energies

MDPI

Review

Review and Analysis of Models for a European Digital Building Logbook

Marta Gómez-Gil, Almudena Espinosa-Fernández and Belinda López-Mesa *

Department of Architecture, University of Zaragoza, 50 018 Zaragoza, Spain; m.gomez@unizar.es (M.G.-G.); almudenaef@unizar.es (A.E.-F.)
* Correspondence: belinda@unizar.es; Tel.: +34-876555167

Abstract: The concept of a Digital Building Logbook (DBL) was first introduced with the European strategy 'Renovation Wave'. It is considered as one of two fundamental parts of which the Building Renovation Passport is composed: the DBL and a Renovation Roadmap. As the implementation of the DBL is a European priority, this paper reviews the existing literature and analyses the most developed European Digital Building Logbook models. The analysis includes iBRoad, ALDREN, X-tendo, and the Study on the Development of a European Union Framework for Buildings' Digital Logbook, from the perspective of seven key aspects: References used as a starting point for the model definition; Identification of the relevant stakeholders in the DBL; Identified potential user needs; Proposed structure of indicators; Data sources; Potential functionalities; and Operation and use. The results show that important advancement has been made, although there is still no consensus about crucial subjects, such as the indicators to be collected or how to collect and use them. This is probably due to the fact that the final functionalities (objective and scope) that the logbook should provide are not fully clear.

Keywords: Digital Building Logbook; Building Renovation Passport; Energy Performance Certificate; energy renovation; energy performance

Citation: Gómez-Gil, M.; Espinosa-Fernández, A.; López-Mesa, B. Review and Analysis of Models for a European Digital Building Logbook. *Energies* **2022**, *15*, 1994. https://doi.org/10.3390/en15061994

Academic Editor: Vincenzo Costanzo

Received: 28 January 2022
Accepted: 7 March 2022
Published: 9 March 2022

1. Introduction

European directives and strategies, such as the 'European Green Deal' and the 'Renovation Wave', point out the importance of the building sector in achieving the climate goals set by the European Union for 2050. In this sense, building decarbonization is a priority [1]. However, to achieve the goals set by EPBD (EU) 2018/844, a higher renovation rate of the existing buildings is required, moving from the current rate of 0.4–1.2% to a rate of 3%. There are many barriers that prevent the renovation rate from growing. They are of different nature: technical, financial, social/behavioral, and institutional, as identified in the literature [2–5]. Among the technical barriers, the lack of skilled workers with energy-efficient materials and renovation techniques, as well as the gap between predicted and actual energy savings achieved due to renovation processes; the fragmentation of the construction sector and the lack of dialogue between the involved stakeholders; the lack of information; and the lack of consideration of users' needs and expectations were mentioned in the literature. Regarding financial barriers, the long pay-back times of renovation interventions, the high investment needed to face a renovation process, the lack of attractive financial tools to make operations viable or the impossibility to access them, and the high risk perceived by the potential investors make the renovation rate remain low. In addition, social/behavioral barriers, such as long decision-making processes, especially in condominiums; the lack of awareness about renovation benefits; the concern about suffering disturbances during site works; and the lack of knowledge about the matter are of great importance because the building owner/user is called to be the booster of renovation processes. Finally, among the institutional barriers, the long administrative procedures needed are perceived as a discouraging burden [2–6].

The barrier of lack of information has hardly been addressed in the literature, even if it is considered a very important one [6]. The lack of open data about the existing buildings makes it difficult to analyze the building's real state (as in [7]), to measure progress in building decarbonization, to raise public awareness about the importance of refurbishment and to design renovation and maintenance strategies [8–10].

The use of Building Passports has been discussed for decades in Europe [8–10] as a way to gather and display building-related information by the construction sector stakeholders to raise environmental and quality awareness of the built environment. However, its use to promote and design building renovation processes is very recent [11–13]. In 2016, the Building Renovation Passport (BRP) was defined by the Buildings Performance Institute Europe (BPIE) [13] (p. 6) as "*a document—in electronic or paper format—outlining a long-term (up to 15 or 20 years) step-by-step renovation roadmap for a specific building, resulting from an on-site energy audit fulfilling specific quality criteria and indicators established during the design phase and in dialogue with building owners*". The BRP was first introduced in an official document with Directive (EU) 2018/844 [14] as a part of the long-term strategies that the European Member Estates had to design to promote the renovation of their building stocks. The BRP was conceived as a natural, more comprehensive, and user-friendly evolution of the Energy Performance Certificate (EPC), which does not only collect data of a building but also provides homeowners with tailored renovation recommendations. No details were given in the Directive regarding the structure of the new tool. Nevertheless, public administrations and research groups that are currently working on its definition agree on the two parts that it should contain [11,13]. The first part consists of a Digital Building Logbook (DBL), and the second part is a Renovation Roadmap that would guide the homeowners or tenants through the renovation processes.

The Digital Building Logbook as an autonomous tool was first introduced at a European scale in the 'Renovation Wave' strategy [15], and it is expected to contribute to creating good conditions for staged renovation. It is understood as a digital repository of all the relevant data on a building, collected throughout its lifecycle, including the information from the Energy Performance Certificates (EPC), the upcoming Level(s) tool, and the Smart Readiness Indicator. The information stored in the DBL should be easily shared among the stakeholders of the construction sector. Thus, it creates an awareness about the importance of renovation, increases transparency and reduces the risk for investors. The DBL is called to solve the problem of data loss and unavailability due to the current asymmetric and obsolete way of gathering data practiced by numerous stakeholders involved in the construction sector [16]. This is a multidimensional problem, which affects all scales: local, national, and European. Locally, in many municipalities of the Member States (MS), construction and renovation licenses are still paper-based, leading to information loss and making information difficult to process and share. At the national level, the lack of horizontal coordination between entities (as pointed out in [17]) leads to an incomplete or fragmented collection of data, which is afterward reflected at the European level. As a matter of fact, the Building Stock Observatory (BSO) database and the BSO datamapper, established in 2016 with the aim to provide reliable and comparable information about the European building stock, represent an example of asymmetry of data gathering at a European scale, as no consistent information is collected or displayed by the different MS about crucial aspects, such as major renovation rates, the energy efficiency value of building shells or the technical building systems. In addition, the DBL is expected to contribute to several policy flagships of the European Union, not only the Renovation Wave but also the European Green Deal, the Circular Economy Action Plan and the strategies "A Europe fit for the digital age" and "Strategy for a Sustainable Built Environment" [18].

On a national scale, several European countries and regions have implemented building logbook initiatives. Currently, running logbooks have already been studied in the literature [12,19,20] and are summarized in Table 1.

Table 1. Summary of building logbooks currently operative.

Country/Region	Initiative	Responsible Agency
Flanders, Belgium	Woningpas	Flemish Energy Agency, Flemish Government
Denmark	Bedrebolig	Danish Energy Agency
Finland	Real estate service manual	Finnish Government
Sweden	BASTA Logbook	BASTA non-profit company
Sweden	Produktkollen	Produktkollen AB
Sweden	Min Villa	Villaagarnas Riksforbund
Belgium	Dossier d'intervention ultérieure	Belgian Federal Government
The Netherlands	Madaster	Madaster Foundation
The Netherlands	Opleverdossier	Dutch Government
Germany	Eigenheim Manager	Eigenheim Manager
Germany	Hausakte	German Government
Germany	Gëbaudepass	German Government
Germany	QDF Hausakte	Bundesverband Deutscher Fertigbau e.V.
United Kingdom	CISBE TM 31	Chartered Institution of Building Services Engineers
Scotland	Home report	Scottish Government
Iceland	Property Register	Registers Iceland
Switzerland	Federal Register	Federal Statistical Office (FSO)
Italy	Fascicolo del Fabbricato	Regional Government based on national requirement
Portugal	Livro de obra	Portuguese Government
Spain	Libro del Edificio	Regional Government based on national requirement
USA	Arc platform	USGBC and GBCI
Greece	Electronic Building ID	Greek Government

Although national-scale building logbook initiatives already exist, there is not an official common model for a European building logbook so far. As the implementation of the DBL is a European priority to trigger buildings renovation, there are several research groups that have been recently working on the definition of this common tool.

This paper presents a review of the most developed European Digital Building Logbook models, with the aim to summarize and compare the available information. The overview includes iBRoad [21], ALDREN [22], and X-tendo [23] projects as well as the Study on the Development of a European Union Framework for Buildings' Digital Logbook (Study EU DBL) [24].

This paper is structured as follows: Section 1 introduces the concept of Building Renovation Passport and Digital Building Logbook and explains their origin. In Section 2, the methodology followed in this review is described. Section 3 provides an explanation of the selected European Digital Building Logbook models. In Section 4, a comparison of the selected models is carried out. Finally, conclusions and recommendations for the next steps are made in Section 5.

