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The Digital Building Logbook as a gateway linked to existing national data sources: The cases of Spain and Italy

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ABSTRACT

The Digital Building Logbook (DBL) was first introduced together with the Renovation Wave initiative, promoted by the European Commission and then defined in the proposal for a recast of the energy performance of buildings Directive, in December 2021, as a repository of relevant data on a building that aims to alleviate the current lack of information of the European building stock. Several data sources on buildings already exist at different levels in Europe, and their interlinkage is crucial for a proper data population of the future Building Logbook. However, these data sources are scattered and heterogeneous, thus, they need to be evaluated to determine their suitability for the DBL. This paper analyses the sources that currently exist in Spain and Italy, focusing respectively on Aragon and Lombardy region, and addressing their interoperability possibilities and the indicators collected. The results show that the available data are not fully aligned with the relevant indicators from the existing proposals for a European DBL, and that few data sources are currently suitable for the DBL, since most of them are not interoperable. Considering the features and limitations of the data sources, a dataflow general scheme based on the definition of the DBL is defined for each case study, and guidelines are presented on data collection and interoperability in order to make its implementation feasible at the European scale.

1. Introduction

One of the main goals of the European Commission (EC) for the near future is to achieve climate neutrality by 2050 in Europe. As intermediate benchmark, the EC aims at cutting greenhouse emissions (GHG) by at least 55% before 2030. To booster the green and digital transition in the field of buildings and to align EU legislation with the 2030 goals, a proposal for the recast of the Directive of the European Parliament and of the Council on the energy performance of buildings (EPBD recast) was launched as a part of the 'Fit for 55 package' [1]. The proposal for the EPBD recast [2,3] remarks the importance of buildings renovation, since European existing buildings are responsible for 40% of energy consumption and 36% of GHG emissions of the EU. Their renovation is key, not only to increase their energy efficiency and to decrease their GHG emissions, but also to create green jobs and booster economy growth [2], and to fight against the depopulation of the urban centres, the excessive cost of rents in the main cities and the degradation of historic buildings [4]. However, the annual renovation rate is very low in Europe (around 1% of the building stock is renovated annually) [5],

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List of abbreviations

AI	Artificial Intelligence
API	Application Programming Interface
BRP	Building Renovation Passport
CEE	Certificado de Eficiencia Energética
CEER	Catasto Energetico Edifici Regionale
CSV	Comma-Separated Values
CURIT	Catasto Unico Regionale degli Impianti Termici
DB	Database
DBL	Digital Building Logbook
DPP	Digital Product Passport
DT	Digital Twin
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
EPD	Environmental Product Declaration
GDPR	General Data Protection Regulation
GHG	Greenhouse Emissions
IEE	Informe de Evaluación del Edificio
INE	Instituto Nacional de Estadística
ITE	Inspección Técnica de Edificaciones
JSON	JavaScript Object Notation
LdE	Libro del Edificio
LEEx	Libro del Edificio Existente
MS	Member States
SIAPE	Sistema Informativo sugli Attestati di Prestazione Energetica
SRI	Smart Readiness Indicator
XML	eXtensible Markup Language

and a further boost is needed to achieve the above mentioned goals.

A great amount of information is generated during building's life cycle. Valuable data are generated at their design and construction phases, during their use stage, when they are renovated and when their lives come to an end. The EPBD highlights the importance of collecting and managing these data in an effective way [2], not only to increase the efficiency of buildings [6], but also to make informed decisions when designing a renovation [7,8] or a maintenance plan [9,10], to reorient public policies and strategies [11,12], to foster the construction sector's digitalization and competitiveness [13], and to contribute to raise the awareness of the population about the importance of renovation.

Despite the existence of this large amount of data on buildings, there is a lack of strategies to efficiently manage and correlate them, and this issue has scarcely been addressed in the literature [6,14]. With the aim of homogenizing data gathering processes and promoting the generation, storage and management of reliable and quality information, the aforementioned Proposal for the EPBD recast [2] introduced the figure of the '*Digital Building Logbook'* (DBL), 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'*. In this sense, as stated in Article 19, this repository should be linked to other data sources, such as national cadastres, Energy Performance Certificate (EPC) registries, technical inspections reports, the Smart Readiness Indicator (SRI) or building renovation passports, in order to develop an interoperable, homogeneous, and coherent national database on energy efficiency. Although it is not specified in the Directive, new sources in development e.g., the Digital Product Passport (DPP) [15], the Environmental Product Declaration (EPD) or the Level(s) assessment framework [16,17] will also be valuable sources of information. Additionally, the digitization of the construction sector will contribute to the collection of a great amount of heterogeneous data through monitoring, Artificial Intelligence (IA), and Digital Twins (DT), among others, and the DBL should be the container or gateway –as we name in this paper-that stores them [6,18].

Even though the concept of DBL was clarified in the abovementioned Directive [2], it has not still become a mandatory tool for the construction sector in Europe. However, some national initiatives already exist [19–21] and several research groups are working on the definition of a European common scheme [14]. At the moment, the most developed initiatives at a European scale are the outcomes from the H2020 projects iBRoad [22,23], ALDREN [24,25], and X-tendo [26,27], as well as the 'Study on the Development of a European Union Framework for Buildings' Digital Logbook' [28]. Even though these experiences constitute an important first step for the definition of the DBL model, some crucial aspects are still under development, such as the functionalities of the DBL and user needs, how it will be operated and used, the connection to existing data sources, and the indicators it should include [14]. Regarding the last aspect, *Gómez-Gil* et al. [14] concluded that there are great differences among the initiatives, since the total number of indicators considered by the 4 proposals was 438, of which only 4 were suggested by all of them, 21 by 3 and 77 by 2 initiatives. That is, 102 out of 438 indicators (23%) were suggested by $\geq$ 50% of the DBL proposed models.

This paper focuses on the mutual connection to existing data sources. So far, this issue has not been addressed in the literature and, therefore, the novelty of this paper is the exploration of this connection for the first time. Starting from the definition of the DBL given by the Proposal for the EPBD recast and including the inputs from the literature, the objective of this paper is to set a general dataflow structure for the DBL, deeply analysing the existing digital building data sources applicable to a region in Spain and Italy, focusing on their indicators and interoperability possibilities, and optimizing the general data flow scheme for the two particular cases.

2. Material and methods

Regarding the DBL functionalities, we start from the assumption that, in addition to serving as a repository of building data, as stated in [29] it should directly contribute to promote energy renovation by providing the necessary information for: a) preparing renovation roadmaps (as pointed out by [9,30]); b) carrying out maintenance plans; and c) assessing the progress of decarbonization (as pointed out by [14,29]) (see Fig. 1).

To produce these services, it is necessary to define the indicators that must be gathered. In this paper, we will identify those indicators available in existing data sources and compare them with those proposed by the European-scale DBL initiatives previously mentioned. Currently, there is not an official positioning from the EC regarding the indicators the DBL should include, nor consensus among the running initiatives and proposals [14]. This research will be useful to identify the already digitized indicators and to support in the decision of other indicators to include.

Besides the available data, it is necessary to explore the possibilities to exploit this information by studying the interoperability features of the databases where it is stored. The interoperability of a database refers to whether or not the stored data can be shared and how. Both aspects are crucial, since the DBL should be seen as a gateway, 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

