbank (EADB)	Statistics Austria	n/a
2	Croatia	National	Energy performance certificate (EPC) information system	Informacijski sustav Energetskih Certifikata (IEC)	Ministry of Physical Planning, Construction and State Assets	Partly
3	France	National	EPC database	Base de données DPE de l'ADEME	ADEME	n/a
4	Germany	National	GEG-registration centre	GEG-Registrierstelle	German Institute for Building Technology	No
5	Hungary	National	Energy performance certificate (EPC) information system	e-tanúsítás	Ministry of Construction and Investment	No
6	Ireland	National	EPC database	EPC database	Sustainable Energy Authority of Ireland (SEAI)	No
7	Italy	Regional and National	SIAPE—information system on energy performance certificates	SIAPE—Sistema Informativo sugli Attestati di Prestazione Energetica	ENEA National Agency for New Technologies, Energy and Sustainable Economic Development	Partly

The EPC databases constitute important and credible data sources for digital building logbooks. If the last paragraph within article 19 in the third revision of the EPBD [3], which proposes the connection of the national EPC databases to digital building logbooks, is accepted, then linking the EPC databases to digital building logbooks will become mandatory. The member states will need to ensure the interoperability of their existing EPC databases. A database is interoperable if it can exchange, interpret, and present shared data in a way that is understood by other databases.

5. The EUB SuperHub Online Platform

Funded by the EU, the EUB SuperHub project has developed the EUB SuperHub online platform. Its main goal is to transform the current building certification and rating systems, to facilitate the EU's transition to a decarbonised, smart, and sustainable building stock by 2050. The platform achieves this by evaluating, assessing, and monitoring buildings throughout their entire life cycle. It comprises four main modules, namely the planning and verification tool (PVT) module, e-passport cockpit (e-cockpit), virtual marketplace (VM), and e-training module.

The e-cockpit is a multi-scale cloud-based geo-referenced interactive database, that will allow a wide array of stakeholders to view key information about the existing building stock and related certificates (e.g., EPC, sustainability certificates, SRI, etc.).

The planning and verification tool (PVT) module is an extension of the e-cockpit module, enabling building owners to upload, share, and store all building-related information. The building owners decide on the building information they would like to share with the public in the e-cockpit. The PVT module provides building data entry and stores them in a digital building logbook and simulations (what-if scenarios).

The virtual marketplace (VM) facilitates the match-making connection between the building users, auditors, and solution and funding providers, as well as other market actors and service providers.

The e-training module is an independent part of the EUB SuperHub platform, providing training material for the platform users. The platform will follow a service-oriented architecture (SOA).

All four modules act together and create a one-stop shop online platform, by meeting the demands of all construction sector value chains in one place. More data about the features and functions of the developed EUB SuperHub online platform can be found in [28].

6. The EUB SuperHub Digital Building Logbook Data Structure

The EUB SuperHub digital building logbook data structure represents one essential layer within the planning and verification tool (PVT) module, and is elaborated considering:

- All the suggestions within the "Study on the Development of an EU Framework for Buildings' Digital Logbook" (Report 1, Report 2, final report), published by the European Commission in 2020 [13,20,21];
- Already existing DBL data structures developed within EU projects (iBRoad, ALDREN, BIM4EEB, and X-tendo) [6–12];
- Requirements defined within already existing EU legislation [22] and the future ones that will be soon adopted (e.g., the proposal for the EPBD recast, published in December 2021 [3]);
- Requirements within grant agreement number 101033916—EUB SuperHub [23].