2. Methodology

The methodology for the review is composed of the following steps:

1. Identification of initiatives on Digital Building Logbooks and selection of models depending on their scope (European scale), ambition level and maturity of the proposal.
2. Identification and study of the key aspects in the definition of the DBL model. The following parameters are used to identify the key aspect:
    1. References used as a starting point for the model definition.
    2. Identification of the relevant stakeholders in the DBL.
    3. Identified potential user needs.
    4. Proposed structure.
    5. Data sources.
    6. Potential functionalities.

7. Operation and use.

3. Comparison of the models.

3. Selection of European Digital Building Logbook Models

Four research work outcomes have been studied and compared in this paper due to their European-scale scope, ambition, and level of definition. Three of them are outcomes of H2020 projects: iBRoad, ALDREN and X-tendo, whereas the fourth is the result of the Study on the Development of a European Union Framework for Buildings' Digital Logbook carried out for the European Commission.

In the following paragraphs, a brief overview of each one is shown.

3.1. iBRoad—Individual Building (Renovation) Roadmaps

The iBRoad project (Table 2) aims to boost the renovation of single-family houses through the implementation of Individual Building Renovation Roadmaps that guide the building owner providing tailored step-by-step renovation plans (iBRoad-Plan) in combination with a building logbook (iBRoad-Log) that acts as a repository of aspects such as energy performance, executed maintenance and building plans. The iBRoad approach is conceived as an evolution of EPCs and energy audits, and it has been tested in Bulgaria, Poland, and Portugal [21,25,26].

Table 2. Projects basic data.

Project/Study Title	Acronym	Duration	Target
Individual Building (Renovation) Roadmaps	iBRoad	June 2017–December 2020	Single-family houses
Alliance for Deep RENovation in Buildings	ALDREN	November 2017–September 2020	Non-residential buildings (mainly hotels and offices)
eXTENDing the energy performance assessment and certification schemes via a mOdular approach	X-tendo	September 2019–August 2022	Entire building stock
Study on the Development of a European Union Framework for Buildings' Digital Logbook	-	2020	Entire building stock

3.2. ALDREN Project—Alliance for Deep RENovation in Buildings

The objective of the ALDREN project (Table 2) is to encourage all the stakeholders involved in the renovation processes to foster and undertake deep renovations by overcoming market barriers and preparing the ground for investment. The ALDREN project proposes a voluntary and modular framework that implements the European Voluntary Certification Scheme (EVCS) to assess the energy performance of buildings with a European common base. The framework is composed of four standalone modules that allow gathering several indicators—Energy rating and target, Energy verification, Comfort and well-being and Cost value risk—plus two reporting tools: a European Voluntary Certificate (EVC) and a Building Renovation Passport (BRP), integrated by the ALDREN BuildLog and the ALDREN RenoMap. The ALDREN methodology has been tested across 20 buildings in France, Spain, Slovakia, the United Kingdom and Italy [11,22,27].

3.3. X-Tendo Project—eXTENDing the Energy Performance Assessment and Certification Schemes via a mOdular Approach

The X-tendo project (Table 2) aims to promote next-generation EPC schemes by introducing a toolbox with ten innovative features—innovative indicators and innovative data handling—that will help to improve usability, integrity, transparency, and harmonization of energy certification, and is targeted to public authorities and implementing agencies. The so-called innovative indicators include Smart Readiness, District Energy, Outdoor Air Pollution, Real Energy Consumption and Comfort, while the innovative data handling are: EPC Databases, Enhanced Recommendations, Financing Options, One-Stop Shops and Building Logbooks [23,28–30].

3.4. Study on the Development of a European Union Framework for Buildings' Digital Logbook

This study (Table 2), compiled in three reports and prepared by R2M Solution, VITO and the BPIE for the European Commission, aims to set a widely accepted definition of the DBL, as well as to provide the basis for the implementation of an EU-scale DBL model. With this aim, consultation among the stakeholders, several interviews with experts of the construction sector and a detailed analysis of forty international building logbook models have been carried out. As a result of this desk research and fieldwork, the main gaps in the existing initiatives have been identified, and a set of actions to address them and prepare the ground for further research has been proposed [18,19,24].

4. Comparison of the DBL Initiatives

Despite the similarities of the four studied proposals regarding their scope and objectives, they have different approaches when it comes to some key aspects. In the following paragraphs, they are identified.

4.1. References Used as a Starting Point for the Model Definition

The first difference among the models relies on their starting point.

The iBRoad-Log first reference is the EPC (Table 3), especially the Portuguese model, established in 2007, which is considered as one of the more complete ones in Europe. Other BRP and DBL initiatives from European countries, such as Portal Casa+ and Woningpas, were identified and analyzed, and the lessons learned were applied to the iBRoad-Log [31]. Qualitative interviews with public authorities and targeted surveys with potential users of the DBL were also carried out in Bulgaria, Poland, and Portugal to gather useful information [32].

Table 3. References used as a starting point for the models' definition.

Reference	iBRoad-Log	ALDREN BuildLog	X-Tendo Logbook	Study EU DBL
EPC models/registers	X	X	X	
BRP/DBL initiatives	X	X	X	X
Other certification schemes		X		
Existing databases on buildings		X		
EU projects outcomes		X		X
Surveys with stakeholders	X		X	X
Interviews with experts	X			X

With a similar approach, the Study on the Development of a European Union Framework for Buildings' Digital Logbook (Table 3) also started from desk research of previous initiatives [19]. The desk research was accompanied by an online survey to gather stakeholder inputs regarding the type of data that should be included in the logbook, its functionalities, and data governance issues. Finally, through interviews with several experts, more in-depth insights were collected [18].

Additionally, in the same line, the X-tendo project (Table 3) developed an analysis of good practices regarding existing EPC databases and registers (as its aim is to provide a framework of new-generation features for energy performance assessment and certification), as well as a study of DBL existing initiatives. Moreover, BPIE and VITO, two X-tendo partners, participated in the development of the Study on the Development of a European Union Framework for Buildings' Digital Logbook; hence some lessons learned were applied to this project [29,33–35]. Additionally, a digital survey was conducted to gather information from potential users [36,37].

The ALDREN BuildLog was conceived from a slightly different starting point (Table 3). Even though several BRP models were identified and studied, the analysis of existing databases related to building characteristics and stocks, such as Eurostat, the Building Stock Observatory (BSO), EPC registers and EU project databases outcomes, and of different certification schemes, such as BREAM, LEED, VERDE, etc. was highly relevant to gather information for the definition of the DBL template [11,38].

To sum up, there is not a common approach in the four DBL models. Nevertheless, the study of existing BRP/DBL initiatives was one of the first steps in all the cases. Additionally,

the analysis of EPC models/registers and surveys with stakeholders were important references for three of the studied proposals.

4.2. Identification of the Relevant Stakeholders in the DBL

Identifying the stakeholders that are involved in the DBL is crucial, not only to take into consideration the specific needs of each one but also to detect the main sources of information and to adapt the logbook interface and structure to final users.

At this point, three different visions have been identified among the DBL proposals.

First, the iBRoad-log is the most ambitious one regarding the range of stakeholders interacting with the logbook. Not only the actors that can take advantage of the DBL or provide data are important for it, but also some collectives that can trigger its implementation, such as Non-Governmental Organizations (NGOs), the media, or consumers associations [25,31,39,40].

The second approach, from the Study on the Development of a European Union Framework for Buildings' Digital Logbook, also considers a large number of stakeholders, focusing on the entire set of actors of the construction sector, public institutions and investors mainly [18].

Finally, the ALDREN BuildLog and the X-tendo logbook consider a shorter number of stakeholders, and the importance of experts and auditors is highlighted [34,35,41].

Through the comparison of the stakeholders considered in the four initiatives, we can conclude that the most important agents are the building's owner and occupants, public authorities, and financial institutions since they are the only ones identified by all of them. They are highlighted grey in Table 4.

Table 4. Stakeholders considered in each DBL proposal. The most important agents, identified by all the DBL initiatives, are highlighted grey.

Stakeholder	iBRoad-Log	ALDREN BuildLog	X-Tendo Logbook	Study EU DBL
Owner/users of the building	X	X	X	X
Tenants/occupants		X	X	X
Architects/designers		X		X
Experts/auditors	X	X		X
Developers				X
Research and Academia	X			X
NGOs and think tanks	X			
Media	X			
Financial and legal services	X	X	X	X
Insurance companies				X
Public authorities	X	X	X	X
Neighborhood associations	X			
Consumers Association	X			
Building Association	X			
Energy sector—business	X			X
Energy sector—engineers	X			X
Construction contractors	X		X	X
Demolition contractors				X
Investors		X		X
Material suppliers				X
Facility and building managers				X
Real estate agents/valuers			X	X

4.3. Identified Potential User Needs

Identifying the user needs and the functionalities from which the stakeholders can benefit is a key for the success in the implementation of the DBL. In this sense, the greater the benefits for users, the lower the perception that the logbook is one more useless administrative burden. As explained in Section 4.1, three of the studies carried out a participative process to gather information from different stakeholders of the building's value chain.