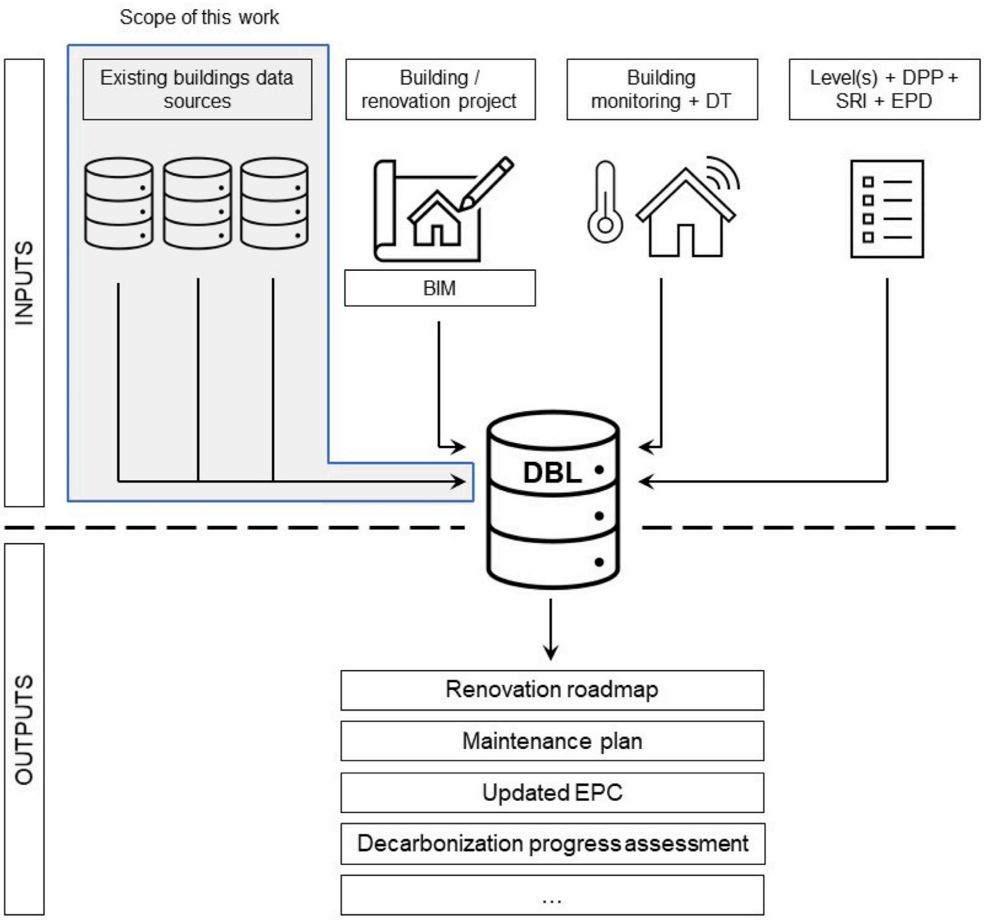

Fig. 1. Proposal of Inputs and outputs of the Digital Building Logbook (DBL) as gateway. Abbreviations: Building Information Modeling (BIM), Digital Product Passport (DPP), Digital Twin (DT), Environmental Product Declaration (EPD), Smart Readiness Indicator (SRI).

through a single application.

The research methodology for this work is comprised of four main steps (Fig. 2):

- STEP 1. Conceptualization of the DBL dataflow structure reflecting the definitions given in the literature review and focusing on the existing data sources on buildings.
- STEP 2. Selection of case studies and data sources overview. This step is composed of 2 sub-steps. The first one should be used in all cases. The second one is only necessary for countries made up of regions with self-governance and autonomy in decision-making. In such cases, regionally or locally managed sources need to be included.
- STEP 3. Building data sources analysis of the case studies.
- STEP 4. Application of the dataflow general structure to the case studies for its validation and databases guidelines definition.

2.1. Case studies

As case studies, we use nationally and regionally managed **digital data sources** on buildings applicable to a region in Spain and Italy. Other valuable non-digital sources in these two countries, such as the *Libro del Edificio* (LdE) and the *Libro del Edificio Existente* (LEEx) in Spain [31] and the *Fascicolo del Fabbricato* in Italy are not included in this analysis because they are not considered suitable for the DBL at its current format.

Studying these two countries is of interest because they present similarities, not only in terms of location and size, but also in terms of territorial organization. In this sense, both countries are set as an aggregate of regions with different levels of self-governance and autonomy in decision-making. This administrative organization is decisive and has a direct influence on the strategies of data gathering on the building stock, since many of the competences regarding buildings –despite the existence of guidelines at the national level– are

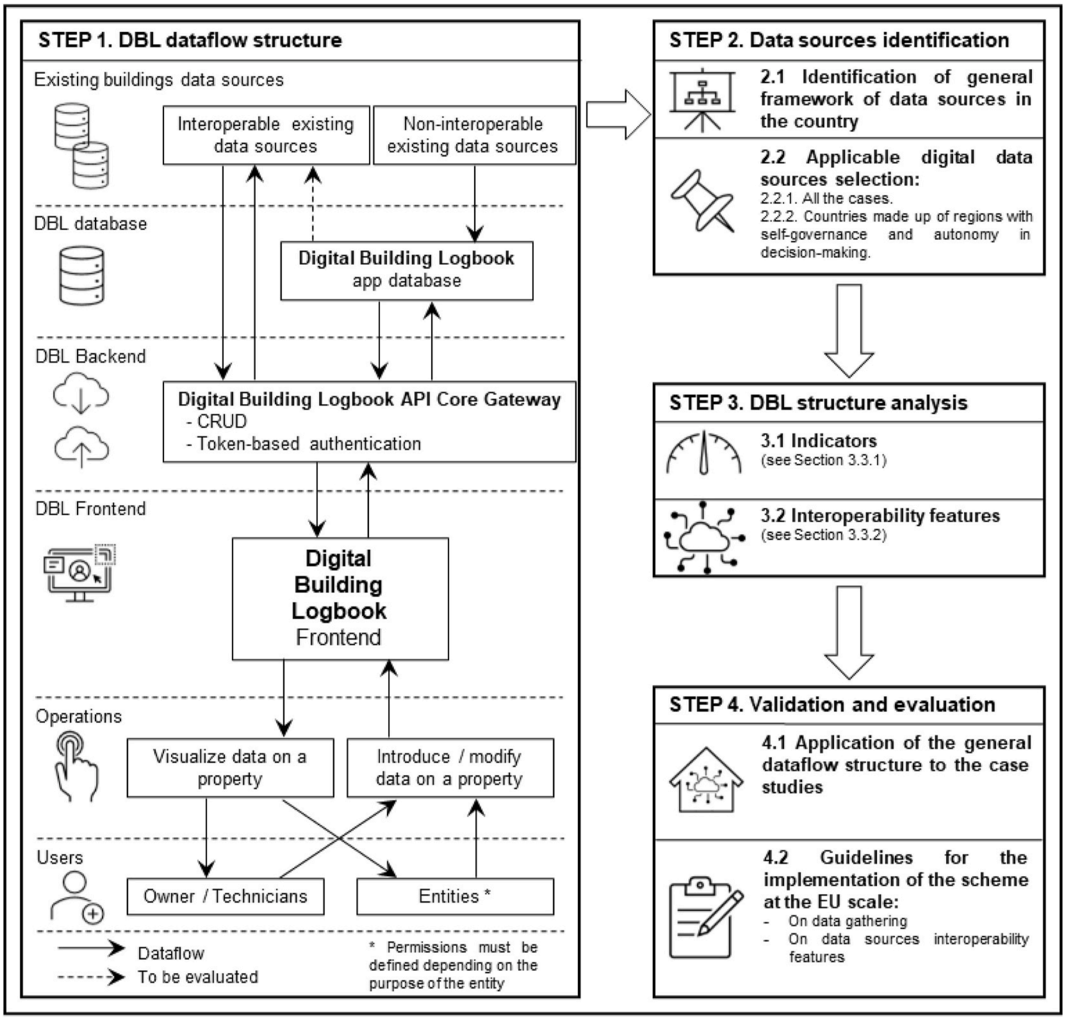

Fig. 2. Steps of the analysis of existing data sources useful for the DBL. Abbreviations: Application Programming Interface (API), Create, Read, Update, Delete (CRUD), Digital Building Logbook (DBL).

delegated to the regional administrations.

Due to the diversity and complexity of the data sources framework at the regional level, which includes the use of different sources in each region of the countries, a detailed study was carried out focusing on two specific territories: Lombardy region in Italy, and Aragon in Spain. Additionally, Zaragoza city was also included in the study due to the existence of a relevant municipal-level tool.

Aragon and Lombardy are both regions located in the north of their countries, and they are made up of three and twelve provinces respectively. On the one hand, Lombardy is the most populated region in Italy, with 9,965,046 inhabitants in 2022 [32], what means almost 17% of the Italian population. On the other hand, in Aragon live 1,314,586 people [33], which is almost 3% of the Spanish population.

In both cases, the capital city is one of the most populated ones in their countries. Milan is the second city in Italy, with 1,371,498 inhabitants in 2022 [32] while Zaragoza is the fifth in Spain, with 675,301 inhabitants in 2021 [34].

Regarding the economy sector clustering, Aragon has traditionally been a territory dedicated to the primary sector, but in recent years this trend has changed, becoming the service sector the most important one, followed by construction, industry and energy, and agriculture and cattle raising [35]. On the other hand, Lombardy region is considered to be one of the economic engines of Europe, and represents around 20% of the Italian GDP. Lombard economic system is very varied, and comprises from agriculture and manufacturing to services. However, industry is the most relevant cluster, which is also known for being an important source of research and innovation [36].

With regard to energy conjuncture, in 2021 in Aragon the final energy consumption was 3,955 ktep, while the final energy intensity was 0.11 ktep/million €. It is important to notice that the renewable energy production reached 1,950 ktep throughout the whole year [37]. In contrast, in Lombardy region in 2019, the final energy consumption reached 23,161 ktep [38], which is almost 6 times the consumption in Aragon. However, the energy intensity calculated with data from 2019 was 0.06 ktep/million €. Regarding renewable energy, Lombardy region produced 3,450 ktep, which is 1.5 times the Aragonese production.

Even though these regions count on several differences, both of them have also important similarities, such as the fact that they are inland regions with a very varied orography, with high peaks and large valleys, which translates into a variety of climatic zones. In fact, according to the Köppen climate classification, in Aragon and Lombardy zones Cfa, Cfb, and Dfc can be found. Additionally, zone Bsk and Dfb are present in Aragon and Lombardy respectively. Together, both regions can be considered representative of a large part of southern Europe in terms of climatic regions.

Additionally, it is important to highlight the effort that public administrations from Aragon and Lombardy are making to create an open data library. This is specially aligned with the objective of the present work.