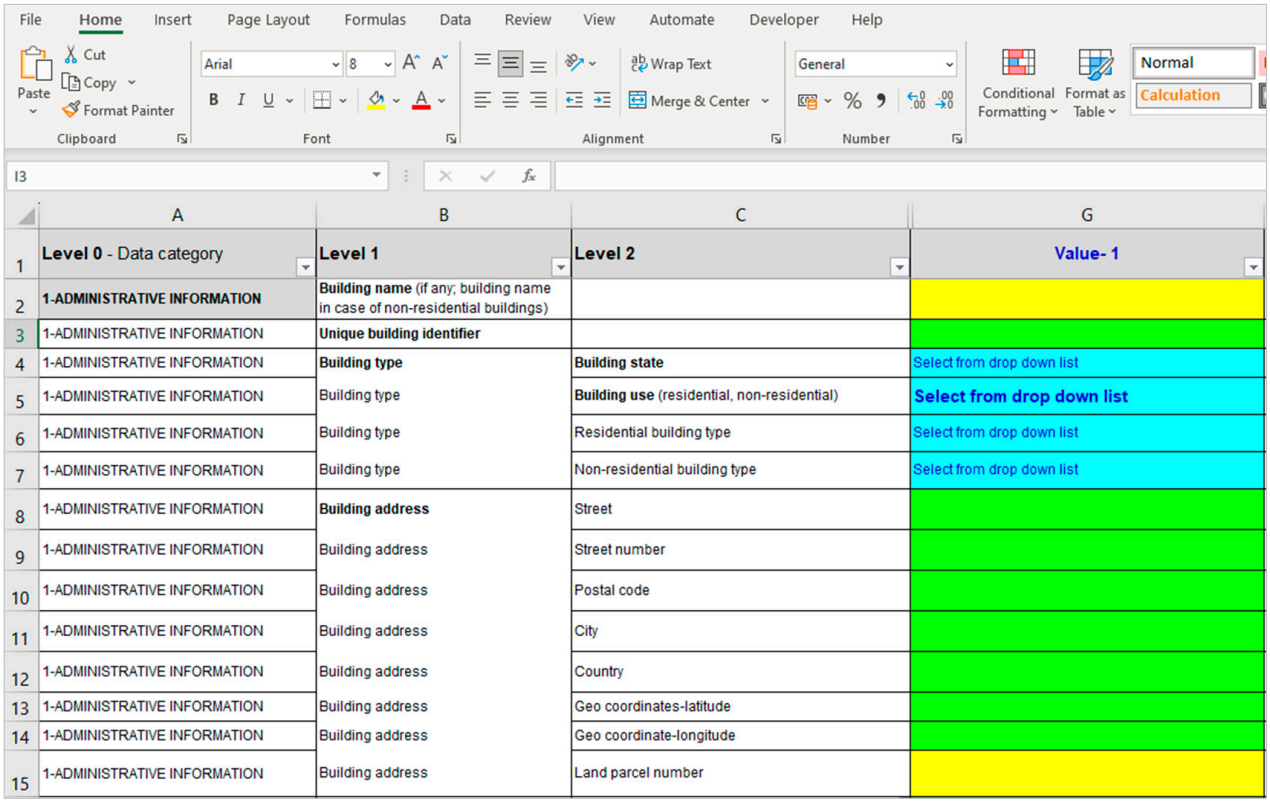
The elaborated EUB SuperHub digital building logbook data structure contains the following eight main categories (Figure 2):

1. Administrative Information
2. General Building Information
3. Building Element Information
4. Building Operation and Use
5. Building Performance
6. Smart Readiness
7. Finance
8. Building Documentation BIM

The EUB SuperHub digital building logbook aligns with the main categories defined in the "Study on the Development of an EU Framework for Buildings' Digital Logbook", with the exception of one additional category, Building Documentation BIM, which has been added as the eighth category. Furthermore, within the EUB SuperHub digital building logbook structure, there is no separate category called Building Material Inventory because it is part of category 3, Building Element Information.

Within the first step, the whole EUB SuperHub digital building logbook structure is defined in one Microsoft Excel worksheet (Figure 3). There are a total of six levels of information (level 0, level 1, level 2, level 3, level 4, and level 5). Level 0 comprises the eight DBL modules, and level 1 presents the main subcategories of each module (category).

Figure 2. The main categories of the evaluated EUB SuperHub digital building logbook.



	A	B	C	G
1	**Level 0** - Data category	**Level 1**	**Level 2**	**Value- 1**
2	**1-ADMINISTRATIVE INFORMATION**	**Building name** (if any; building name in case of non-residential buildings)		
3	1-ADMINISTRATIVE INFORMATION	**Unique building identifier**		
4	1-ADMINISTRATIVE INFORMATION	**Building type**	**Building state**	Select from drop down list
5	1-ADMINISTRATIVE INFORMATION	Building type	**Building use** (residential, non-residential)	**Select from drop down list**
6	1-ADMINISTRATIVE INFORMATION	Building type	Residential building type	Select from drop down list
7	1-ADMINISTRATIVE INFORMATION	Building type	Non-residential building type	Select from drop down list
8	1-ADMINISTRATIVE INFORMATION	**Building address**	Street	
9	1-ADMINISTRATIVE INFORMATION	Building address	Street number	
10	1-ADMINISTRATIVE INFORMATION	Building address	Postal code	
11	1-ADMINISTRATIVE INFORMATION	Building address	City	
12	1-ADMINISTRATIVE INFORMATION	Building address	Country	
13	1-ADMINISTRATIVE INFORMATION	Building address	Geo coordinates-latitude	
14	1-ADMINISTRATIVE INFORMATION	Building address	Geo coordinate-longitude	
15	1-ADMINISTRATIVE INFORMATION	Building address	Land parcel number	

Figure 3. Screenshot of the worksheet containing the EUB SuperHub digital building logbook data structure.