In order to properly prepare the testing process of the iBRoad concept that was going to take place in Bulgaria, Poland and Portugal, a study was conducted by Ipsos to gather information about the users' profile, needs and preferences [32].

The study comprised three parts in each country:

1. A round table with eight participants, lasting 90 min.
2. Interviews with three public authorities' members.
3. Around 500 targeted surveys with potential users.

Within these targeted surveys, five topics were assessed: general attitude towards energy renovation, views from buyers, views from homeowners, perspectives on the renovation roadmap and perspectives on the logbook (Table 5).

Table 5. Perceived usefulness/importance of the DBL topics according to the surveys. * In the Study on the Development of a European Union Framework for Buildings' Digital Logbook (Study EU DBL), the exact figure is not provided in the survey, but a bar size. The 40% more important topics of each survey are highlighted grey.

Topic	iBRoad-Log	X-Tendo Logbook	Study EU DBL *
Building's features/description	54%	-	87%
Ownership information	-	-	54%
Information on occupancy	-	-	41%
Basic information about the house	52%	-	-
Building material inventory	-	-	75%
Technical specifications of walls, windows, insulation, etc.	51%	65%	-
Condition of walls and roof	-	71%	-
Energy renovations completed	49%	54%	-
Designs and plans on building interventions	-	-	72%
Information on renovation potential	-	-	53%
Energy use, water consumption and energy bills	47%	-	65%
Energy Performance Certificate	47%	-	76%
Other ratings and certifications	-	-	43%
Building plans	45%	40%	72%
Designs and plans of the main surroundings and land	-	-	22%
3D/BIM models of the building and its system	-	-	63%
Specifications and designs of heating system and other equipment	43%	-	82%
Age of equipment (e.g., boiler, oven, radiators)	-	61%	-
Service life of installed equipment	-	51%	-
Results from an energy audit	38%	-	-
Smart readiness indicator	-	-	39%
Dynamic data (smart meters, sensors, etc.)			49%
Inspection and maintenance reports	38%	-	-
Information about property tax	37%	-	-
Contractors' details	25%	-	-
A summary of the renovation roadmap	21%	-	-
Information about financing for energy-efficient renovations	17%	-	-
Construction company/contractor used for previous renovations	-	21%	-
Taxation information	-	-	20%
Financial, legal and insurance documents	-	35%	30%
Cost information—material, products, equipment, etc.	-	-	18%

During the interviews with public authorities members, the analyzed topics were: what information about residential buildings is being collected and if it is sufficient; if energy renovation is an important political priority and what are the main barriers to setting up programs promoting residential renovation; if more building data would be useful in designing and implementing renovation schemes and what would be the value of a logbook; and what would be the potential value of a building renovation roadmap.

Within the ALDREN project, several webinars and workshops were carried out with the aim of sharing the ALDREN framework. The first training workshop [42], which took place in November 2018, was an interactive event with open discussion and polling sessions with the REHVA network. During the session, valuable information was gathered about the Building Renovation Passport and digital logbook [43].

Within the X-tendo project, a digital survey was conducted in April 2020 by Ipsos Belgium to gather information about the needs, views, and expectations of potential users (mainly homeowners, landlords and tenants of residential buildings) of EPCs and their linked innovative features investigated by the X-tendo framework when buying, selling, renting, or renovating a property. The survey was conducted in five projects implementation countries, including Poland, Portugal, Greece, Romania, and Denmark and 2563 people participated, with at least 501 respondents in each country [36]. Although some differences between countries were found, the main responses were consistent across countries; thus, a high replicability potential for the logbook was identified.

Regarding the building logbook, the following questions [37] were launched to the participants:

1. "If you decided to buy or rent a property, how important would it be that a document or folder with all the building-related documents (dwelling's condition, maintenance activities etc.) is present for the property?"
2. "Did you receive a folder or document with all the building-related documents (dwelling's condition, maintenance activities etc.) when you bought the property or started renting it?" The answers were classified according to building types, tenure status and renovation status.
3. What information would they like to find in the logbook? (Table 5)
4. Some additional inquiries are available at the national level in reports 2.4 of the X-tendo project [37] and 4.2 [35].

Finally, during the Study on the Development of a European Union Framework for Buildings' Digital Logbook, several collaborative actions were organized.

During the first part of the study, individual interviews took place with 32 stakeholders from different groups of the construction value chain; an online survey with 93 respondents from 19 countries was run; a webinar with 68 attendees was organized, and a stakeholder meeting with 66 participants took place [24].

The online survey, where several groups from the entire construction value chain had representation, consisted of 17 inquiries that can be consulted in [18], gathering information about the background and profile of the respondents, their connection and knowledge about the DBL and, finally, technical issues, such as their point of view about the data fields that the logbook should incorporate (Table 5), its potential data sources, main functionalities, update needs, and ownership and liability issues. Questions about the role of the EC in the design and implementation of the DBL and actions to be addressed to facilitate its deployment were asked in the surveys and in the individual interviews with the experts.

The main findings from the online survey were compared with the ones from Report 2 [19] through Krippendorff's alpha method to investigate their degree of agreement, i.e., the gap between stakeholders' expectations and what is implemented in real initiatives [24].

In May 2020, a webinar gathering 68 attendees from different stakeholders' groups was organized. In the event, the results of the activities that had taken place until that moment were presented and discussed, including the results of the previous survey and the definition of the DBL, lately established [24]. A new poll was then launched containing inquiries about the key benefits that the DBL should provide, the key features for the development of a successful tool and the main barriers for the logbook to overcome [19].

Finally, the first part of the study was concluded with a stakeholder event with 66 attendees that took place in July 2020 to receive inputs about the identification of priority actions to be implemented by the EC and to explore synergies with other EU initiatives.

During the second part of the study, some experts were selected to be interviewed to assess the development of the last part of the final report (Chapters 5 to 7) and, finally, a second and last stakeholder event with 96 attendees took place in November 2020, to make an overview of the project's main results and gather stakeholders' feedback [24].

Table 5 summarizes potential users' views about the information they would like to find in a building logbook according to their importance. It must be noted that the way the inquiry was stated and the format of the possible answers make the percentages

obtained in the surveys of each project doubtful to be directly compared. For this reason, we first identify the most important topics in each survey and afterward, we make comparisons. The 40% more important topics of each survey are highlighted grey in Table 5. When comparing the results, four data topics were pointed out as the most important ones in two surveys: "building's features/description," "technical specifications of walls, windows, insulation, etc.", "energy use, water consumption and energy bills," and "Energy Performance Certificate." Other prominent subjects were: "basic information about the house," "building material inventory," "condition of walls and roof," "energy renovations completed," "design and plans on building interventions," "building plans," "specifications and designs of heating system and other equipment," and "age of equipment." It should be noted that the only topic that appeared in the three surveys was "building plans," which obtained a medium relevance in all the cases.

4.4. Proposed Structure

Generally, a digital building logbook consists of a series of indicators about a building, classified in different modules or categories. Nevertheless, each DBL proposal presents a particular scheme with different levels, indicators, and categories.

iBRoad and X-tendo share the same approach regarding the structure of the logbook, although they differ in the indicators that they propose. On the one hand, regarding the structure, the X-tendo model follows a similar vision to the iBRoad-log [31,35]. They propose a fixed-flexible structure, meaning that it counts on different levels of granularity: there is some fixed information (common at European level, levels 0 to 2) and flexible information (that can be adapted to accommodate to national and regional needs, levels 3 onwards). On the other hand, regarding the proposed indicators, in the iBRoad-log, they are classified into 5 modules: general and administrative information; building construction information; building energy performance; building operation and use; and SMART information, making a total of 68 indicators (at level 2). The X-tendo logbook, at the same level, counts on 216 indicators, classified into 8 categories: administrative information; general information; building descriptions and characteristics; building operation and use; building performance; building material inventory; smart readiness; and finance.

The final version of the ALDREN Buildlog consists of 6 modules (2 more in the ALDREN RenoMap) with their own subcategories and protocols for data gathering, entry and calculation: building picture; energy rating and target; energy verification; comfort and well-being; cost value and risk; and documentation and BIM. Although all the modules have been defined, only the 88 indicators for the category "building picture" are available now. Unlike the other logbook models, the modules of the ALDREN BuildLog were designed to work separately, with the aim to provide different levels of data access for various stakeholders in each category. It is important to point out that this scheme was designed for non-residential buildings, mainly hotels and offices, which makes the set of indicators differ slightly from the other DBL proposals [38,41].