3. Steps description and results

3.1. DBL dataflow structure

The DBL dataflow structure scheme reflects the flow of information that takes place from the sources it is hosted in up to the Frontend, where it is visualized by end users. Depending on the user's permissions, the reverse path may also be possible, i.e., the data can be introduced and modified from the Frontend and be stored in the database.

To optimize the dataflow, it is necessary first to determine how the interaction between the data sources can be done and, in order to achieve this, it is necessary to study the sharing possibilities of the existing databases (DBs). Depending on this criterion, the model could be based on Application Programming Interfaces (APIs), could have its own database or could be a hybrid model, combining both systems. Some basic concepts about databases interoperability are explained in the following paragraphs.

An **Application Programming Interface or API** is a software intermediary that allows the communication between two software tools or applications. To be able to communicate, the systems need to have an **endpoint**, which is basically a communication channel, and to work with compatible **data interchange formats** e.g., JavaScript Object Notation (JSON), eXtensible Markup Language (XML) or comma-separated values (CSV). This means that the system that requests the information encodes a message in a format that can be decoded by the receiver [39].

During the communication process, the operations that the server should perform are determined by **methods** [40]. Regarding the DBL, the most used one is 'GET' which serves to 'retrieve whatever information (in the form of an entity)' from the other system [41]. Additionally, 'PUT' or 'POST', which are used to send data to the other server to create or update a resource [42], may be used depending on the final functionalities and permissions of the final users of the DBL.

A DBL architecture based on APIs has the advantage of being permanently updated as long as the data sources are updated too. This typology of architecture is efficient, and makes it easy, safe, and fast to integrate data from multiple platforms.

On the contrary, the DBL could host its own regularly updated DB, which means that the data would be downloaded from the data sources, stored in a server, and shown when required.

This approach has the advantage of being mostly independent from the data source, which means that a failure in the source would not impact the DBL. However, the main database would need to be regularly updated and the complexity of the creation and maintenance of the system increases substantially.

Finally, in a hybrid version, some data would be requested from data sources through APIs, when possible, and stored in own databases when API endpoints are not available.

It is important to notice that the approach used on the DBL depends largely on the availability and nature of data sources in each country. Despite the DBL model must follow some general common guidelines that allow the comparison and compilation along the EU member States (MS), the heterogeneity of the continent makes it necessary to envisage a flexible model able to connect DBs of different nature and to collect different indicators depending on the countries' needs. Thus, the architecture (backend) of the DBL can vary slightly depending on the national context or, even regional.

3.2. Data sources identification

The second step consisted in the identification of the existing digital data sources on buildings in the investigated countries, focusing on the mandatory in force ones in the case study territories.

3.2.1. Countries of study and their framework overview

In Spain and Italy there is a variety of databases/sources and tools for data gathering on buildings. Some of them are nationally managed and are applicable to the whole country, while others are regionally or locally managed and are applicable to some regions. Considering this, a classification of them was made (Table 1).

3.2.2. Case study selection and their framework overview

As explained before, Spain and Italy are countries where regions have a great level of self-governance and autonomy in decision-making. For this reason, a second sub step was required. In this stage 2 regions were selected as case studies, Aragon (and the city of Zaragoza) and Lombardy region, and the digital data sources applicable to these cases were determined and analysed. Table 2 summarizes and briefly describes the sources currently in force in those territories.

3.3. DBL structure analysis

As previously exposed, this research focuses on studying and comparing the two main parameters on building data sources: indicators and interoperability of DBs. In the following paragraphs, the results of the analysis are presented.

3.3.1. DBL indicators

Regarding the indicators in the existing digital data sources, the main object of study in this paper is their degree of suitability or level of alignment with the objectives of the DBL.

We have observed that historically, DBs on buildings were focused on collecting general, descriptive, or administrative data. Few DBs that provide technical information related to the constructive characteristics, the energy performance, the description of the materials or the improvement potential of buildings were identified. In fact, this research reveals that the only Italian and Spanish DBs that provide open information on these issues are the energy performance certificates registries, which are quite recent.

To determine the level of alignment of the available data with those desirable for the DBL, the indicators are analysed by clusters in three steps. First, the desirable indicators covered by the existing data sources in the case studies in Italy and Spain are identified and counted. This is done by comparing the indicators in the digital sources with the most relevant indicators proposed by the four European DBL models, i.e., those indicators suggested by $\geq 50\%$ of the four initiatives (see section 1). In order to simplify this set of 102 indicators, the equivalent ones were grouped, making a total of 83 indicators mentioned by $\geq 50\%$ of the four DBL models. Secondly, the whole set of indicators included in the existing data sources in Italy and Spain are identified and counted. In third place, the number of indicators obtained in the two previous steps is compared.

Table 3 and Fig. 3 summarize the number of available indicators in the nationally (Spain and Italy), regionally (Aragon and Lombardy region), and locally (Zaragoza city) managed data sources in comparison to the indicators that the DBL should include, grouped by clusters. Access conditions of the sources, this is, whether the data are open or not, were also considered. The complete set of indicators is available in Appendix A.

As shown in Fig. 3, the share of available indicators collected in comparison to those that should be collected is slightly higher in the Spanish case than in the Italian one (40% vs. 35%). However, in the Italian case, most of the available data (90%) are open source, whereas in Spain, only 36% of the gathered indicators are open.

The analysis of indicators by clusters (Table 3), shows that in the Spanish case study, only the cluster ‘General and administrative

Table 1
Current data sources/tools on buildings in Spain and Italy.

Scale	Sources/Tools			
	Spain		Italy	
Nationally managed	Catastro/Cadastre	Registro de la Propiedad/ Land Registry	Catasto/Cadastre of Buildings + Land Registry	Sistema Informativo sugli Attestati di Prestazione Energetica (SIAPE)/ Information System on Energy Performance Certificates
Regionally managed	Registros del Certificado de Eficiencia Energética (CEE)/ Energy Performance Certificate (EPC) registries	Informe de Evaluación del Edificio (IEE)/ Building Assessment Report	Catasto Energetico Edifici Regionale/Energy Performance Certificate regional registries	Catasto Unico Impianti Termici/ Thermal Systems Cadastre
Locally managed	Inspección Técnica de Edificaciones (ITE)/Technical Inspection of Buildings	Urban licenses, urban files … viewers		Urban licenses, urban files … viewers
Building-scale	Libro del Edificio (LdE)/Building Logbook	Libro del Edificio Existente (LEEx)/ Existing Buildings Logbook	Fascicolo del Fabbricato, Libretti di manutenzione degli impianti	

Table 2
Current data sources/tools on buildings in Aragon, Zaragoza, and Lombardy region. [43,44,45,46,47,48,49,50,51,52].

National data sources / tools (Spain)	National data sources / tools (Italy)
Catastro / Cadastre The Real Estate Cadastre is an administrative register where rustic, urban and special properties are described [43]. It is run by the Ministry of Hacienda and applies to the whole territory of Spain, except Basque Country and Navarre, where there are regional cadastres [43]. The Cadastre was originally created with the aim to gather the information needed to manage and collect administrative taxes. However, in the recent years, its potential for becoming a data source on the real estate market has been identified, multiplying its interest for public entities, companies, and citizens.	Catasto / Cadastre of Buildings + Land Registry In the past, the Cadastre and the Land Registry were managed by different authorities due to their different functions: the Cadastre surveyed and mapped real estate properties and land, and the Land Registry registered ownership and charges on properties [44]. However, currently, the *'Agenzia delle Entrate'*, which is in charge for collecting tax revenues, holds both functions: cadastral and property registration ones [45, 46]. The Cadastre is applicable to the whole Italian territory, except for Bolzano, Trento, Trieste and Gorizia, where the system called Austrian *'tavolare'* is still in force.
Registro de la Propiedad / Land Registry This 'Title system' registry, run by the Ministry of Justice, was created with the aim of recording acts, contracts and judicial and administrative resolutions that affect property, as well as rights on real estate [47, 48]. It is coordinated with the Cadastre and, unlike this, the inscription in the Property Register is not mandatory, but it is still a very common practice.	Registered technicians are in charge for uploading the cadastral information and they are the only ones authorized to query (upon payment of a fee) the database files in PDF format. The queryable data set includes general and administrative information, as well as the floor plans of each property. In addition, each owner can query and download in PDF format the data related to their property.
In Spain, a national EPC register has not been created yet, and every region manages its own register.	Sistema Informativo sugli Attestati di Prestazione Energetica (SIAPE) / Information System on Energy Performance Certificates In Italy, the Interministerial Decree of 26 June 2015 – Adaptation of the national guidelines for the energy certification of buildings, is the latest transposition of the European regulations on the Energy Performance Certificate. It establishes national guidelines for the certification of energy efficiency as well as the obligation to create a national cadastre containing information on energy performance certificates and thermal installations.
Regional databases (Aragon)	Regional databases (Lombardy region)
Registros del Certificado de Eficiencia Energética (CEE) / Energy Performance Certificate (EPC) registries Since Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings [49] took effect, several Royal Decrees were approved to transpose the European legislation into the Spanish one. The last one was Royal Decree 390/2021, of June 1, which approves (and updates) the basic procedure for the certification of the energy efficiency of buildings, the scope and the contents of the EPC [50]. In Spain, the EPC shows the non-renewable primary energy consumption of a property as well as the CO_2 emissions. According to these parameters, an energy class is assigned to the dwelling, from A (the most efficient) to G (the least efficient). Administrative and general data about the property is also shown in the EPC, as well as a set of proposals for its performance improvement.	To apply the mentioned Decree, each region created its own cadastre, updating the data into the national cadastre annually. Catasto Energetico Edifici Regionale (CEER) / Energy Performance Certificate regional registries The CEER, created in 2016, is the regional registry of Lombardy region and provides data to the national cadastre on energy needs, energy label, geometric characteristics, technical systems and use or renewable energy of buildings. It allows open visualization of disaggregated -table format- EPC data and is updated weekly. Catasto Unico Regionale degli Impianti Termici (CURIT) / Thermal Systems Cadastre The CURIT was created in 2008 with the aim of collecting and managing data on buildings thermal systems in Lombardy region. It is also used to control the fulfilment of maintenance operations and to monitor the evolution of the regional buildings' facilities stock.