Although it is a common suggestion to keep the DBL data structure as simple as possible, a comprehensive digital building logbook data structure, containing eight main

modules, has been developed within the EUB SuperHub project, trying to fulfil and take into account the different aforementioned requirements.

The third category, 3—Building Element Information, contains the highest percentage of total data entry fields (42.03%), followed by the fifth category, 5—Building Performance (22.01%) (Figure 4).

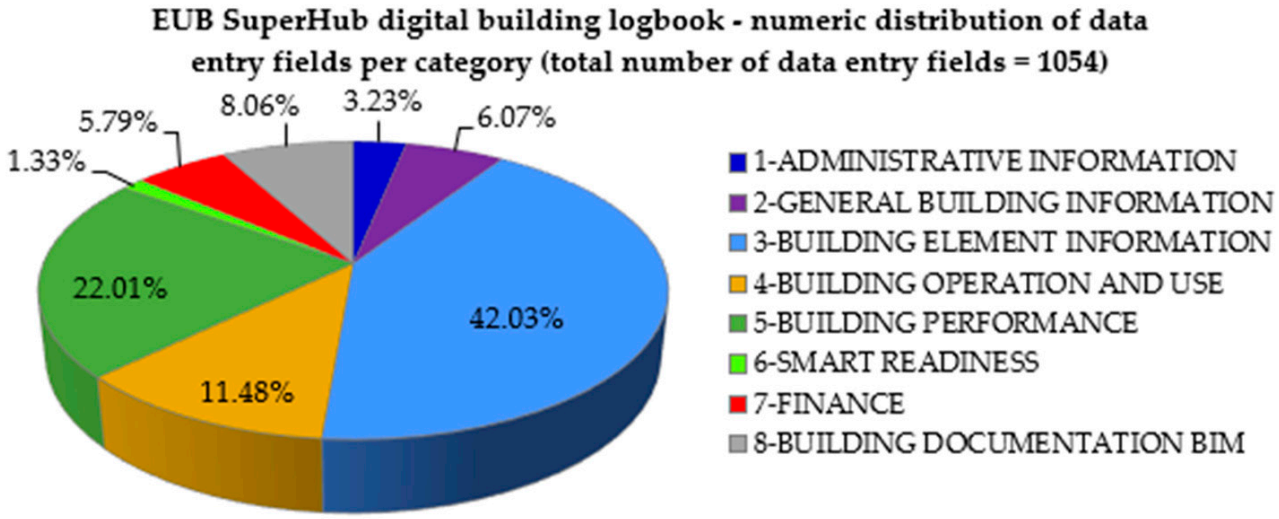


Figure 4. SuperHub digital building logbook data—numeric distribution of data entry fields per category.

Appendix A provides the EUB SuperHub digital building logbook data structure, containing three of a total of total six horizontal levels. Due to the substantial amount of information in each category, it was not feasible to include the entire developed DBL data structure in this paper. The whole EUB SuperHub digital building logbook data structure can be found in [24].

6.1. Module 1: Administrative Information

The first category, named 1. Administrative Information, provides the data related to the building name (if any, building name in case of non-residential buildings), unique building identifier, building type, building address, ownership, building owner, DBL author/s. The elaborated DBL data structure covers buildings in the different building life-cycle phases (so-called building states):

- New buildings:
  - New buildings in the design phase;
  - New buildings in the construction phase;
  - New buildings in the as-built phase.
- Existing buildings in the use phase;
- Renovated buildings:
  - Renovated buildings in the design phase;
  - Renovated buildings in the construction phase;
  - Renovated buildings in the as-built phase.

The proposed EUB SuperHub digital building logbook is intended to be applicable to the entire building stock (residential and non-residential buildings), although there are not so many data entry fields added, particularly for the specific building features (e.g., the number of rooms in a hotel, the category of a hotel, number of offices in an office building, number of beds of a health establishment with accommodation, etc.).

All data entry fields referring to building address, except land parcel number, will be automatically assigned based on the user claim in the EUB SuperHub platform. Furthermore, some data related to the building owner (private person, public institutions/company)

and DBL author will also be automatically assigned based on user login data in the EUB SuperHub platform [28].

6.2. Module 2: General Building Information

The second category, named 2. General Building Information, specifies basic building data (e.g., year of construction, history of any major renovations or replacements, building pictures, number of floors, historical status, building surroundings, etc.), building geometry (e.g., floor area, building's envelope area, building volume, shape factor, etc.), and geometric characteristics (e.g., type of construction, roof type, facade type).

Given the requirements in the grant agreement [23], the elaborated EUB Superhub digital building logbook also holds data about any major renovations or replacements. The DBL author can choose all the renovated building elements by checking corresponding checkboxes. Each renovated building element is connected to the date by entering the year of renovation.

