

Article

Data Discovery for Digital Building Logbook (DBL): Directly Implementing and Enabling a Smarter Urban Built Environment

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Abstract: Digital Building Logbooks (DBLs) are the EU repositories for all building-related data. Logbook implementation conveys challenges, but it must be recognised that relevant things already exist. This article bridges the gap at the data discovery level by assessing the existing data and comparing it with EU DBL studies. Action research is the methodology, employing Portugal as an example. A deductive approach and interpretivism are used, supporting the data discovery journey. When evaluating existing datasets with DBL EU guidelines data requirements, the findings demonstrate a match from 90.6% to 82.6%, depending on the level: cadastral parcel, building or building unit. Several additional observed datasets suit the DBL framework, constituting a path for future research. Insights into the dataset landscape from a specific perspective are offered. Given the deliverables' characteristics, the study results can be generalised. The data discovery journey led to the understanding that duplicates and inconsistencies exist. A strategic approach for data sharing, governance and usage should be established to solve them, increasing digital maturity, integration and interoperability. Revising the legal framework is found to be paramount. Working from the existing elements and aligning them with data space assumptions can make DBL implementation more straightforward.

Keywords: buildings; cadastral parcels; statistical data; twin transition; Green Deal; data spaces; data governance; urban environment; construction process



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1. Introduction

Building data are paramount for different purposes [1]. In all countries, documentation captures relevant building-related aspects for one or more defined objectives, such as the energy performance, parcel property, financial value, statistics or technical characteristics, to name a few [2]. However, recent studies have identified that this documentation is still mostly paper-based or, when digital, it is stored in databases owned and managed by specific authorities, with limited accessibility in terms of data sharing and integration [3,4]. In addition, it is recognised that datasets are often incompatible with each other, and when compatible, different descriptions are used [5].

This way of working is no longer consistent with the objectives set by the European Union (EU) for urban planning, sustainable cities and trends for energy efficiency and a circular economy [6,7]. Some concerns are not new, and efforts have been made to tackle difficulties and implement improved processes. It is worth highlighting activities such as the INSPIRE Directive, which, since 2007, is aiming to coordinate the organisation, quality, availability, accessibility and sharing of spatial information [8], or the developments made since 2002, leading to the present version of the EU Energy Performance Certificate (EPC) for buildings [9]. A point in time is being reached where it is possible to aspire to twin several concerns and forecast how it is possible to build a data structure that is building oriented, where several datasets are capable of being organised and clustered to deliver improved

outcomes for different purposes, enabling a more sustainable built environment [10]. The Digital Building Logbook (DBL) aims to cover all these requirements [11].

This paper builds on the existing research and a proposal for an EU DBL framework, using deduction and action research to demonstrate this opportunity and evaluate the knowledge and implementation gaps in the data, processes and legal framework. Portugal is used as an example. The objective is to provide interpretations and evidence that substantial work has already been conducted and communicate its helpfulness in making the implementation more straightforward. At the same time, it provides insights into the changes that must occur to better suit the adoption requirements set for DBLs. Considering this motivation and objectives, the research provides answers to the following questions:

- How can DBL implementation in Portugal be streamlined?
- What existing processes, tools and databases are relevant to the DBL?
- To what extent do they answer to the EU DBL framework requirements?

The DBL concept was first introduced with the European Renovation Wave strategy [12]. It was considered one of the two fundamental parts of the Building Renovation Passport (BRP), together with the renovation roadmap [13]. The strategy was established to promote and accelerate EU-built stock refurbishment, raising the bar of its performance in terms of energy efficiency, life cycle costs, sustainability and carbon emissions [12]. The link to the EPC is prominent and established from the beginning. Ongoing projects working in EPC digitalisation were evaluated to see to which extent they could provide a starting point for the DBL [13].

Despite the essential purpose and relevance of the EPC, the logbook is meant to capture a broader range of data [14]. From the initial studies promoted by the EU on the framework came the definition of DBL as a common repository for all relevant building data, facilitating information sharing within the construction sector. The DBL is assumed to be a dynamic tool that allows a variety of data, information and documents to be recorded, accessed, enriched and organised under specific categories. It represents a record of major events and changes over a building's life cycle, such as change of ownership, tenure or use, maintenance, refurbishment and other interventions [3]. Following this study publication, Mêda (2022) proposed a process-based framework for the DBL, evidencing the moment it is deployed and the interactions through the construction life cycle [15]. At the same time, Gómez-Gil (2022) identified new digital technologies contributing to the DBL, from 3D scanning to BIM and the IoT, as well as the relations with relevant EU sustainability policy tools, such as the Smart Readiness Indicator or Level(s) [16]. The findings point to the DBL as an enabler for the Digital Twin (DTw) at a building scale [16,17].