	Data are registered by technicians and installers and can be consulted openly in table format. The available information includes the main data that technically characterize buildings systems, such as power, energy source or brand, as well as energy parameters, such as the efficiency of the system.
Local databases (Zaragoza)	
Registro de la Inspección Técnica de Edificaciones (ITE) / Technical Inspection of Buildings Repository The Technical Inspection of Buildings (ITE) was regulated at the national level by Royal Decree – Law 8/2011, of July 1 [51]. This regulation stated that all the residential buildings older than 50 years must be subject to a periodic technical inspection to ensure their good condition and proper conservation status and determine the eventual conservation works that may be necessary. However, this Royal Decree – Law was repealed by Law 8/2013, of June 26, on urban renovation, regeneration, and renewal [52]. This regulation admitted that the ITE was insufficient to guarantee its main objective, and, additionally, it had not been implemented in all the Spanish regions, thus, a new tool was introduced: the Building Assessment Report (IEE). However, the ITE is still used in some regions, like Aragon. Regarding the ITE, every municipality creates and manages its own registry. In the case of the city of Zaragoza, in addition to the registry, there is an ITE viewer that should display the data to the citizens. However, the tool is not working due to update works on the site. In Zaragoza, urbanistic data can be also gathered from the Urban files and the Municipal licenses viewer.	

Table 3
Summary of available/non-available data, and open/non-open data in the case studies in comparison with the most relevant proposed indicators. The values of ≥50% of available data with respect to desirable indicators are highlighted light grey. The values of ≥50% of open data with respect to available indicators are highlighted dark grey.

Clusters of indicators	Spanish case study				Italian case study			
	Available data	Non-available data	Open data	Non-open data	Available data	Non-available data	Open data	Non-open data
General and administrative information (24)	12	12	11	1	11	13	9	2
Construction information and materials (21)	8	13	1	7	0	21	0	0
Technical systems and Smart Readiness (22)	9	13	0	9	14	8	14	0
Energy efficiency, operation, and use (8)	3	5	0	3	3	5	3	0
Financial information (7)	1	6	0	1	1	6	0	1
Conservation status and pathologies (1)	0	1	0	0	0	1	0	0
Total (83)	**33**	**50**	**12**	**21**	**29**	**54**	**26**	**3**

information' has more than 50% of the desired indicators available, whereas in the Italian one, the cluster 'Technical systems and Smart Readiness' is the only one with over 50% of indicators available. Regarding access conditions of the indicators, 'General and administrative information' in Spain and Italy case studies, and 'Technical systems and Smart Readiness' and 'Energy efficiency, operation, and use' in the Italian one, are the categories where more than 50% of the data fields are open.

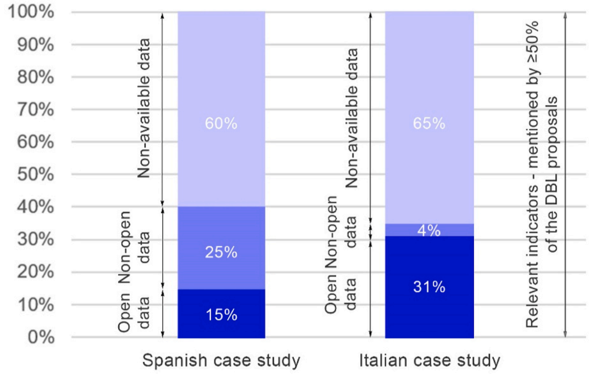

Fig. 3. Data availability and access conditions in the case studies considering the relevant indicators mentioned in the DBL proposals. Abbreviations: Digital Building Logbook (DBL).

When considering not only the indicators proposed by the DBL initiatives, but including all the indicators hosted in the databases, the results (Table 4 and Fig. 4) show that the data for the Italian case vary slightly (37% of data available), which means that the available indicators are very aligned with those proposed. On the other hand, in the case of Spain, the number of indicators available increases exponentially (60%), which means that, although many more data are being collected, these are not especially aligned with those considered more relevant/suitable for the DBL. Regarding the access conditions, in the Italian case study, open indicators remain in 34% whereas, in the Spanish one, the share increases considerably, reaching 37%.

With these new considerations, in the Spanish case, within the clusters 'General and administrative information', 'Construction information and materials', 'Energy efficiency, operation, and use', and 'Conservation status and pathologies' more than 50% of the indicators are available, whereas in the Italian case study, the categories where ≥50% of the data fields are collected are 'Technical systems and Smart Readiness' and 'Energy efficiency, operation, and use'.

The clusters where more than 50% of the indicators are open are coincident with the above-mentioned, adding the clusters 'General and administrative information' and 'Construction information and materials' to the Italian case.

3.3.2. Interoperability of the existing databases

To individualise the operation and dataflow scheme of the DBL for Spain and Italy, focusing on the selected regions, it is necessary to identify whether the existing databases are interoperable, i.e., if they have the capability of communicating with each other, and how this can be done. Table 5 shows the results of the analysis conducted on databases interoperability possibilities. In Table 6 a query feature is developed for the interoperable data sources.

As displayed in Table 5, data sources are currently fully suitable for the DBL in the selected case studies. This is the case of the Aragonese EPC registry, the CEER and the CURIT, which are all regionally managed. It is considered that they are suitable because they are fully open, are able to communicate with other applications through a public API endpoint, and use appropriate interchange

Table 4
Summary of available/non-available data and open/non-open data in the Spanish and Italian case studies. The values of ≥50% of available data are highlighted light grey. The values of ≥50% of open data with respect to available indicators are highlighted dark grey.

Clusters of indicators	Spanish case study				Italian case study			
	Available data	Not available data	Open data	Not open data	Available data	Not available data	Open data	Not open data
General and administrative information (47)	34	13	30	4	17	30	11	6
Construction information and materials (62)	45	17	23	22	4	58	4	0
Technical systems and Smart Readiness (45)	16	29	2	14	34	11	34	0
Energy efficiency, operation, and use (22)	11	11	7	4	16	6	16	0
Financial information (7)	1	6	0	1	1	6	0	1
Conservation status and pathologies (10)	9	1	9	0	0	10	0	0
Total (193)	**116**	**77**	**71**	**45**	**72**	**121**	**65**	**7**

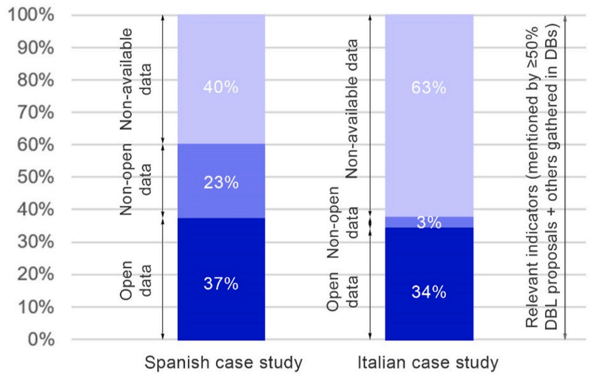

Fig. 4. Data availability and access conditions in the Spanish and Italian case studies considering the relevant indicators mentioned in the DBL proposals and all the data fields stored in the studied data sources. Abbreviations: Database (DB), Digital Building Logbook (DBL).

formats, including JSON. On the contrary, the land registries, managed at the national level in Spain and Italy, are unlikely to be suitable for the DBL in the near future, since they do not count on a public API endpoint and, what is more, the free and immediate exchange of data needed for the DBL goes against their business model, which involves a formal requirement and/or the payment of a fee to have access to the data.

3.3.2.1. Query features. In the cases of the interoperable data sources, two different ways to formulate the request query were proposed (see Table 6). In the opinion of the authors, the DBL must be associated to a building since this is the only way to accompany its whole life cycle. Therefore, it is considered that the entry data of the DBL should be a cadastral reference or a postal address, since they are fixed parameters, and they are the only ones that remain unchanged throughout the entire life of the building. These two possibilities were for databases that count on a public API endpoint.