6.3. Module 3: Building Element Information

There is a definition within the EPBD directive 2010/31/EU [29] stating that "building element" means a technical building system or an element of the building envelope. The category named 3. Building Element Information, comprises all relevant information about the building envelope and technical building system (TBS) (Figure 5).

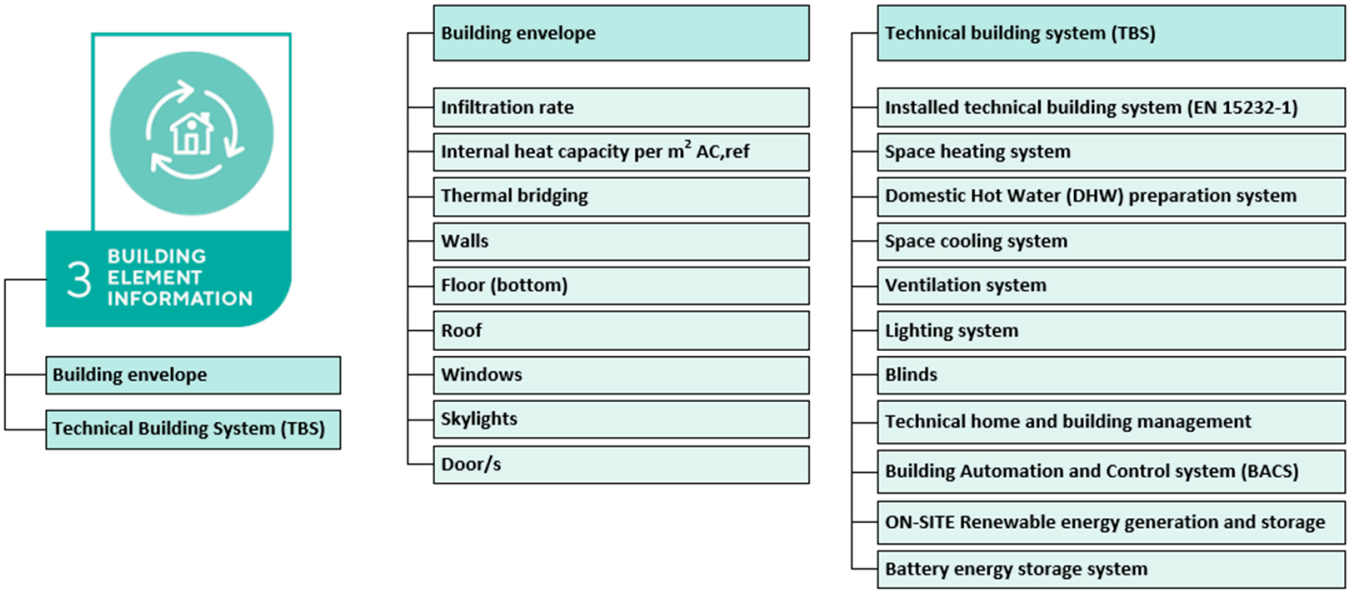


Figure 5. 3-Building Element Information: overview of main subcategories.

The first subcategory, named Building Envelope, refers to the following integrated elements of a building which separate its interior from the outdoor environment: walls, floor (bottom), roof, windows, and skylights. It is noteworthy that building material inventory is placed within this category.

The second subcategory, named Technical Building System (TBS), comprises the broad range of technical equipment used for space heating, space cooling, ventilation, domestic hot water preparation, built-in lighting, building automation and control, on-site renewable energy generation (e.g., photovoltaic system, solar thermal system) and storage, or a combination thereof, including those systems using energy from renewable sources, of a building or building unit.

According to the grant agreement, the elaborated EUB SuperHub digital building logbook needs to:

- Document and store records about materials used (material passport); for that reason, building material inventory is placed within the Building Envelope subcategory;
- Hold records of expected end of life of the technical building system.

The elaborated EUB SuperHub digital building logbook collects the following data for each building's construction (walls, floor (bottom), roof) as follows:

- Insulation (insulated/not insulated);
- U value (W/(m^{2}K));
- Surface area (m^2);
- Data about each layer.

For each layer of a building's construction, a list of data is collected which represents the material passport (e.g., material type, thickness, thermal conductivity, density, thermal capacity, vapour permeability, material location, wight, volume, GWP, PERT, PENRT, life span, fire resistance class, waste category).

The elaborated EUB SuperHub DBL collects all required data relating to the technical building system (seven main categories) to calculate the BACS efficiency class, according to the European standard EN 15232-1:2017 [30].