The Study on the Development of a European Union Framework for Buildings' Digital Logbook presents a set of 83 data fields or indicators classified into 8 categories: administrative information; general information; building descriptions and characteristics; building operation and use; building performance; building material inventory; smart readiness; and finance. The indicators that compose each category are a result of the desk research, and their relevance depends on their context. In addition to the definition of the set of indicators, the following parameters are also specified for each one: the source of the indicator, whether it is core or complementary, the building type, whether it is suitable for new or existing buildings if it is static or dynamic and the easy of collection [18].

To easily compare the four data models, the indicators of each one were classified by categories defined by the authors of this paper (Appendix A). These categories are general and administrative information, construction information and materials, building technical systems and smart readiness, energy performance, operation and use, and finance (Table 6). In parentheses, the percentage of indicators in each category can be found. The category

with the highest number of indicators in each model is highlighted dark grey. The category with the second-highest number of indicators is highlighted light grey. Figure 1 shows the importance of each category for the DBL models according to its number of indicators. Some adjustments have been made to the original indicators to be able to assimilate the indicators from the different models, and this has affected the accounting of indicators.

Table 6. Number of indicators of each category and percentage they represent in each model. The category with the highest number of indicators in each model is highlighted dark grey. The category with the second-highest number of indicators is highlighted light grey.

Category	iBRoad-Log	ALDREN BuildLog	X-Tendo Logbook	Study EU DBL	Total Times Considered
General and administrative information	19 (26%)	25 (33%)	32 (16%)	29 (35%)	105
Construction information and materials	6 (8%)	16 (21%)	49 (24%)	19 (23%)	90
Building technical systems and smart readiness	17 (23%)	35 (45%)	79 (38%)	14 (17%)	145
Energy performance, operation and use	28 (39%)	1 (1%)	34 (16%)	8 (10%)	71
Finance	3 (4%)	0 (0%)	12 (6%)	12 (15%)	27
Total	73 (100%)	77 (100%)	206 (100%)	82 (100%)	438

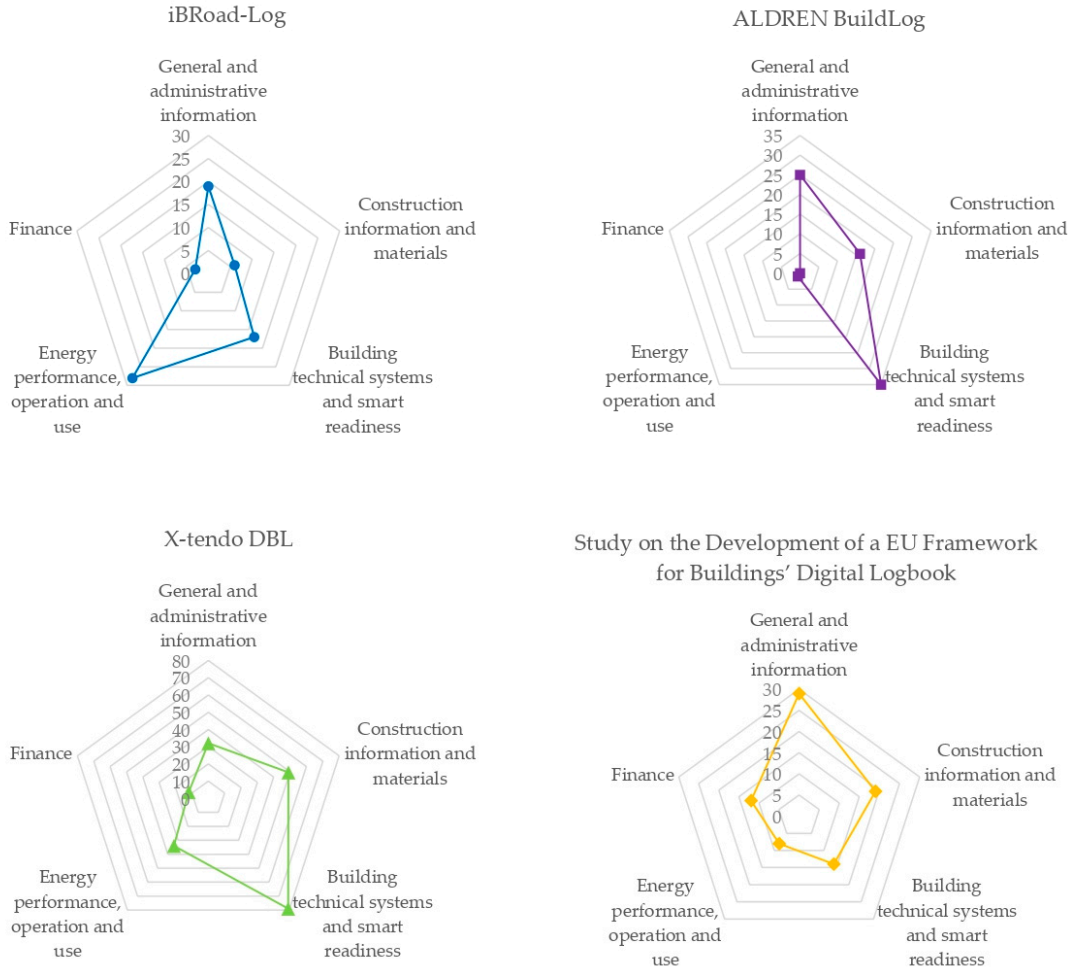

Figure 1. Data categories in studied DBL initiatives.

Through the analysis of Table 6 and Figure 1, we can observe the great difference that exists among the approaches of the four logbook models. There is no consensus about

the indicators to be collected. In general, the category with a higher number of indicators, due to its huge relevance in the X-tendo logbook is "building technical systems and smart readiness," with 145 indicators, followed by "general and administrative information," with 105, "construction information and materials", with 90, "energy performance, operation and use," 71 indicators and, finally, "finance," with 27 indicators. Figure 1 shows the great difference that exists among the approaches of the four logbook models. There is no consensus about the indicators to be collected.

Although it can be thought that the more indicators collected, the more useful the DBL is, it is not always true because, in most of the member States, problems gathering information from the logbook sources are frequent. Thus, paper-based information is still common, along with outdated as-built data [44].

4.5. Data Sources

To set up a DBL, it is not only necessary to define the data to be collected to fill the proposed data fields, but also to know who owns the needed information, whether it is available in opensource or not, if there is any limitation factor, such as data protection issues, and how the information can be linked. Different approaches have been identified in the studied DBLs, but all of them agree on the importance of incorporating existing databases in building information.

Within the iBRoad project, an effort to identify the main sources for the iBRoad BuildLog in Portugal, Bulgaria, Germany, and Poland was made, and several possible sources were defined: public authorities, energy sector, financial services, construction industry, research and academia, the building user, real estate market, utility companies, qualified experts, energy auditors, consumers association and other national associations [25]. The specific contribution of each one can also be consulted in [31]. In the same report, a method to integrate data from external databases is also explored.

In contrast, the main source for the ALDREN BuildLog is the ALDREN Auditor, who creates the DBL database through a detailed inspection of the building and the collection of all documentation from the owner and other existing databases [41]. Nevertheless, other sources can contribute to collecting some specific information, such as existing databases (Eurostat, the Building Stock Observatory, EPC registers, previous EU projects, other certification schemes) and data gathered by means of ICT technologies [38].

In the same way, external databases, such as EPC registers, are pointed out as important sources for the X-tendo logbook. In the near future, data coming from the Smart Readiness Indicator, material passports and ICT technologies (such as sensors and IoT) will also contribute to generating high-quality information. On the contrary, information submitted by the owner is considered less reliable than the one from public authorities and official databases [34,35].

Similarly, for the Study on the Development of a European Union Framework for Buildings' Digital Logbook, the DBL collects different types of data from different sources. These sources include existing public and private databases at the European or national level (databases of interest are identified in [24]) but also information gathered through smart equipment connected to the building, from the homeowner and auditors, utility companies, the construction industry, third-party service providers, public authorities, among others [18,24].

In conclusion, the most popular data sources according to the four DBL initiatives are the building users, the construction industry, public authorities, financial institutions, qualified experts/auditors, utility companies, existing databases and ICT technologies (Table 7).

Table 7. Data sources for the DBL.