3.4. Validation and evaluation

In the fourth step the general DBL dataflow structure envisaged in the first stage was applied to the two case studies, with the aim of validating the general model and setting general guidelines for its applicability at the European scale.

3.4.1. Application of the general dataflow structure to the case studies

Considering the results of the analysis conducted on the interoperability of the data sources and the different approaches on DBs architecture mentioned in Step 1 (Section 3.1), the general dataflow structure was applied to the case studies.

In the Spanish case, the analysis showed that sources of all natures exist: the Aragonese EPC registry is fully interoperable, allowing an architecture based on APIs; the Cadastre allows the massive download of data, what means that a database for the DBL can be created and frequently updated; the Land registry, on the other hand, does not allow data exchange currently; the Zaragoza ITE registry remains unknown until the update of the website.

With these premises, a hybrid DBL model is envisaged (Fig. 5), where the DBL interchanges information through APIs using HTTP methods, with the Aragonese EPC registry and the DBL database. The DBL database is created to store the data downloaded massively from the Cadastre and from future partially interoperable sources, is regularly updated, and communicates through the DBL core API with the DBL Frontend.

Even though the most used method would be GET, which is used to retrieve information, depending on the final functionalities of the DBL, PUT or POST methods may be also used to introduce or modify data from the Frontend. These new data would be stored in the DBL database or in the existing sources, depending on their permissions. In this case, this may be possible only when interacting with the Aragonese EPC registry.

In all the cases, the recommended data interchange format is JSON, since it is a lightweight and concise format, with good compatibility, human readable, it can be easily parsed and is the most common in modern databases [53–56].

Regarding the non-interoperable data sources, a link to the source website may be provided, allowing the user to access the desired information directly from the source by following the specified procedures.

In the Italian case study, two types of data sources were identified. On the one hand, the CEER and the CURIT are totally interoperable databases, thus, requests can be directly made using HTTP methods (GET) and, on the other hand, the Cadastre and Land Registry and the SIAPE, are not interoperable sources, which means that non-open information can be retrieved from them. With these considerations, a dataflow structure based on APIs is envisaged (Fig. 6), with the limitations that no data can be retrieved from the mentioned data sources. In such cases, as suggested in the Spanish case, a link to the source website may be provided, to directly access the desired information from the source. Regarding the introduction/modification of data by the end user, when allowed, the data may be directly provided from the Frontend and communicated to the data sources using HTTP methods (PUT/POST). Once again, the recommended data interchange format is JSON due to the previously exposed reasons.

Table 5
Data sources interoperability features. Abbreviations: Application Programming Interface (API), Catasto Energetico Edifici Regionale (CEER), Catasto Unico Regionale degli Impianti Termici (CURIT), Digital Building Logbook (DBL), Energy Performance Certificate (EPC), Inspección Técnica de Edificaciones (ITE), Sistema Informativo sugli Attestati di Prestazione Energetica (SIAPE).

Source	**Spanish Cadastre**	**Spanish Land Registry**	**Aragon EPC registry**	**Zaragoza ITE registry**	**Italian Cadastre and Land Registry**	**SIAPE**	CEER	CURIT
Level of application	National (except Basque Country and Navarre)	National	Regional (Aragon)	Local (Zaragoza)	National (except Bolzano and Trento)	National (data from Sardinia, Tuscany, Campania, and Basilicata not available)	Regional (Lombardy)	Regional (Lombardy)
Access conditions	Partially open data: non-protected data are fully open, while protected data are available only for the property owners	Partially open data: information on a property can be requested by anyone whether its registration code or the owner's data are known. It is also necessary to plead legitimate interest and the payment of a fee	Full open data	Supposed to be open data (not working)	Partially open data: information on a property is open for its owner in PDF format. Registered technicians can visualize the whole building stock prior payment in the same format	Aggregated data are full open for citizens while disaggregated data are open for public authorities	Full open data	Full open data
Interoperability	Collaborating public entities can establish protocols with the Cadastre to exchange information regularly. Additionally, it is also possible to make punctual requests of information by sending a XML query, but the response from the source is not immediate	Not interoperable. A public API does not exist so far	Public API endpoint available	A new version of the website will be launched soon, and no details were found about its interchange possibilities	A public API endpoint does not exist so far	A public API endpoint does not exist so far	Public API endpoint available	Public API endpoint available
Interchange format	XML	–	JSON, XML, CSV, XLS	?	–	–	CSV, GeoJSON, JSON, RDF-XML, XML	CSV, GeoJSON, JSON, RDF-XML, XML
Suitability for the DBL	Since the DBL needs a quick response from the APIs, the massive download (a regularly update) of public cadastral data and their incorporation into a DBL database seems the most appropriate option	This source is not suitable for the DBL, since an API endpoint does not exist so far and, additionally, the payment of the fee prevents the data from arriving to the DBL immediately	The architecture of this database is completely suitable for the DBL	It cannot be assessed until the new version of the website is launched	This source is not suitable for the DBL, since an API endpoint does not exist so far and even creating one, the payment of a fee and the privacy of data prevent the DB from being suitable for the DBL	Since the DBL needs disaggregated data, its public version is not suitable for the DBL currently	The architecture of this database is completely suitable for the DBL	The architecture of this database is completely suitable for the DBL
Query feature	–	–	*1	–	–	–	*2	*3

Table 6
Formation of the request query for the interoperable databases. Abbreviations: Catasto Energetico Edifici Regionale (CEER), Catasto Unico Regionale degli Impianti Termici (CURIT), Energy Performance Certificate (EPC).

		Search by Cadastral Reference	Search by Address
*1 Aragon EPC registry	Query form	https://opendata.aragon.es/GA_OD_Core/preview?resource_id=237&filters=%7b%22refcatastral%22:%22**A**/0%22%7d	https://opendata.aragon.es/GA_OD_Core/preview?resource_id=237&filters={%22munic%22:%20%22**B**%22,%22direccion%22:%22**C**%20**D**%20**E**%20Pl:%20**F**%20Pt:%20**G**%22}
	Parameters	A: 20 characters cadastral reference.	B: municipality, C: acronym of the street/square, etc., D: name of the street, E: police number, F: floor number, G: door.
	Example	https://opendata.aragon.es/GA_OD_Core/preview?resource_id=237&filters=%7b%22refcatastral%22:%223240201XM7134A0017PX/0%22%7d	https://opendata.aragon.es/GA_OD_Core/preview?resource_id=237&filters={%22munic%22:%20%22ZARAGOZA%22,%22direccion%22:%22CL%20BIARRITZ%202%20Pl:%2005%20Pt:%20D%22}
*2 CEER	Query form	https://www.dati.lombardia.it/resource/bbky-sde5.json?comune_catastale=**A**&sezione=**B**&foglio=**C**&particella=**D**&subalterno=**E**	https://www.dati.lombardia.it/resource/bbky-sde5.json?comune=**F**&indirizzo=**G**%20**H**%20**I**&piano=**J**
	Parameters	A: municipality, B: cadastral section, C: page number, D: parcel, E: subordinate.	F: municipality, G: street/square/road, etc., H: name of the street/square/road, etc., I: police number, J: floor number.
	Example	https://www.dati.lombardia.it/resource/bbky-sde5.json?comune_catastale=PAVIA&sezione=B&foglio=16&particella=622&subalterno=15	https://www.dati.lombardia.it/resource/bbky-sde5.json?comune=PAVIA&indirizzo=PIAZZA%20ADDOBBATI%209&piano=TERZO
*3 CURIT	Query form	https://www.dati.lombardia.it/resource/big4-6pbw.json?ubicazione_comune=**A**&catasto_foglio=**B**&catasto_particella=**C**&catasto_subalterno=**D**	https://www.dati.lombardia.it/resource/big4-6pbw.json?ubicazione_comune=**E**&ubicazione_toponimo=**F**&ubicazione_indirizzo=**G**&ubicazione_civico=**H**
	Parameters	A: municipality, B: page number, C: parcel, D: subordinate.	E: municipality, F: street/square/road, etc., G: name of the street/square/road, etc. H: police number.
	Example	https://www.dati.lombardia.it/resource/big4-6pbw.json?ubicazione_comune=Roverbella&catasto_foglio=22&catasto_particella=22&catasto_subalterno=302	https://www.dati.lombardia.it/resource/big4-6pbw.json?ubicazione_comune=Roverbella&ubicazione_toponimo=VIA&ubicazione_indirizzo=PO&ubicazione_civico=1

3.4.2. General guidelines for the implementation of the scheme at the European scale

The implementation of the DBL at a European scale is not a reality yet, to some extent due to the aspects mentioned in Section 1. In order to overcome some of the barriers that faces the DBL, some guidelines on data gathering and on data sources interoperability are proposed.