6.4. Module 4: Building Operation and Use

The fourth category, 4. Building Operation and Use, provides the data related to the following subcategories: Building Use, Climate Data Actual, Metered Data, Inspection of Heating and Air-Conditioning Systems (EPBD), and Building Element Maintenance.

The first subcategory, named Building Use, collects the data about the number of occupants, daily usage time, and annual usage time of a building, but also daily HVAC system operating hours and setting room temperatures (for heating and cooling periods), which could vary over time.

The second subcategory, named Climate Data Actual, collects the data about the locality of a building (e.g., latitude, longitude, altitude), actual weather data (outside air temperature, solar radiation, wind speed, heating degree days, cooling degree days), solar potential, and soil/terrain.

The Metered Data subcategory is of the utmost importance and includes all data that is measured on a monthly or hourly basis, such as energy consumption, renewable energy generated on-site, water consumption, and domestic hot water consumption within a selected building.

The fourth subcategory relates to the regular inspection of heating and air-conditioning systems (EPBD) according to the requirements of the EPBD directive, gathering the main data related to regular inspections such as date, ID of the inspection, validity data or future inspection data, tailored renovation recommendations, and inspection service contact data and reports, which are also part of the last module, 8. Building Documentation BIM.

The last subcategory within this module refers to the maintenance of building elements, having in mind the maintenance of the building envelope and maintenance of the technical building system (TBS). This part of DBL collects basic data: ID of the maintenance, which building element was maintained and when and by whom, and a brief description of the performed maintenance. If possible, it would be preferable to also upload maintenance reports/certificates.

6.5. Module 5: Building Performance

The category named 5. Building Performance has the following four main subcategories:

- Energy Performance Certification (EPBD);
- EUB SuperHub Certification (EUB e-passport);
- Sustainability Certification (e.g., DGNB, BREEAM, LEED, Protocollo ITACA, KGA in the state of Vorarlberg in Austria);
- Key Performance Indicators (KPIs).

According to the grant agreement [23], the elaborated EUB SuperHub digital building logbook needs to hold records of all EPCs and sustainability certificates (if available).

The second subcategory, known as EUB SuperHub Certification, focuses on the EUB SuperHub certificate, also called the EUB e-passport, which is the primary result that the project aims to produce (see Task 2.5, The EUB SuperHub transnational framework and passport [23]).

The third subcategory, Sustainability Certification, involves gathering shared information about sustainability certificates. A brief overview about the local building sustainability rating system used among the EUB SuperHub consortium countries and regions, covering the main features of each local sustainability rating system, can be found in [31].

The final subcategory in this module includes 21 key performance indicators (KPIs) that were chosen and defined by the consortium team. These KPIs cover a variety of thematic areas, such as energy consumption, renewable energy, greenhouse gas (GHG) emissions during both use and the product's life cycle, indoor air quality, thermal comfort, costs, smart buildings, resilience, e-mobility, and daylight sufficiency.

6.6. Module 6: Smart Readiness

The sixth category, 6. Smart Readiness, covers the smart readiness of the building, e-mobility, as another important issue, since mobility must be CO_2-neutral in the future, and potential.

Within the topic of smart readiness, the smart readiness indicator (SRI) needs to be calculated in %. The second topic covers the charging infrastructure for e-mobility, and the third topic refers to the following two potentials:

- Smart district potential;
- Demand response potential.

The smart district potential gives information related to the infrastructure available in the building's surroundings (considering the possibility to interact with it), promoting a better management of the building or the infrastructure. Demand response is a change in electricity consumption by consumers, to help keep the supply and demand of electricity in balance.

6.7. Module 7: Finance

The seventh category, 7. Finance, provides the data related to all types of possible costs related to the building, such as annual rent, annual property tax, market value, property price paid, renewal costs, EPC costs, operational costs, and energy revenues. According to the grant agreement, the developed EUB SuperHub digital building logbook needs to cover operational energy costs.

6.8. Module 8: Building Documentation BIM

In the last category, named 8. Building Documentation BIM, there are all kind of documents related to the building, such as permits, manuals, design and plans of the building, tenancy agreements, utility contracts, utility bills, documents related to building construction and maintenance, energy performance certificates, sustainability certificates, reports on the inspection of heating and air-conditioning systems, valuation reports, insurance documents, weather files, BIM, and building pictures. The digital building logbook supports the integration of IFC files that can be later imported into the planning and verification tool (PVT) module of the platform and displayed there.