Data Source	iBRoad-Log	ALDREN BuildLog	X-Tendo Logbook	Study EU DBL
Public authorities	X		X	X
Energy sector	X			
Financial services	X		X	X
Construction industry	X		X	X
Research and academia	X			
Building users	X	X		X
Real estate market	X		X	
Utility companies	X		X	X
Third-party service providers			X	X
Qualified experts/auditors	X	X		X
Consumers association	X			
Other national associations	X			
Existing databases		X	X	X
ICT Technologies		X	X	X
Smart Readiness Indicator			X	
Material passports			X	

4.6. Potential Functionalities

The functionalities of the logbook refer to the services built around it [18,35]. Although there is no consensus regarding all the functionalities the DBL should provide (see Table 8), all the proposals agree that the main function of the tool is to serve as a repository of the relevant information of a building, especially general, administrative, and constructive data. Four more functionalities were pointed out by the four logbook models [18,24,25,33,38], including the "assessment of the energy performance" and "smart readiness"; the "connection to the renovation roadmap"; and the "link to external databases." These five functionalities are highlighted dark grey in Table 8, as the most important ones already identified.

Table 8. Functionalities of the Digital Building Logbook. The functionalities considered by all the DBL initiatives are highlighted dark grey, and those considered by three of them are highlighted light grey.

Functionality	iBRoad-Log	ALDREN BuildLog	X-Tendo Logbook	Study EU DBL
Repository and checklist of building data	X	X	X	X
Operation and maintenance plan	X		X	X
Energy performance assessment	X	X	X	X
Health and well-being assessment	X	X		
Building analysis and status	X	X	X	
Alerts and reminders	X		X	
Link to the renovation roadmap	X	X	X	X
Link to external databases	X	X	X	X
Smart readiness assessment	X	X	X	X
Lifecycle costing				X
Comparison with similar buildings	X			X
Integration with BIM/3D models		X	X	X
Link to financial incentives	X			X
Best practices repository	X			
Traceability of building materials			X	X
Bringing together building sector stakeholders	X		X	X
Improved overview of the building stock (benchmarks)	X			X
Construction project management tools				X
RES potential (benchmarks)	X			

In the next level, four functions were considered relevant for three of the logbooks: containing an "operation and maintenance plan"; providing the "building analysis and status";

"integration with BIM/3D models"; and "bringing together building sector stakeholders." These four functions are highlighted light grey in Table 8.

In contrast, "health and well-being assessment," "alerts and reminders," "life cycle costing," "comparison with similar buildings," "link to financial incentives," "best practices repository," "traceability of building materials," "improved overview of the building stock," "providing construction project management tools," and "establishing RES potential," were considered potential functionalities for only one or two logbook proposals.

4.7. Operation and Use

Once the data template and sources for the DBL are defined, it is time to design the way it will work. At the moment, three different approaches have been identified. On the one hand, data can be gathered and introduced manually to a worksheet. On the other hand, the information can be automatically collected and displayed from existing databases. A third option is a hybrid approach, where the previous methodologies are combined.

The iBRoad-Log is an example of the last approach, where three types of data integration were envisaged:

1. Through an initial load, the building-related information is inserted from existing databases. In this process, the data is sent by the external entities in text format and is later inserted into the chosen database.
2. Some information is inserted during the lifecycle of the building manually by authenticated users, such as the homeowner or energy auditors.
3. Finally, some information from third parties is necessary for the implementation of the solution, such as users' authentication/validation information or some building-related data [31].

The ALDREN BuildLog settled in two versions—digital extended, composed by an Excel file, and paper portable by printing a Word file—is composed by worksheets that currently are fed manually by trained experts. Nevertheless, a direct link to active databases and other sources has been considered and may be developed in future research. The ALDREN BRP is complementary to EPCs and other certification schemes; thus, it needs to be permanently updated and linked with these tools [38].

The creation of the ALDREN BRP follows a five-step procedure [41], where the first three correspond to the creation of the DBL:

1. First interview between the auditor and the homeowner and selection of the modules for the logbook (the selection of the modules depends on the needs and investment).
2. Building inspection carried out by the auditor, survey with the owner and collection of all documentation.
3. Calculation, by the auditor, of the selected modules and integration of the indicators.

Finally, the digital and paper versions of the BRP are generated and delivered to the owner.

The data architecture of the X-tendo logbook will be described in forthcoming reports. However, it will be based on the link between different existing databases by using common protocols and interfaces [35]. At the moment, the same three approaches for data linkage of the Study on the Development of a European Union Framework for Buildings' Digital Logbook are being considered and will be further studied.

Finally, following the criteria exposed in the Renovation Wave, the Study on the Development of a European Union Framework for Buildings' Digital Logbook understands the DBL as a gateway that allows data storage and exchange between several data repositories (EPC registries, Level(s) framework, smart readiness indicator, etc.). However, to enable interoperability and consistency between databases, it is necessary to establish a semantic data model of the core DBL elements and the use of common languages [24]. At this point, three approaches have been considered to accomplish the linkage of the databases [18]:

1. The DBL as a database with physical storage.
2. The DBL as a digital gateway to information.
3. Hybrid versions.

To further explore this topic, the study recommends carrying out a technical study on technical linkage mechanisms and guidelines that should include the following tasks:

1. Technical requirements to allow the linkage of databases.
2. Data properties.
3. Creation of new market opportunities.

5. Conclusions

The Digital Building Logbook is a digital repository of all the relevant data on a building collected throughout its lifecycle. This paper identifies and compares the existing European scale DBL initiatives: iBRoad-Log, ALDREN BuildLog, X-tendo logbook 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.

Concerning the stakeholders involved in the DBL, based on the studied initiatives, it can be concluded that the most important agents are the building's owner and occupants, public authorities, and financial institutions.

Through participatory processes with potential users of the DBL, their main needs and priorities regarding the logbook were identified. According to the users, four data topics were pointed out as the most important ones: "building's features/description," "technical specifications of walls, windows, insulation, etc.", "energy use, water consumption and energy bills," and "Energy Performance Certificate." Other subjects, such as "basic information about the house," "building material inventory," "condition of walls and roof," "energy renovations completed," "design and plans on building interventions," "building plans," "specifications and designs of heating system and other equipment," and "age of equipment," were considered relevant too.

A Digital Building Logbook consists of a series of data fields or indicators about a building, classified in different modules or categories. To compare the structure of the four DBL proposals, the indicators of each one were classified by the same categories, defined by the authors of this paper: (1) General and administrative information, (2) Construction information and materials, (3) Building technical systems and smart readiness, (4) Energy performance, operation and use; and (5) Finance. The analysis shows great differences among the structure of the indicators in the four logbook models. Whereas in the iBRoad-log, most of the indicators (65%) are in categories 1 and 4, in the ALDREN, they are in 1 and 3 (78%), in the X-tendo logbook in 2 and 3 (62%), and in the Study EU DBL in 1 and 2 (58%). The fifth category had the lowest number of indicators in three of the models. Additionally, the absolute number of indicators varies from 68 in the iBRoad-log to 214 in the X-tendo logbook. The numbers of common indicators proposed by the four models (4 out of 438) and by three of the models (21 out of 438 indicators) are very low, representing only 6% in total. Therefore, we can conclude that there is no consensus about the indicators to be collected.

Identifying the sources that collect and may provide the data for the DBL is also crucial for the success of the tool. According to the studied initiatives, the most popular data sources according to the four DBL initiatives are the building users, the construction industry, public authorities, financial institutions, qualified experts/auditors, utility companies, existing databases and ICT technologies.

The functionalities of the logbook refer to the services built around it. In this sense, all the proposals agree that the main function of the tool is to serve as a repository of the relevant information of a building. Besides, four more functionalities were pointed out: the assessment of the energy performance and smart readiness, the connection to the renovation roadmap, and the link to external databases.

Regarding the operation and use of the logbook, none of the proposals has defined a procedure to automatically gather, store and share the information.

Thus, the first step towards the definition of a European Digital Building Logbook has been taken thanks to the emerging initiatives. Nevertheless, there is still a long way to go to synthesize all the information collected and translate it into a cost-effective, useful model for all the involved stakeholders. In fact, there is no consensus about crucial subjects, such as the indicators to be collected or how to collect them. This is probably due to the fact that the final functionalities (objective and scope) that the logbook should provide have not been fully decided, nor have they been linked to the indicators.

The authors of this paper think that the indicators should be reduced to the minimum number in order to achieve the maximum simplification of the use of DBL, avoiding information noise and potential obstacles that may prevent massive data collection. In order to identify which are the essential indicators to collect, the authors think that the DBL functionalities should be more clearly defined. The DBL should contain a useful data set for the definition of a building renovation roadmap, which guides stakeholders and triggers renovation works [38]. As buildings get renovated, the progress towards the building sector decarbonization must be monitored, as stated in Directive (EU) 2018/844 [14]. The decarbonization process should follow the European goals established in the different strategies, such as the Renovation Wave, the Green Deal, etc. We propose to simplify the indicators set, walking the road backward, from the European goals to the DBL indicators [45] (Figure 2). We will first identify the European goals for the decarbonization of the building sector and then link progress indicators to specific goals. Afterward, we will identify how renovations should be to fulfill the goals. This will be useful to identify the functionalities of the DBL. Finally, DBL indicators will be selected for these functionalities. Future research will focus on developing this scheme (Figure 2).