- Guidelines on data collection:
  - o Regarding the available information on buildings, **new data need to be collected.** To maximize the potential of the DBL to foster renovation and improve energy efficiency, it is necessary to gather data on the real performance of buildings (needs, consumption), interior conditions, users' behaviour, etc. as well as to include information on physical accessibility and conservation status, which can act as a lever to promote renovation. Additionally, a great lack of information on new technologies and facilities (SRI, EV charging points, etc.) was identified and needs to be solved in order to promote the digitalization and modernization of the building stock.
  - o Most of the collected data are not public or are not even hosted in databases. This fact prevents data from maximizing their usefulness. To overcome this barrier, open data should be encouraged, always respecting the General Data Protection Regulation (GDPR).
  - o The Thermal System Cadastre, currently running in Lombardy region, can be considered a **best practice** due to the information provided on buildings systems. Its implementation is highly recommended and replicable in other territories, since it makes it

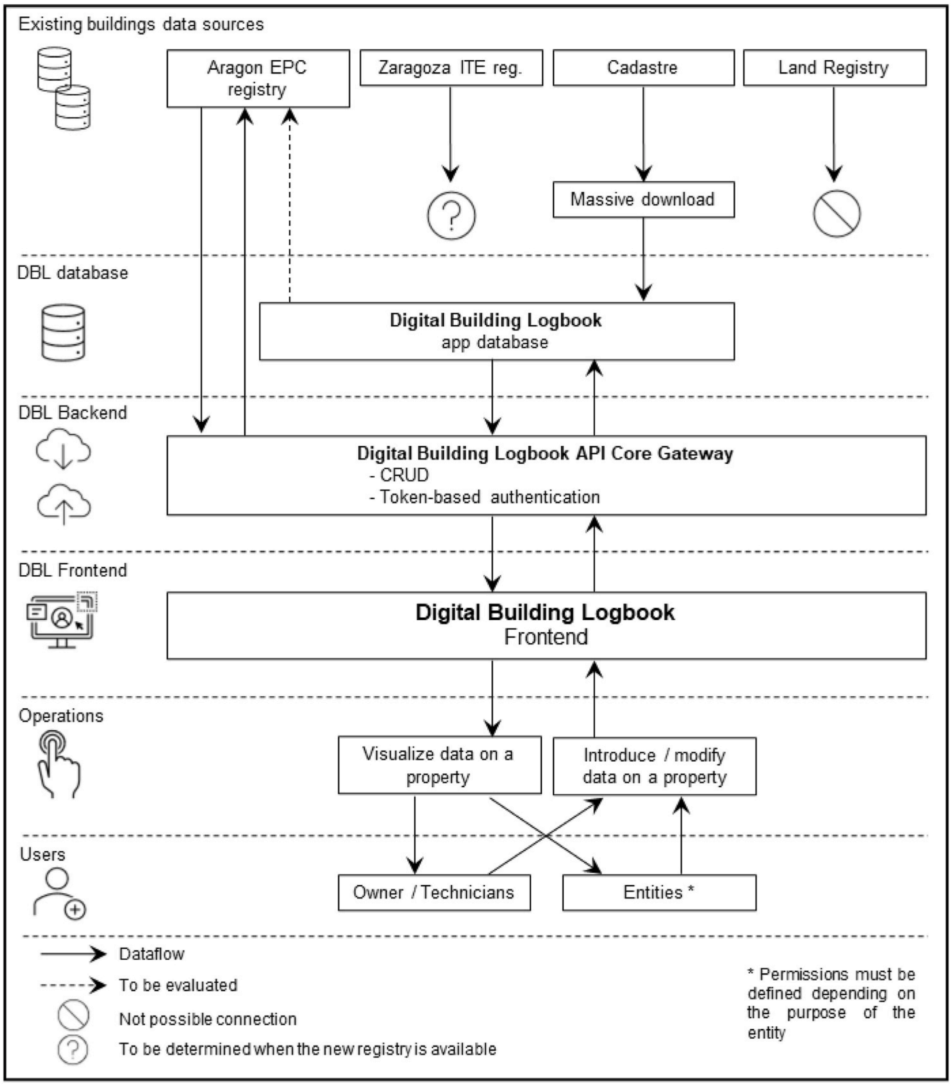

Fig. 5. Envisaged dataflow structure for the case of Zaragoza, including applicable regional (Aragonese) and national (Spanish) data sources. Abbreviations: Application Programming Interface (API), Create, Read, Update, Delete (CRUD), Digital Building Logbook (DBL), Energy Performance Certificate (EPC), Inspección Técnica de Edificaciones (ITE).

much easier to establish maintenance plans and to evaluate the improvement potential of the systems present in the building stock.

- o **The data** gathering **process needs to be homogenized and updated.** The lack of general guidelines and methodologies leads to the collection of poor-quality and heterogeneous data. As an example, in some sources data are collected at the building scale, while in others dwelling or building scale is used. Additionally, some sources present aggregated data, used for statistical purposes, but not suitable for the DBL. In the Spanish Cadastre even though the reference scales are the dwelling and the building, some buildings appear grouped –such as university campus and condominiums, and the information cannot be visualized by fraction. This fact opens the debate of what scale the DBL should have. In a country like Spain, the second in Europe with the highest number of multi-family buildings, only behind Latvia [57], this discussion is crucial.
- o Especially in countries configured as an aggregate of regions with different levels of self-governance and autonomy in decision-making, like Spain and Italy, the horizontal and vertical coordination of the administrations in charge for collecting data on buildings is crucial because lack of coordination can lead to the asymmetry of data. As an example, in Spain some Autonomous Communities carry out their own buildings Census, which are independent from the national one, conducted by the Instituto Nacional de Estadística (INE). This fact results in different update timings, as well as in different parameters collected, which makes it difficult to establish comparisons between the regions.

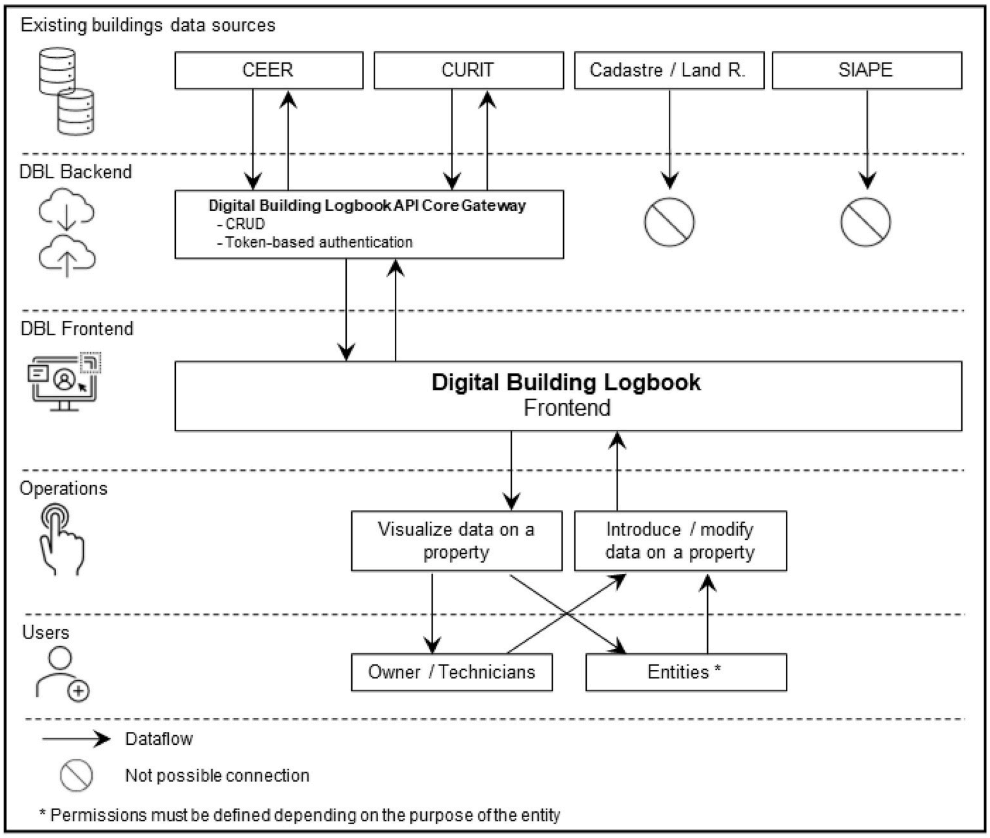

Fig. 6. Envisaged dataflow structure for the case of Lombardy Region, including applicable national (Italian) data sources. Abbreviations: Application Programming Interface (API), Catasto Energetico Edifici Regionale (CEER), Catasto Unico Regionale degli Impianti Termici (CURIT), Digital Building Logbook (DBL), Sistema Informativo sugli Attestati di Prestazione Energetica (SIAPE).