7. Conclusions

This paper aims to present in detail the digital building logbook data structure, developed within the EU-funded Horizon 2020 EUB SuperHub project. The EUB SuperHub digital building logbook data structure represents a main pillar of the development of the next-generation energy performance assessment and certification underpinning the developed EUB SuperHub online platform and EUB e-passport, and is elaborated considering:

- All the suggestions within the "Study on the Development of an EU Framework for Buildings' Digital Logbook" (Report 1, Report 2, final report), published by the European Commission in 2020 [13,20,21];
- Already existing DBL data structures developed within EU projects (iBRoad, ALDREN, BIM4EEB, and X-tendo) [6–12];
- Requirements defined within already existing EU legislation [22] and the future ones that will be soon adopted (e.g., the proposal for the EPBD recast, published in December 2021 [3]);
- Requirements within grant agreement number 101033916—EUB SuperHub [23].

Given all of the above mentioned requirements, the comprehensive EUB SuperHub digital building logbook data structure is elaborated, containing eight main modules: 1. Administrative Information, 2. General Building Information, 3. Building Element Information, 4. Building Operation and Use, 5. Building Performance, 6. Smart Readiness, 7. Finance, 8. Building Documentation BIM.

Many valuable national building-related databases already exist across project partner countries involved in this project, which could be possible data sources for the elaborated digital building logbook. Many of those national databases are not publicly available or are only partially publicly available. Following the last paragraph within article 19 of the third proposed revision of the energy performance of buildings directive, published in December 2021 [3], all national EPC databases will need to be interoperable and integrated with the digital building logbook. When adopted, the third revision of the energy performance of buildings directive will pave the way to digital building logbooks. The purpose of the digital building logbook is to bring these data sources together and become a common gateway to access data.

Introducing the concept of digital building logbooks, to overcome the main challenge of a lack of access to sufficient building-related data, is of the utmost importance and can contribute to:

- Access to information;
- Information sharing within the construction sector, among building owners and occupants, financial institutions, and public authorities;
- A higher renovation rate of existing buildings—promoting energy renovation by providing the necessary information;
- Better informed decision making;
- Simplification of the construction process;
- Improved market information and transparency;
- Better management of inspections and better operation, use, and maintenance of a building;
- A better overview of the building stock at all levels;
- Better monitoring progress towards climate goals—better assessment of the progress of decarbonisation;
- More effective policy making, etc.

A digital building logbook can be an essential tool in the era of digitalization. It can contain all relevant building-related data over the entire life cycle of a building, from the design phase through the construction, operation, performance, maintenance, and deterioration. Overall, a digital building logbook can be an essential tool for managing buildings in the digital age, providing different types of stakeholders with different information for different purposes at the right time.

Author Contributions: Conceptualization, M.M.P. and A.K.; methodology, M.M.P.; formal analysis, M.M.P.; investigation, A.K., E.B. and P.G.; resources, M.M.P., A.K., E.B. and P.G.; writing—original draft preparation, M.M.P.; writing—review and editing, A.K., E.B. and P.G.; visualization, M.M.P. All authors have read and agreed to the published version of the manuscript.

Funding: The research leading to these results has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101033916.

Data Availability Statement: Not applicable.

Acknowledgments: This work was conducted within the EU-funded Horizon 2020 three-year EUB SuperHub project (European building sustainability performance and energy certification hub) started in June 2021, coordinated by Geonardo from Hungary, and involving seven EU project partner countries (1—Austria, 2—Croatia, 3—France, 4—Germany, 5—Hungary, 6—Ireland, 7—Italy).

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

ALDREN	Alliance for deep renovation in buildings
API	Application programming interface
BIM	Building information model
BIM4EEB	BIM-based fast toolkit for efficient renovation in buildings
BPMN	Business Process Modelling Notation
BREEAM	Building research establishment environmental assessment method
BUILDCHAIN	Building knowledge book in the blockchain distributed ledger
CSV	Comma-separated values
Cr	Energy carrier
D	Deliverable
D	Discontinued
DBL	Digital building logbook
Demo-BLog	Development and demonstration of digital building logbooks
DGNB	Deutsche Gessellschaft für Nachhaltiges Bauen (German Sustainable Building Council—Germany)
DHW	Domestic hot water
EADB	Energieausweisdatenbank (energy performance certificate database in Austria)
EBC	European Builders Confederation
EMIS	Energy Management Information System (Croatia)
EN	European norm
EU	European Union
EUB SuperHub	European building sustainability performance and energy certification hub
EV	Electrical vehicle
EPBD	Energy performance of buildings directive
EPC	Energy performance certificate
GHG	Greenhouse gases
GWP	Global warming potential
HIP	Home information pack
HVAC	Heating, ventilation, and air-conditioning
IAQ	Indoor air quality
IBRoad	Individual building renovation roadmaps
ID	Identification
IEC	Informacijski sustav energetskih certifikata (national EPC database in Croatia)
IFC	International foundation class
IoT	Internet of things
IP	In place
JRC	Joint Research Centre
KGA	Kommunalgebäudeausweis
KPI	Key performance indicator
LCA	Life-cycle assessment
LCC	Life-cycle cost
LEED	Leadership in energy and environmental design
OpenDBL	One-step open DBL solution
P2E	Passport Efficacité Energétique (building renovation passport in France)
PERT	Total renewable primary energy
PENRT	Total non-renewable primary energy