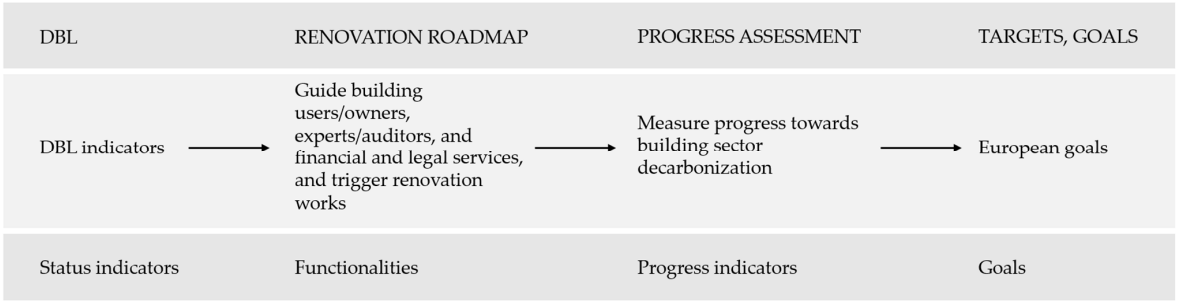

Figure 2. Future research scheme.

Author Contributions: Conceptualization, M.G.-G. and B.L.-M.; methodology, M.G.-G. and B.L.-M.; validation, B.L.-M., and A.E.-F.; formal analysis, M.G.-G. and B.L.-M.; investigation, M.G.-G.; resources, B.L.-M.; data curation, M.G.-G.; writing—original draft preparation, M.G.-G.; writing—review and editing, B.L.-M. and A.E.-F.; visualization, M.G.-G.; supervision, B.L.-M. and A.E.-F.; project administration, B.L.-M. and A.E.-F.; funding acquisition, B.L.-M. All authors have read and agreed to the published version of the manuscript.

Funding: This work was founded by the MINISTRY OF SCIENCE AND INNOVATION OF SPAIN, grant number PID2019-104871RB-C21 and by GOBIERNO DE ARAGÓN, grant number T37_20R: Grupo de Investigación en Arquitectura.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

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

Appendix A

Classification of the indicators proposed in each DBL model by categories defined by the authors of this paper.

Table A1. Module 1: general and administrative information.

Indicator	iBRoad-Log	ALDREN BuildLog	X-Tendo Logbook	Study EU DBL
DBL Author			X	X
DBL Last update			X	X
Building ID/name—national code (cadasters)	X	X	X	X
Building ID—Inspire ID	X			
Building ID—energy suppliers ID (energy delivery point)	X			
Property ID (legal/ fiscal registration)	X	X	X	X
Ownership type			X	X
Building use/type (according to the use license)		X	X	X
Building category		X		
Building user information	X			
Year of construction		X	X	X
Year of renovation		X		
Address data	X	X	X	X
Climate data (zone)	X	X	X	X
Heating degree days		X	X	
Cooling degree days		X		
Norm outdoor temperature			X	
Geo Coordinates	X	X		
Orientation			X	
Altitude			X	
Soil/terrain			X	X
Historical context				X
Building surroundings				X
Floor area		X	X	X
Heated/cooled floor area			X	X
Heated/cooled volume		X	X	
Number of floors		X	X	X
Number of occupants			X	X
User profile/behavioral insights	X		X	X
Indoor temperature			X	
Shape factor A/V		X		
Physical accessibility			X	X
Building general features	X			
Unit general features	X			
Number of bedrooms		X		
Number of offices		X		
Number of workstations		X		
Number of floors				
Area of corridors		X		
Area of conference		X		
Area of banquet/common areas		X		
Area of office space room		X		
Area of working space		X		
Area of common restrooms		X		
Area of sports spaces		X		
Urban licenses	X		X	X
Design and plans	X		X	X
Photographs	X			

Table A1. *Cont.*

Indicator	iBRoad-Log	ALDREN BuildLog	X-Tendo Logbook	Study EU DBL
Building information modeling BIM			X	X
Inspections information	X			
Conservation Status	X			
Expected lifetime			X	X
Tenancy agreement			X	X
Insurance documents			X	X
Safety manual			X	X
Fire safety plan				X
Maintenance log	X		X	X
Utilities contract			X	X
Maintenance service contract	X		X	X
Energy and Construction market (industries involved)	X			

Table A2. Module 2: construction information and materials.

Indicator	iBroad-Log	ALDREN BuildLog	X-Tendo Logbook	Study EU DBL
Building envelope construction:			X	
Whole building solar absorption (g. A)			X	
Yie-value periodic thermal transmittance			X	
Airtightness			X	
Facades:	X			X
External wall furniture		X		
External wall main structure		X		
Surface area			X	
U-value		X	X	X
Insulation (Y/N)		X		
Thickness of insulation		X	X	
Insulation type			X	
Insulation thermal conductivity			X	
Layer material (for n layers)			X	
Layer thermal conductivity (for n layers)			X	
Layer thickness (for n layers)			X	
Windows:	X			X
External windows opening		X		
U-value (frame/glazing)		X	X	X
Glazed facade		X		
Windows orientation			X	
Surface area			X	
Frame factor			X	
Multiple glazed percentage			X	
g-value			X	
Facade protection elements/sheltered sides		X	X	
Shutters and solar protection		X	X	
Factor for ambient on back side			X	
Floors:	X			
Number of heated floors		X		
Surface area			X	
U-value		X	X	X
Structure slab		X		
Thickness of insulation			X	
Insulation type			X	
Insulation thermal conductivity			X	
Layer material (for n layers)			X	

Table A2. *Cont.*

Indicator	iBroad-Log	ALDREN BuildLog	X-Tendo Logbook	Study EU DBL
Layer thermal conductivity (for n layers)			X	
Layer thickness (for n layers)			X	
Roofs:	X			X
Roof covering		X		
Surface area			X	
U-value		X	X	X
Roof main structure		X		
Thickness of insulation			X	
Insulation type			X	
Insulation thermal conductivity			X	
Layer material (for n layers)			X	
Layer thermal conductivity (for n layers)			X	
Layer thickness (for n layers)			X	
Doors	X			X
Thermal bridges (U-value)	X		X	
Material inventory:				
Material X—type			X	X
Material X—location			X	X
Material X—volume			X	X
Material X—weight			X	X
Material X—embodied carbon			X	X
Material X—life span			X	X
Material X—fire resistance class			X	X
Material X—waste category			X	X
Material X—certificate			X	X
Material X—chemical declaration			X	X
Material X—Global Trade Item Number			X	X

Table A3. Module 3: building technical systems and smart readiness.

Indicator	iBRoad-Log	ALDREN BuildLog	X-Tendo Logbook	Study EU DBL
Primary energy conversion factor for energy carrier			X	
Appliances			X	
Heating system:	X			
Type of heating system		X	X	X
Number of units installed			X	
Generator X		X		X
Average efficiency rate of generation at X		X	X	
Brand name		X		
Energy label		X		
Age		X	X	
Date of installation			X	
Last inspection			X	
Power:		X		
Nominal electrical power			X	
Nominal thermal power			X	
Energy source	X		X	
Heat generation			X	
Net energy for space heating			X	
Heat supply temperature			X	
Certificate/warranty			X	
Manual			X	
Operational thermal efficiency of the space heating system			X	
Cooling system:	X			

Table A3. *Cont.*

Indicator	iBRoad-Log	ALDREN BuildLog	X-Tendo Logbook	Study EU DBL
Type of cooling system		X		X
Number of units installed			X	
Average efficiency rate of cooling system at X		X	X	
Brand name		X		
Energy label		X		
Age		X		
Date of installation			X	
Last inspection			X	
Power:		X		
Nominal electrical power			X	
Nominal thermal power			X	
Fuel type	X		X	
Storage			X	
Certificate/warranty			X	
Manual			X	
Domestic hot water system (DHW):	X			X
Number of boilers		X		
Boiler X		X		
Tank size X		X	X	
Tank age X		X		
Fuel type	X		X	
System efficiency			X	
Service present			X	
Manual			X	
Certificate/warranty			X	
Primary pipework insulation present			X	
Ventilation system:	X			
Typology of ventilation system		X	X	X
Average efficiency rate of ventilation system		X	X	
Filter type/class			X	
Airflow control at room level			X	
Heat recovery efficiency			X	
Operational thermal efficiency of the heat recovery unit			X	
Temperature of ventilation return air			X	
Temperature of ventilation supply air			X	
Ventilation airflow rate			X	
Ventilation rate			X	
Date of installation			X	
Last inspection			X	
Certificate/warranty			X	
Manual			X	
Equivalent solar area/net heated area ratio:			X	
Installed capacity			X	
Exported energy			X	
Date of installation			X	
Last inspection			X	
Certificate/warranty			X	
Manual			X	
Lighting system:	X			X
Lighting is considered (Y/N)			X	
Number of CFL lamps		X	X	
Number of halogen lamps		X	X	
Number of LED lamps		X	X	
Number of other lamps		X	X	
Total power			X	
Lighting system efficiency			X	
Transport system:				