- Guidelines on data sources interoperability features:
  - o Most of the analysed data sources are not technically prepared for their incorporation into the DBL. It is highly recommended that all the sources can guarantee the access to their databases by providing **public APIs.** Additionally, it would be desirable **that the interchange formats are homogenized and modernized.** The problem arises when these alterations mean going against the data sources business model, as in the case of the Spanish Land Registry or the Italian Cadastre and Land Registry.
  - o **The standardization of the properties' identification parameters is needed.** When formulating a query feature to request any information from the data sources, if the search is conducted by cadastral reference, no problems were identified, however, in searches conducted by address, the heterogeneity in the structure of the address field (simple names/composed of several words/with order inversion, etc.) makes it difficult to formulate queries. Thus, homogenization is needed.
  - o The implementation of a **token-based authentication system is extremely recommended** in order to enable users to verify their identities in the platform and to be assigned the corresponding permissions: visualize, introduce or modify data.

4. Discussion and conclusions

Considering the definition of the Digital Building Logbook given by the proposal for the EPBD recast and the outputs from the literature, a first operation and dataflow scheme of the DBL was proposed. In order to apply this general framework to the specific case studies in Spain and Italy, a comparative analysis on the existing data sources on buildings in both countries was conducted. The research focused on two main parameters: the indicators collected and the interoperability possibilities of the data sources.

Through this research it was proved that, currently, some existing data sources on buildings in Spain and Italy are not properly structured for being incorporated into the DBL. Some of these data sources are national: Cadastre and Land Registry. Others are regionally managed, such as the Aragonese EPC registry, the CEER and the CURIT, or locally managed, such as the Zaragoza ITE registry.

On the one hand, most of the indicators proposed by the four existing initiatives for a European DBL –iBRoad, ALDREN and X-tendo H2020 projects and the ‘Study on the Development of a European Union Framework for Buildings’ Digital Logbook’– are non-available. Thus, in the Spanish case study, barely 40% of the identified data files are gathered, whereas in the Italian one, the percentage is only 35%. In addition, a significant amount of the available data is not open −64% in the Spanish case and 10% in the Italian one–, which prevents their efficient use.

On the other hand, the interoperability of the data sources is another central aspect. Through this study, we have found that crucial sources, such as the cadastres, are not interoperable, i.e., they are not prepared for connecting with external applications. Only the EPC registry from Aragon, as well as the CEER and the CURIT in Lombardy region count on a public API.

In conclusion, to efficiently incorporate the analysed data sources into the DBL, it is necessary to review the indicators that need to be collected, adapting them to the new needs and technological advances. That is, more information on the real status of the buildings, on their use stage and on their physical accessibility conditions must be collected, to set maintenance and renovation roadmaps, as well as to assess the progress of renovation. Additionally, it must be foreseen the generation, soon, of a large and heterogeneous amount of data coming from ICTs, which will increase the complexity of the panorama even more. Moreover, the promotion of interoperable and open data sources is encouraged to make the implementation of the European DBL feasible. Additionally, it is recommendable that data can be downloaded in a format that allows their treatment, for example, for statistical purposes.

This work presents the limitation that the study was conducted only in one region in Spain (Aragon) and another one in Italy (Lombardy region) and, since Spain and Italy are countries where there are significant differences between regions due to their administrative configuration, a detailed analysis in more regions is highly recommended to make a more rigorous extrapolation to the national panorama of both countries.

Future research will focus on the definition of an accurate set of indicators suitable for the future services of the DBL, i.e. the generation of a renovation and maintenance plan, the update of the EPC and the decarbonization progress assessment. Furthermore, the complete definition of the European DBL architecture will be addressed, considering this analysis on data sources as the starting point.

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Author contributions

Marta Gómez-Gil: Conceptualization, Methodology, Investigation, Data curation, Writing - Original Draft, Funding acquisition. **Marta Maria Sesana**: Methodology, Data curation, Writing - Original Draft, Writing - review & editing, Supervision. **Graziano Salvalai**: Conceptualization, Methodology, Investigation, Writing - review & editing. **Almudena Espinosa-Fernández**: Validation, Writing - review & editing, Visualization, Supervision. **Belinda López-Mesa**: Validation, Writing - review & editing, Visualization, Supervision, Project Administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data used is open and has been referenced

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APPENDIX A. Indicators from buildings existing data sources

In the following tables, a set of indicators is presented and clustered. The indicators considered relevant by $\geq$ 50% of the DBL proposals are highlighted grey and their sources are identified, whereas the indicators obtained from the existing data sources on buildings from the case study regions are not highlighted.

Open indicators are identified with an ‘O’, while not open indicators are represented with a ‘N’.

Note: SIAPE is not considered in the tables because only aggregated data are collected.

Table A1
Category 1: General and administrative information [58–61].

Category	Indicator	Spain					Italy	
		SP Cad.	Land Reg.	Ara EPC reg.	Zara ITE reg.	IT Cad.	CEER	CURIT
General and administrative information	Cadastral reference [58-61]	O	O	O	O	N	O	O
	Property ID (CRU/IDUFIR) [58-60]	N	O	-	-	-	-	-
	Owner type (public/private) [59-61]	N	O	-	O	N	-	-
	Owner identity	N	O	-	O	N	-	-
	Property/soil cadastral value	N	-	-	-	-	-	-
	Tenancy agreement [59,60]	-	-	-	-	-	-	-
	Insurance documents [59,60]	-	-	-	-	-	-	-
	Utilities contract [59,60]	-	-	-	-	-	-	-
	Location [58-61]	O	O	O	O	N	O	O
	Geo Coordinates [58,61]	O	-	O	-	-	-	-
	Climatic zone [58-61]	-	-	-	-	-	O	-
	Heating degree days [60,61]	-	-	-	-	-	-	-
	Property general description	-	O	-	-	-	-	-
	Soil/terrain (urban /rural) [59,60]	O	O	-	-	N	-	-
	Main use [59-61]	O	-	O	O	N	O	-
	Type of building (multifamily building, dwelling, commercial venue…) [59-61]	O	-	-	-	N	O	O
	Number of occupants [59,60]	-	-	-	-	-	-	-
	User profile/behavioral insights [58-60]	-	-	-	-	-	-	-
	Dwellings (number and area)	O	-	-	O	N	-	-
	Commercial venues (number and area)	-	-	-	O	-	-	-
	Parking lots (number and area)	-	-	-	O	-	-	-
	Building status (new/existent)	-	-	O	O	-	O	-
	Graphic area	O	-	-	O	N	-	-
	Built area (total and by dwelling) [59-61]	O	-	-	O	N	-	-
	Living area	O	O	O	O	N	-	-
	Heated/cooled floor area [59,60]	-	-	-	-	-	O	-
	Heated/cooled volume [60,61]	-	-	-	-	-	O	-
	Number of floors [59-61]	-	-	-	O	-	-	-
	Floors above ground	-	-	-	O	-	-	-
	Floors below ground	-	-	-	O	-	-	-
	Year of construction [59-61]	O	-	O	O	-	O	-
	Year of renovation and type (deep, superficial...)	O	-	-	O	-	-	-
	Streets width	O	-	-	-	-	-	-
	% common areas	O	O	-	-	-	-	-
	Crops	O	-	-	-	-	-	-
	Dwellings and common areas description	-	-	-	O	-	-	-
	Accessibility [59,60]	-	-	-	-	-	-	-
	Construction quality	O	-	-	-	-	-	-
	Charges	-	O	-	-	-	-	-
	Graphic information (site plan and pictures)	O	-	N	O	N	-	-
	Geometry (plans) [58-60]	-	-	-	-	N	-	-
	BIM, twins, etc. [59,60]	-	-	-	-	-	-	-
	Applicable legislation (NBE, CTE…)	-	-	N	-	-	-	-
	Urban licenses [58-60]	-	-	-	-	-	-	-
	Protection of the building / surroundings: Zone	-	-	O	-		-	-
	Protection of the building / surroundings: Grade	-	-	O	-		-	-
	Protection of the building / surroundings: Subgrade	-	-	O	-		-	-

The indicators considered relevant by ≥50% of the DBL proposals are highlighted grey.

Table A2
Category 2: Construction information and materials.