PTNB	Plan de transition numérique du bâtiment (building digital transition plan—France)
PV	Photovoltaic
PVT	Planning and verification tool
Q&A	Question and answer
R&I	Research and innovation
SEAI	Sustainable Energy Authority of Ireland
SIAPE	Sistema Informativo sugli Attestati di Prestazione Energetica (information system on energy performance certificates—Italy)
SME	Small and medium-sized enterprise
SOA	Service-oriented architecture
SRI	Smart readiness indicator
TBS	Technical building system
UD	Under development
UK	United Kingdom
UUID	Universally unique identifier
VAT	Value added tax
VM	Virtual marketplace
XML	Extensible markup language
X-tendo	Extending the energy performance assessment and certification schemes via a modular approach

Appendix A. The EUB SuperHub Digital Building Logbook Data Structure Containing Three of a Total of Six Horizontal Levels

Level 0	Level 1	Level 2
1. Administrative Information	Building name	
	Unique building identifier	
	Building type	Building state
		Building use (residential, non-residential)
		Residential building type
		Non-residential building type
	Building address	Street
		Street number
		Postal code
		City
		Country
		Geo coordinates—latitude
		Geo coordinate—longitude
		Land parcel number
	Building location	Climate zone
		Climate data station
	Ownership	Ownership type 1
		Ownership type 2
		Building owner
	DBL author	DBL author
		DBL last update
	Comments	

Level 0	**Level 1**	**Level 2**
2. General Building Information	Basic building data	Year of construction
		Building renovation
		Building pictures
		Base height
		Number of storeys (floors)
		Floor height
		Building height
		Topmost floor heated
		Number of heated basement floors
		District heating access
		Vertical transport—lift (elevator)
		Lift position
		Historical status
		Fire safety
		Seismic resilience
		Physical accessibility (design for all)
		Building surroundings
	Building geometry	Footprint area
		Bottom floor area
		Total floor area (unheated and heated area)
		Useful floor area (heated area)
		Building's envelope area A (sum of areas of external faces of the building, e.g., walls, roofs, floors)
		Building volume V
		Shape factor A/V (envelope area volume ratio)
	Building construction basics	Type of construction
		Roof
		Façade type
3. Building Element Information	Building envelope	Infiltration rate
		Internal heat capacity per m^2 $A_{C,ref}$
		Thermal bridging
		Walls
		Floor (bottom)
		Roof
		Windows
		Skylights
		Doors

Level 0	**Level 1**	**Level 2**
3. Building Element Information	Technical building system (TBS)	Installed technical building system (EN 15232-1)
		Space heating system
		Domestic hot water (DHW) preparation system
		Space cooling system
		Ventilation system
		Lighting system
		Blinds
		Technical home and building management
		Building automation and control system (BACS)
		On-site renewable energy generation and storage
		Battery energy storage system
4. Building Operation and Use	Building use	Reference year
		Number of occupants
		Daily usage time
		Annual usage days
		Daily HVAC system operating hours
		Setting room temperature
		User behavior
	Climate data actual	Locality—name (JRC, Eurostat)
		Locality—latitude
		Locality—longitude
		Locality—altitude
		Weather data actual
		Solar potential
		Soil/terrain
	Metered data	Energy consumption
		On-site renewable energy generation
		Exported renewable energy generated on-site
		Auto-consumed renewable energy generated on-site
		Water consumption
		Domestic hot water consumption
	Inspection of heating and air-conditioning systems (EPBD)	Inspection type
		Inspection of heating system (EPBD)
		Inspection of air-conditioning system (EPBD)
		Inspection of heating and air-conditioning systems (EPBD)

Level 0	**Level 1**	**Level 2**
4. Building Operation and Use	Building element maintenance	Date
		ID of the maintenance
		Building element
		Maintenance log—brief description
		Validity or future maintenance data
		Maintenance service contact
		Maintenance certificate/report
5. Building Performance	Energy performance certification (EPBD)	Energy performance certificate (EPC)
		EPC number
		Issue date
		Validity date
		EPC type
		EPC rating (EPC label)
		EPC support documentation
		Tailored renovation recommendations
		Climate resilience potential
		Energy performance calculation
		Energy assessor (auditor)
	EUB SuperHub certification	EUB SuperHub certificate
		EUB SuperHub certificate number
		Issue date
		EUB SuperHub rating
		Main indicator name used for determination of EPC rating
		Main indicator value
		Main indicator unit
		Assessor (auditor)
	Sustainability certification	DGNB certification system
		BREEAM certification system
		LEED certification system
		Protocollo ITACA certification system
		... X sustainability certification system