Table A3. *Cont.*

Indicator	iBRoad-Log	ALDREN BuildLog	X-Tendo Logbook	Study EU DBL
Considered (Y/N)			X	
Efficiency			X	
Building automation and controls (BAC)	X			
Sewer system				X
Rainwater drainage				X
District heating access			X	X
Renewable energy:	X			X
Reporting information regarding energy generation	X	X		
Storage of locally generated energy		X	X	
Optimizing self-consumption of locally generated energy		X		
CHP control		X		
Metering system information:	X			
Control system for heating and cooling		X	X	
Emission control for TABS		X	X	
Control of distribution heat temperature		X		
Control of distribution pumps in network		X		
Intermittent control of emission and/or distribution		X		
Storage and shifting of thermal energy:				
Heating system		X	X	
Cooling system			X	
Control of DHW storage charging			X	
Heat generator control for combustion and district heating			X	
Interaction between TBS and/or BACS			X	
Smart information:				
EV Charging points (Y/N)	X	X		X
EV Charging points features	X	X	X	
EV Charging grid balancing			X	
SRI Smart Readiness Indicator	X		X	X
Smart district indicators	X		X	X
Smart grid integration			X	
Demand response potential			X	X
Other smart indicators	X			

Table A4. Module 4: energy performance, operation and use.

Indicator	iBRoad-Log	ALDREN BuildLog	X-Tendo Logbook	Study EU DBL
EPC general information:				
Expert name	X			
Expert ID	X			
Type of EPC	X			
EPC Number	X			
Energy label	X		X	X
Issue date	X			
Term date	X			
Photograph report	X			
EPC support documentation	X			
Audit general information:				
Expert name	X			
Professional order	X			
Audit date	X			
Energy label	X			
Photograph report	X			
Energy audit support documentation	X			

Table A4. *Cont.*

Indicator	iBRoad-Log	ALDREN BuildLog	X-Tendo Logbook	Study EU DBL
Global primary energy demand (renewable/not renewable)			X	
Energy needs for cooling			X	
Energy needs for heating			X	
Primary energy demand by use:				
Cooling (renewable/not renewable)	X		X	
Heating (renewable/not renewable)	X		X	
DHW (renewable/not renewable)	X		X	
Lighting (renewable/not renewable)	X		X	
Mechanical ventilation (renewable/not renewable)	X		X	
Transport (renewable/not renewable)			X	
Primary energy use by end-use	X			
Energy consumption by use:	X			
Heating (estimated/measured/dynamic/calculated)			X	X
Electricity (estimated/measured/dynamic/calculated)			X	X
Hot water (estimated/measured)			X	X
Useful energy demand by use:				
Electricity			X	
Heating			X	
Domestic hot water			X	
Cooling			X	
Lighting			X	
Mechanical ventilation			X	
List of energy suppliers	X			
Tailored renovation recommendations	X		X	X
Climate resilience potential			X	X
Solar potential			X	X
Renewable energy production	X	X		X
Annual calculated production (equivalent solar area)			X	
Annual measured production (equivalent solar area)			X	
Renewable energy consumption			X	
Energy delivered for space cooling by energy carrier	X		X	
Energy delivered for other purposes (excl. Non-EPC uses) by energy carrier	X		X	
Percentage from the total heat generation			X	
Global CO2 emission			X	
Estimated carbon emission use			X	
Comfort level	X			
Outdoor air quality			X	
Particular matter (2.5, 10)			X	
Radon			X	
Asbestos			X	

Table A5. Module 5: economic and financial information.

Indicator	iBRoad-Log	ALDREN BuildLog	X-Tendo Logbook	Study EU DBL
Annual rent/property tax			X	X
Governmental taxes and incentives	X			
Financial programs	X			
Property value	X		X	X
Valuation date			X	X
Valuation method			X	X

Table A5. *Cont.*

Indicator	iBRoad-Log	ALDREN BuildLog	X-Tendo Logbook	Study EU DBL
Valuation author			X	X
Valuation document			X	X
Property yield			X	X
Annual maintenance costs			X	X
Annual electricity cost			X	X
Annual water cost			X	X
Annual heating cost				X
Annual gas cost			X	
Other costs				X
Building costs			X	

References

1. López-Mesa, B. De la sociedad fósil a la sociedad hipocarbónica: La ciudad inteligente como estrategia facilitadora. *Arbor* **2022**, *198*, a636. [CrossRef]
2. D'Oca, S.; Ferrante, A.; Ferrer, C.; Pernetti, R.; Gralka, A.; Sebastian, R.; Op 't Veld, P. Technical, Financial, and Social Barriers and Challenges in Deep Building Renovation: Integration of Lessons Learned from the H2020 Cluster Projects. *Buildings* **2018**, *8*, 174. [CrossRef]
3. Palm, J.; Reindl, K. Understanding barriers to energy-efficiency renovations of multifamily dwellings. *Energy Effic.* **2018**, *11*, 53–65. [CrossRef]
4. Bagaini, A.; Croci, E.; Molteni, T. Boosting energy home renovation through innovative business models: ONE-STOP-SHOP solutions assessment. *J. Clean. Prod.* **2022**, *331*, 129990. [CrossRef]
5. Alam, M.; Zou, P.X.W.; Stewart, R.A.; Bertone, E.; Sahin, O.; Buntine, C.; Marshall, C. Government championed strategies to overcome the barriers to public building energy efficiency retrofit projects. *Sustain. Cities Soc.* **2019**, *44*, 56–69. [CrossRef]
6. Cuchí, A.; de la Puerta, I. Diagnóstico de la Rehabilitación en las Comunidades Autónomas. Luces y Sombras de un Sector que no Despega. 2016. Available online: http://www.observatoriociudad3r.com/wp-content/uploads/2018/02/Informe-Rehabilitaci%C3%B3n-CCAA-Jul-2016.pdf (accessed on 28 February 2022).
7. Monzón, M.; López-Mesa, B. Buildings performance indicators to prioritise multi-family housing renovations. *Sustain. Cities Soc.* **2018**, *38*, 109–122. [CrossRef]
8. Blum, A. "Building passport"—A tool for Quality, Environmental Awareness and Performance in the Building Sector. In Proceedings of the OECD/IEA Joint Workshop on the Design of Sustainable Building Policies, Paris, France, 28–29 June 2001.
9. Blum, A. Documentation, assessment and labelling of building quality the German 'building passport' issue. In *Sustainable Urban Development 3*; Vreeker, R., Deakin, M., Curwell, S., Eds.; Routledge Taylor & Francis Group: Abingdon, UK, 2008; pp. 156–173. ISBN 9780415322195.
10. Talamo, C.; Bonanomi, M. *Knowledge Management and Information Tools for Building Maintenance and Facility Management*; Springer International Publishing: Berlin/Heidelberg, Germany, 2015; pp. 1–211. [CrossRef]
11. Sesana, M.M.; Rivallain, M.; Salvalai, G. Overview of the available knowledge for the data model definition of a building renovation passport for non-residential buildings: The ALDREN project experience. *Sustainability* **2020**, *12*, 642. [CrossRef]
12. Sesana, M.M.; Salvalai, G. A review on Building Renovation Passport: Potentialities and barriers on current initiatives. *Energy Build.* **2018**, *173*, 195–205. [CrossRef]
13. Fabbri, M.; de Groote, M.; Rapf, O. Building Renovation Passports—Customised Roadmaps towards Deep Renovation and Better Homes. 2016. Available online: https://www.bpie.eu/wp-content/uploads/2017/01/Building-Passport-Report_2nd-edition.pdf (accessed on 18 January 2022).
14. European Parliament and Council of the European Union. Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L0844&from=ES (accessed on 17 January 2022).
15. European Commission. A Renovation Wave for Europe—Greening our Buildings, Creating Jobs, Improving Lives. In Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Brussels, Belgium. 2020. Available online: https://eur-lex.europa.eu/resource.html?uri=cellar:0638aa1d-0f02-11eb-bc07-01aa75ed71a1.0003.02/DOC_1&format=PDF (accessed on 18 January 2022).
16. Davidson, I.N.; Skibniewski, M.J. Simulation of Automated Data-collection in Buildings. *J. Comput. Civil Eng.* **1995**, *9*, 9–20. [CrossRef]
17. Rubio del Val, J.; Espinosa-Fernández, A.; Monzón-Chavarrías, M.; López-Mesa, B. Evaluation of public residential renovation policies in Spain 2013–2017. *An. Edif.* **2020**, *6*, 6–12. [CrossRef]
18. Volt, J.; Toth, Z.; Glicker, J.; De Groote, M.; Borragán, G.; De Regel, S.; Dourlens-Quaranta, S.; Carbonari, G. *Definition of the Digital Building Logbook: Report 1 of the Study on the Development of a European Union Framework for Buildings' Digital Logbook*; European Commission: Brussels, Belgium, 2020. [CrossRef]