Category			Indicator	Spain				Italy		
				SP Cad.	Land Reg.	Ara EPC reg.	Zara. ITE reg.	IT Cad.	CEER	CURIT
Construction information and materials	Structure	Foundations	Type	-	-	-	O	-	-	-
			Material	-	-	-	O	-	-	-
		Vertical structure	Type	-	-	-	O	-	-	-
			Material	-	-	-	O	-	-	-
		Horizontal structure	Type	-	-	-	O	-	-	-
			Material	-	-	-	O	-	-	-
		Stairs	Type	-	-	-	O	-	-	-
			Material	-	-	-	O	-	-	-
	Façades	Description	Type	-	-	N	O	-	-	-
			Composition [58-61]	-	-	N	O	-	-	-
			Orientation	-	-	N	-	-	-	-
			Surface	-	-	N	-	-	-	-
			U-value [59-61]	-	-	N	-	-	-	-
		Elements (description)	Cantilevers	-	-	-	O	-	-	-
			Cornice	-	-	-	O	-	-	-
			Gutter	-	-	-	O	-	-	-
			Handles	-	-	-	O	-	-	-
	Roofs	Description	Type	-	-	N	O	-	-	-
			Composition	-	-	N	O	-	-	-
			Surface	-	-	N	-	-	-	-
			U-value [59-61]	-	-	N	-	-	-	-
	Floors	Description	Type	-	-	N	-	-	-	-
			Composition	-	-	N	-	-	-	-
			Surface	-	-	N	-	-	-	-
			U-value [58-61]	-	-	N	-	-	-	-
	Windows	Description	Orientation	-	-	N	-	-	-	-
			Dimensions	-	-	N	-	-	-	-
			Shutter box [60,61]	-	-	-	-	-	-	-
		Solar protections	Type [60,61]	-	-	N	-	-	-	-
		Frame	Material	-	-	N	-	-	-	-
			Frame %	-	-	N	-	-	-	-
			U-value [59-61]	-	-	N	-	-	-	-
			Surface	-	-	N	-	-	-	-
		Glazing	Type	-	-	N	-	-	-	-
			Thickness	-	-	N	-	-	-	-
			Solar factor	-	-	N	-	-	-	-
			U-value [59-61]	-	-	N	-	-	-	-
			Surface	-	-	N	-	-	-	-
	Doors		Description [58,59]	-	-	-	-		-	-

Building envelope surface			-	-	-	-	-	O	-
Form factor			-	-	-	-	-	O	-
Yie-value			-	-	-	-	-	O	-
Equivalent solar area/useful area			-	-	-	-	-	O	-
Thermal bridges		Description [58,60]	-	-	N	-	-	-	-
Other elements	Canopies	Description	-	-	-	O	-	-	-
	Antennas	Description	-	-	-	O	-	-	-
	Poles	Description	-	-	-	O	-	-	-
	Chimneys	Description	-	-	-	O	-	-	-
	Machines	Description	-	-	-	O	-	-	-
	Lettering	Description	-	-	-	O	-	-	-
	Awnings	Description	-	-	-	O	-	-	-
Material inventory	Material X	Type [59,60]	-	-	-	-	-	-	-
		Location [59,60]	-	-	-	-	-	-	-
		Volume [59,60]	-	-	-	-	-	-	-
		Weight [59,60]	-	-	-	-	-	-	-
		Embodied carbon [59,60]	-	-	-	-	-	-	-
		Life span [59,60]	-	-	-	-	-	-	-
		Fire resistance class [59,60]	-	-	-	-	-	-	-
		Waste category [59,60]	-	-	-	-	-	-	-
		Certificate [59,60]	-	-	-	-	-	-	-
		Chemical declaration [59,60]	-	-	-	-	-	-	-
		Global Trade Item Number [59,60]	-	-	-	-	-	-	-

The indicators considered relevant by ≥50% of the DBL proposals are highlighted grey.

Table A3
Category 3: Technical systems and Smart Readiness.

Category		Indicator	Spain				Italy		
			SP. Cad.	Land Reg.	Ara. EPC reg.	Zara. ITE reg.	IT Cad.	CEER	CURIT
Technical systems and Smart Readiness	Sewer system	Type	-	-	-	O	-	-	-
	Water supply	Type	-	-	-	O	-	-	-
	DHW system	Y/N	-	-	-	-	-	O	-
		Brand	-	-	-	-	-	-	O
		Description [58-61]	-	-	N	-	-	O	O
		Year of installation	-	-	-	-	-	O	O
		Power	-	-	N	-	-	O	O
		Energetic vector [58,60]	-	-	N	-	-	O	O
		Efficiency	-	-	N	-	-	O	-
	Heating system	Y/N	-	-	-	-	-	O	-
		Brand	-	-	-	-	-	-	O
		Description [58-61]	-	-	N	-	-	O	O
		Year of installation [60,61]	-	-	-	-	-	O	O
		Energetic vector [58,60]	-	-	N	-	-	O	O
		Power	-	-	N	-	-	O	O
		Emissive elements	-	-	-	-	-	-	O
		Efficiency [58,60,61]	-	-	N	-	-	O	-
	Cooling system	Y/N	-	-	-	-	-	O	-
		Brand	-	-	-	-	-	-	O
		Description [58,59,61]	-	-	N	-	-	O	O
		Year of installation	-	-	-	-	-	O	O
		Power	-	-	N	-	-	O	O
		Energetic vector [58,60]	-	-	N	-	-	O	O
		Efficiency [58,60,61]	-	-	N	-	-	O	-
	Mechanical ventilation	Y/N	-	-	-	-	-	O	-
		Description [58-61]	-	-	-	-	-	O	-
		Year of installation	-	-	-	-	-	O	-
		Power	-	-	-	-	-	O	-
		Efficiency [58,60,61]	-	-	-	-	-	O	-
	Lighting	Y/N	-	-	-	-	-	O	-
		Description [58-61]	-	-	-	-	-	O	-
		Power	-	-	-	-	-	O	-
		Efficiency	-	-	-	-	-	O	-
	Transport (Y/N)		-	-	-	-	-	-	-
	Gas supply	Description	-	-	N	-	-	O	-
	Renewable energy production [58,59,61]		-	-	N	-	-	O	-
	District heating access [59,60]		-	-	-	-	-	-	-
	Storage of locally generated energy [60,61]		-	-	-	-	-	-	-
	Control system for heating and cooling [60,61]		-	-	-	-	-	-	-
	Emission control for TABS [60,61]		-	-	-	-	-	-	-
	EV Charging points features [58-61]		-	-	-	-	-	-	-
	Smart Readiness Indicator (SRI) [58-60]		-	-	-	-	-	-	-
	Smart district indicators [58-60]		-	-	-	-	-	-	-
	Climate resilience potential [59,60]		-	-	-	-	-	-	-
	Demand response potential [59,60]		-	-	-	-	-	-	-

The indicators considered relevant by ≥50% of the DBL proposals are highlighted grey.

Table A4
Category 4: Energy efficiency, operation and use.

Category	Indicator	Spain				Italy		
		SP Cad.	Land Reg.	Ara. EPC reg.	Zara. ITE reg.	IT Cad.	CEER	CURIT
Energy efficiency, operation and use	EPC number	-	-	O	-	-	O	-
	EPC expedition date	-	-	O	-	-	O	-
	EPC validity	-	-	O	-	-	O	-
	Energy label [58-60]	-	-	-	-	-	O	-
	CO2 emissions	-	-	O	-	-	O	-
	Emissions label	-	-	O	-	-	-	-
	Total energy demand	-	-	-	-	-	O	-
	Energy demand by use [58,60]	-	-	N	-	-	-	-
	Energy consumption	-	-	O	-	-	O	-
	Energy consumption by use [58-60]	-	-	N	-	-	O	-
	Energy consumption by energy vector	-	-	-	-	-	O	-
	Not renewable energy consumption	-	-	N	-	-	O	-
	Energy consumption label	-	-	O	-	-	O	-
	Useful thermal performance index for heating	-	-	-	-	-	O	-
	Comparison with similar buildings	-	-	-	-	-	O	-
	Solar potential [59,60]	-	-	-	-	-	-	-
	Exported energy	-	-	-	-	-	O	-
	nZEB (Y/N)	-	-	-	-	-	O	-
	Conservation and maintenance plan [58-60]	-	-	-	-	-	-	-
	Maintenance and service contracts [58-60]	-	-	-	-	-	-	-
	Safety manual [59,60]	-	-	-	-	-	-	-
	Tailored renovation recommendations [58-60]	-	-	N	-	-	O	-

The indicators considered relevant by ≥50% of the DBL proposals are highlighted grey.

Table A5
Category 5: Financial information.

Category	Indicator	Spain				Italy		
		SP. Cad.	Land Reg.	Ara. EPC reg.	Zara. ITE reg.	IT Cad.	CEER	CURIT
Financial information	Annual property tax [59,60]	-	-	-	-	N	-	-
	Property value [58-60]	N	-	-	-	-	-	-
	Valuation information [59,60]	-	-	-	-	-	-	-
	Property yield [59,60]	-	-	-	-	-	-	-
	Annual maintenance costs [59,60]	-	-	-	-	-	-	-
	Annual electricity cost [59,60]	-	-	-	-	-	-	-
	Annual water cost [59,60]	-	-	-	-	-	-	-

The indicators considered relevant by ≥50% of the DBL proposals are highlighted grey.

Table A6
Category 6: Conservation status and pathologie

			Spain				Italy		
Category	**Indicator**		**SP. Cad.**	**Land Reg.**	**Ara. EPC reg.**	**Zara. ITE reg.**	**IT Cad.**	**CEER**	**Cat. Imp.**
Conservation status and pathologies	Status		-	-	-	O	-	-	-
	Expected lifetime [59,60]		-	-	-	-	-	-	-
	Date of last inspection		-	-	-	O	-	-	-
	Date of next inspection		-	-	-	O	-	-	-
	Approval report		-	-	-	O	-	-	-
	Technical report		-	-	-	O	-	-	-
	Cracks and detachments	Description	-	-	-	O	-	-	-
	Humidity	Description	-	-	-	O	-	-	-
	Movements and deformations	Description	-	-	-	O	-	-	-
	Degradation and deficiencies	Description	-	-	-	O	-	-	-

The indicators considered relevant by ≥50% of the DBL proposals are highlighted grey.

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