Level 0	**Level 1**	**Level 2**
	Key performance indicators (KPIs)	Energy consumption
		Renewable energy
		Greenhouse gas emissions (in use stage)
		Life-cycle global warming potential
		Thermal comfort
		Indoor air quality (IAQ)
		Life-cycle cost
		Smart readiness indicator
		Climate change and resilience
		E-mobility
		Daylight sufficiency
6. Smart Readiness	Smart readiness	Smart readiness indicator (SRI)
	E-mobility	Charging infrastructure for E-mobility
		Total number of available parking spaces
		Number of purpose-built electrical recharging spaces (number of E-parking spaces)
		Number of pre-cabled recharging stations
		Electrical vehicle (EV) charging station types
		Electrical vehicle (EV) charging types
		Electrical vehicle (EV) charging capacity
		Total charging capacity
		Maximum charging capacity per E-parking space (when charging one car only)
		Electrical vehicle (EV) grid balancing
		Electrical vehicle (EV) charging information and connectivity
	Potential	Smart district potential
		Demand response potential
7. Finance	Annual rent	Annual rent
		Annual rent per useful floor area
	Annual property tax	Annual property tax
		Annual property tax per useful floor area
	Building valuation	Market value
		Rent value
		Valuation date
		Real estate valuer
		Valuation approach
		Valuation purpose
		Valuation cost
		Valuation cost per useful floor area

Level 0	Level 1	Level 2
	Property selling	Property price paid
		Property price paid per useful floor area
	Renewal cost	Renewal costs
		Renewal costs per useful floor area
		Brief description of renewal
		Total renewal cost—life-cycle costs
		Total renewal cost—life-cycle costs per useful floor area
	Property yield	
	Certificate costs	Energy performance certification (EPBD)
		DGNB certification system
		BREEAM certification system
		LEED certification system
		Protocollo ITACA certification system
		. . . X certification system
	Cost of reports on the inspection of heating and/or air-conditioning systems	Cost of report on the inspection of heating system
		Cost of report on the inspection of heating system per useful floor area
		Cost of report on the inspection of air-conditioning system
		Cost of report on the inspection of air-conditioning system per useful floor area
		Cost of reports on the inspection of heating and/or air-conditioning systems
		Cost of reports on the inspection of heating and/or air-conditioning systems per useful floor area
	Operational costs	Annual energy costs for each energy carrier (cr) (e.g., electricity, natural gas, district heating system...)
		Annual energy costs for each energy carrier (cr) (e.g., electricity, natural gas, district heating system...) per useful floor area
		Energy price with VAT included for each energy carrier (cr) (e.g., electricity, natural gas, district heating system...)
		Total annual energy costs
		Total annual energy costs per useful floor area
		Annual water costs
		Annual water costs per useful floor area
		Annual maintenance costs for technical building system
		Annual maintenance costs for technical building system (TBS) per useful floor area

Level 0	Level 1	Level 2
		Other annual maintenance costs
		Other annual maintenance costs per useful floor area
		Annual building insurance costs
		Annual building insurance costs per useful floor area
		Other annual running costs
		Other annual running costs per useful floor area
		Sum of all annual running costs
		Sum of all annual running costs per useful floor area
	Energy revenues	Annual energy revenues
		Annual energy revenues per useful floor area
8. Building Documentation BIM	Permits	Location (planning) permit
		Building permit
		Construction permit
		Use permit
	Fire safety report	
	Seismic resilience report	
	Manuals	Safety manual
		User manual
	Fire safety plan (evacuation plan, signalization, alarms)	
	Design and plans of the building	Architectural plans
		3D model
		Technical building system (TBS) plan 1, 2, 3, . . . x
		As built plans
	Tenancy agreement/s	
	Building utilities	Utility contracts
		Utility bills
	Building construction bills	
	Building maintenance	Maintenance service contract
		Maintenance bills
		Maintenance certificate/report
	Building certification system	Energy performance certification (EPBD)
		EUB SuperHub certification
		Sustainability certification

Level 0	Level 1	Level 2
	Inspection of heating and air-conditioning systems (EPBD)	Report on the inspection of heating system
		Report on the inspection of air-conditioning system
		Report on the inspection of heating and air-conditioning systems
	Building valuation	Valuation report
	Building insurance	Insurance document
	Weather data	Weather file
		Weather file for year 2030
		Weather file for year 2050
	Building information model—BIM	
	Building pictures	
	Thermal image building pictures	

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