19. Carbonari, G.; Ricci, M.; Dourlens-Quaranta, S.; Calderoni, M.; Loureiro, T.; Sterling, R.; Glicker, J.; Toth, Z.; Volt, J.; De Groote, M.; et al. *Building Logbook State of Play: Report 2 of the Study on the Development of a European Union Framework for Buildings' Digital Logbook*; European Commission: Brussels, Belgium, 2020. [CrossRef]
20. Volt, J.; Fabbri, M.; Wouters, P. *Technical Study on the Possible Introduction of Optional Building Renovation Passports: Final Report*; European Commission: Brussels, Belgium, 2020. [CrossRef]
21. iBRoad Project. Available online: https://ibroad-project.eu/ (accessed on 15 December 2021).
22. ALDREN Project. Available online: https://aldren.eu/ (accessed on 15 December 2021).
23. X-tendo Project. Available online: https://x-tendo.eu/ (accessed on 15 December 2021).
24. Dourlens-Quaranta, S.; Carbonari, G.; De Groote, M.; Borragán, G.; De Regel, S.; Toth, Z.; Volt, J.; Glicker, J. *Study on the Development of a European Union Framework for Digital Building Logbooks: Final report*; European Commission: Brussels, Belgium, 2021. [CrossRef]
25. Sousa Monteiro, C.; Fragoso, R.; Papaglastra, M.; Deliyannis, A.; Pehnt, M.; Mellwig, P.; Lempik, J.; Werle, M. The Concept of iBRoad: The Individual Building Renovation Roadmap and Building Logbook. Potential Funcionalities and Graphical Guidelines When Setting Up the iBRoad Concept. 2018. Available online: https://ibroad-project.eu/news/the-ibroad-concept-in-practice/ (accessed on 11 January 2022).
26. CORDIS iBRoad. Available online: https://cordis.europa.eu/project/id/754045 (accessed on 16 December 2021).
27. CORDIS ALDREN. Available online: https://cordis.europa.eu/project/id/754159/es (accessed on 16 December 2021).
28. Zuhaib, S.; Borragán Pedraz, G.; Verheyen, J.; Kwiatkowski, J.; Hummel, M.; Dorizas, V. Exploring Innovative Indicators for the Next-Generation Energy Performance Certificate Features. 2020. Available online: https://x-tendo.eu/wp-content/uploads/2020/06/D3.1-Exploring-innovative-indicators-for-the-next-generation-EPC-features.pdf (accessed on 10 January 2022).
29. Volt, J.; Zuhaib, S.; Schmatzberger, S.; Zsolt, T. Energy Performance Certificates. Assessing Their Status and Potential. 2020. Available online: https://x-tendo.eu/wp-content/uploads/2020/05/X-TENDO-REPORT_FINAL_pages.pdf (accessed on 12 January 2022).
30. CORDIS X-Tendo. Available online: https://cordis.europa.eu/project/id/845958/es (accessed on 16 December 2021).
31. Libório, P.; Fragoso, R.; Sousa Monteiro, C.; Fernandes, J.; Silva, E.; Vande Casteele, T. The Logbook Data Quest. Setting Up Indicators and Other Requirements for a Renovation Passport. 2018. Available online: https://ibroad-project.eu/news/the-logbook-data-quest/ (accessed on 17 December 2021).
32. Volt, J.; Fabbri, M.; de Groote, M. Understanding Potential User Needs. A Survey Analysis of the Markets for Individual Building Renovation Roadmaps in Bulgaria, Poland and Portugal. 2018. Available online: https://ibroad-project.eu/news/understanding-user-needs/ (accessed on 17 December 2021).
33. Maia, I.; Kranzl, L.; Toth, Z.; Volt, J.; Monteiro, C.; Fragoso, R. Exploring Methodologies and Concepts for the Implementation of New Energy Performance Certificates Features for Better Data Handling—Logbook. 2021. Available online: https://x-tendo.eu/wp-content/uploads/2020/01/D4.4-Logbook.pdf (accessed on 16 December 2021).
34. Toth, Z.; Volt, J.; Zuhaib, S.; Broer, R. Introductory Reports. Building Logbook. 2021. Available online: https://x-tendo.eu/wp-content/uploads/2021/03/X-TENDO_MINI_7_Building-logbook_02.pdf (accessed on 11 January 2022).
35. Toth, Z.; Maia, I.; Rosa, N.; Volt, J. Technical Specifications of Energy Performance Certificates Data Handling: Understanding the Value of Data. 2020. Available online: https://x-tendo.eu/wp-content/uploads/2020/11/X-tendo_D4.2_final-1.pdf (accessed on 11 January 2022).
36. Zuhaib, S.; Schmatzberger, S.; Volt, J.; Toth, Z.; Kranzl, L.; Eugenio Noronha Maia, I.; Verheyen, J.; Borragán, G.; Sousa Monteiro, C.; Mateus, N.; et al. Next-generation energy performance certificates: End-user needs and expectations. *Energy Policy* **2022**, *161*, 112723. [CrossRef]
37. Schmatzberger, S.; Zuhaib, S.; Kranzl, L.; Eugenio Noronha Maia, I.; De Groote, M.; Verheyen, J.; Borragán Pedraz, G.; Rosa, N.; Fragoso, R.; Thielsen, C.; et al. Understanding End-User Needs and Expectations of the Next-Generation Energy Performance Certificates Scheme. 2020. Available online: https://x-tendo.eu/wp-content/uploads/2020/11/X-tendo-D2.4-end-users-survey.pdf (accessed on 5 January 2022).
38. Salvalai, G.; Sesana, M.M.; Ligier, S. D2.6—ALDREN Methodology Note on Rendering of the Collected Data and Results in a Building Renovation Passport. 2019. Available online: https://aldren.eu/wp-content/uploads/2020/12/D2_6.pdf (accessed on 7 January 2022).
39. Corovessi, A.; Touloupaki, E.; Kanellou, E. iBRoad Stakeholders Meetings. Key Notes and Findings of 1st Physical Events Round. 2018. Available online: https://ibroad-project.eu/news/ibroad-stakeholders-meetings-2/ (accessed on 13 January 2022).
40. Corovessi, A.; Kanellou, E. iBRoad Stakeholders as Real Driver of Positive Change. Step 1: Identification Process across Europe. 2017. Available online: https://ibroad-project.eu/wp-content/uploads/2018/06/H2020-iBRoad-WP6-Deliverable-6.1.pdf (accessed on 13 January 2022).
41. Sesana, M.M.; Salvalai, G.; Brutti, D.; Mandin, C.; Wei, W. ALDREN: A Methodological Framework to Support Decision-Making and Investments in Deep Energy Renovation of Non-Residential Buildings. *Buildings* **2021**, *11*, 3. [CrossRef]
42. ALDREN Training Workshop. Feedback and Proposals for the Training Program. 2018. Available online: https://aldren.eu/wp-content/uploads/2018/11/ALDREN_training_workshop_slide_deck_final.pdf (accessed on 3 January 2022).
43. ALDREN Training Workshop: Brussels, 12 November 2018. REHVA Brussels Summit. Poll Results. 2018. Available online: https://aldren.eu/wp-content/uploads/2018/11/ALDREN_Poll_Results.pdf (accessed on 3 January 2022).

44. Signorini, M.; Lupica Spagnolo, S.; Dejaco, M.C. A Digital Logbook as an Interactive Tool to Fulfil Service Companies' Needs and Requirements in Building Renovations. In *IOP Conference Series: Materials Science and Engineering 2021*; IOP Publishing: Bristol, UK, 2021; Volume 1044. [CrossRef]
45. Gómez-Gil, M.; López-Mesa, B.; Espinosa-Fernández, A. Diseño conceptual del Digital Building Logbook para garantizar su capacidad de evaluación del progreso de la actividad rehabilitadora en el parque residencial. *Jorn. Jóvenes Investig. del I3A* **2021**, *9*, 1–2. Available online: https://papiro.unizar.es/ojs/index.php/jji3a/article/view/6009 (accessed on 25 February 2022).