The paper has the following structure: Section 1 provides a brief context regarding the Digital Building Logbook, its positioning and the associated meaningful elements used to describe the motivation and problems observed. The research questions and a summary of the methods are introduced. Section 2 presents the materials and methods used, outlining the reasons for choosing the action research methodology, a deductive approach and interpretivism and how these are implemented in the research context. Section 3 presents the essential elements framing the research at the EU level, namely the most recent outcomes in terms of guidelines for a common DBL framework and how this should be understood and positioned considering the common European data spaces strategy. These elements constitute a fundamental background for the DBL policy. The design and development compose Section 4, where the results from a previous EU study on DBLs across member states are presented and where relevant existing deliverables/elements in Portugal not captured by that study are contextualised. The section concludes with a framework of the existing elements and databases evidencing the communication gaps and setting the ground for detailed demonstration at the data level in the following section. The section Demonstration explains and provides visualisations of the data landscape and meaningful datasets for the DBL deriving from the existing elements and databases using knowledge graphs. Section 6 evaluates and discusses all aspects presented by setting the links between DBL data requirements, as the EU framework, and the existing datasets in Portuguese

databases and deliverables. This part also discusses the constraints of technology and the legal framework. Finally, Section 7 presents the main conclusions aligned with the research goals and views for possible future research.

DG-Grow produced the most recent DBL study, consisting of a handbook to guide EU member states in setting up and operationalising DBLs under a common framework [18]. The document states its ultimate goal is to accomplish a seamlessly built environment for data exchange across Europe. The framework consists of a semantic data model, data management plan and data dictionary for European DBLs [18]. According to Papadaki (2023), the future of construction is about setting new actions and commitments and aligning efforts to identify and close critical gaps [10]. This research pursues this vision by exploring the existing developments to demonstrate and evaluate their potential in bridging gaps and streamlining DBL implementation.

2. Materials and Methods

This research aims to effect changes in how DBL is perceived by the research community and construction value chain stakeholders, namely on the understanding that relevant data for its materialisation are already available. In parallel, it aims to provide evidence of the bottlenecks that must be solved at the data, process and legal framework levels. In essence, it follows Lewin's exemplification when stating that action research promotes the discussion of problems followed by decisions on how to proceed [19]. The research strategy framework defined by Nogeste (2015) is used to assist the method's design [20], where action research is the methodology, adopting the interpretivism paradigm [21] and the deductive approach [22].

Due to the study characteristics, the paradigm followed is interpretivism, as it relies on the assertion that a phenomenon is observed; in this case, different existing deliverables are found to be relevant for the EU DBL framework and interpreted by the authors according to their axiological positions. Kifokeris (2021) and Parameswaran (2024) are examples of works where interpretivism has been used in the construction industry [23,24]. Knowledge is understood as the personal experience formed and where it is likely that different interpretations might arise from different individuals when observing the same phenomenon [25]. Another aspect supporting the paradigm is the awareness of the knowledge and how it is employed, with continuous explanations and discussions throughout the sections composing the present article [25].

According to Tong and Thomson (2017), the deductive approach consists of six steps: theory, hypothesis, data collection, findings, hypothesis testing and revise theory [26]. For the present case, the theory corresponds to the notion that DBL implementation can be streamlined by working on existing deliverables. The EU DBL framework summarised by the defined levels, layers and datasets builds the hypothesis. The Data collection step identifies and exposes the existing and meaningful elements, highlighting their purposes for the construction value chain in today's processes. The findings and hypothesis testing derive from demonstrating the dataset landscape and how they match the framework assumed in the hypothesis. Revise theory stems from the evaluation of introducing in-depth knowledge and expanding on the details of the observed situation, setting aspects to be further explored/discussed. The systems model of action research addressed by Christie (1992) is used, embedding the deductive approach presented in Figure 1.

Data collection was performed using desk research [27] and document reviews [24], capturing the relevant elements for the background and Design and Development sections. EU studies on DBLs and the identified Portuguese legal framework and guidelines on relevant DBL datasets composed the sample. Knowledge graphs are increasingly being utilised in the built environment domain, given their capacity to provide relatively easy and visually structured content [28,29]. Relevant datasets from the deliverables can be easily presented through knowledge graphs, setting the needed ground for the analysis and future research focused on deeply exploring dataset harmonisation and relationships/links.

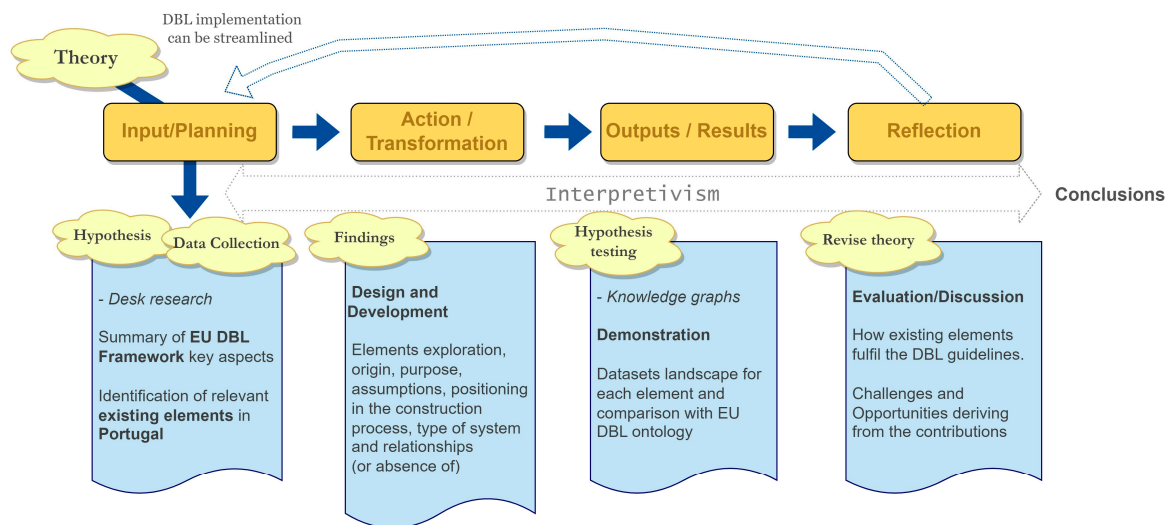


Figure 1. Research design systematisation, embedding the deductive approach in the action research cycle and endorsing the section's titles.

3. Common European Data Spaces and EU DBL Framework (2023)

3.1. Common European Data Spaces

The common European Data Spaces derive from the European strategy for data published in February 2020 [30] to speed up economic development and harness the value of data for the benefit of society in strategic sectors and domains of public interest [31].

In the documents, it is recognised that these spaces should achieve the following [30]:

- include the deployment of data-sharing tools and services;
- include data governance structures compatible with relevant EU legislation that provide transparent and fair ways, the rights of access to and ability to process data;
- improve data availability, quality and interoperability in domain-specific areas and across sectors.

Without neglecting the two initial aspects, this last one, mainly regarding the visions across sectors, is very relevant considering this research goal. In addition, the following aspects from the 2022 staff working document are particularly relevant considering this research's initial assumptions: to avoid fragmentation, high integration costs and the creation of silos, the data spaces must build upon international standards. Two examples are INSPIRE (for spatial data) and FAIR principles, which favour the interoperability and exploitation of data on EU computing infrastructures (e.g., cloud and HPC). The objective relies on becoming more interconnected and progressively being made interoperable, leading to a genuine European data space [31].

The quick changes and progress in computing, connectivity, the Internet of Things (IoT), artificial intelligence (AI) and cybersecurity, among others, led to the update of the staff document in 2024. A densification of criteria and more detailed strategic thinking are presented in this update, and it is worth noting that the number of data spaces has expanded from ten to fourteen [32]. Before detailing how the construction sector frames the strategy, it is relevant to mention that multi-country projects in data infrastructures and services are encouraged. In this respect, it sounds very aligned with the existing systems for construction statistics and to what extent these could be improved to bring added value not just for the statistical indicators but mainly to become more integrated in the construction process value chain. Another topic deserving to be highlighted is the 2024 rolling plan for ICT standardisation, where four processes are considered the key focus areas for this type of initiative. These are data governance, data discovery, data sharing and data usage [32]. The present work focuses mainly on data discovery and usage to provide insights on sharing and governance-level improvements.

Regarding construction, it is key to note that the strategy does not provide a specific data space for now. To some extent, construction and the urban environment are partially covered by cultural heritage, energy, public administration and Green Deal data spaces. Regarding the last one, the references to the INSPIRE Directive and the Digital Product Passport (DPP) are relevant, especially considering the role of DPPs as DBL enablers [33–35]. In addition, the 2024 staff document also states that recent evolutions in building- and construction-related data, such as DBLs and the digitalisation of building permit processes, will be duly considered [32]. Eventually, a construction data space might be considered, or others will be strengthened to integrate all meaningful aspects and define the necessary boundaries. In one way or another, the outcomes from the present research are expected to be relevant for informed decisions.

3.2. Technical Guidelines for Digital Building Logbooks

Following the initial DBL studies, the European Commission launched an initiative intending to produce principles and guidelines that the member states could adopt to set up and operationalise DBLs under a common framework. The technical guidelines for DBLs were published in November 2010 after an eighteen-month process involving a team of researchers and the participation of numerous multi-country industry stakeholders [18]. The long and dense document provides detailed elements for practical, technical and economic implementation. Despite the relevance of exploring it in detail, for the present research, it is fundamental to systematise some aspects that will be used later for comparison as part of the case demonstration and evaluation. It is worth mentioning the assumption that the DBL should not replicate what is already there but rather connect and integrate existing data sources. Some listed sources are Geographic Information Systems (GISs), DPP, Building Information Modelling (BIM), Building Renovation Passport and Material Passport (MP), with the last two being mainly for renovation processes. This is compatible with the common data space principles and aligned with the data perspective assumed for this research.

The first aspect deserving to be presented in detail is the idea of the logbook as a multi-level information layer with the ability to compile, cluster, manage and govern the information related to the soil where the building is built (cadastral parcel), the built entity itself (building) and the different units into which the building can be divided, for example, apartments (building unit). This vision aligns with the existing practices, previous research and INSPIRE assumptions, to name a few. Figure 2 was developed using the different DBL levels from the guidelines as a reference.

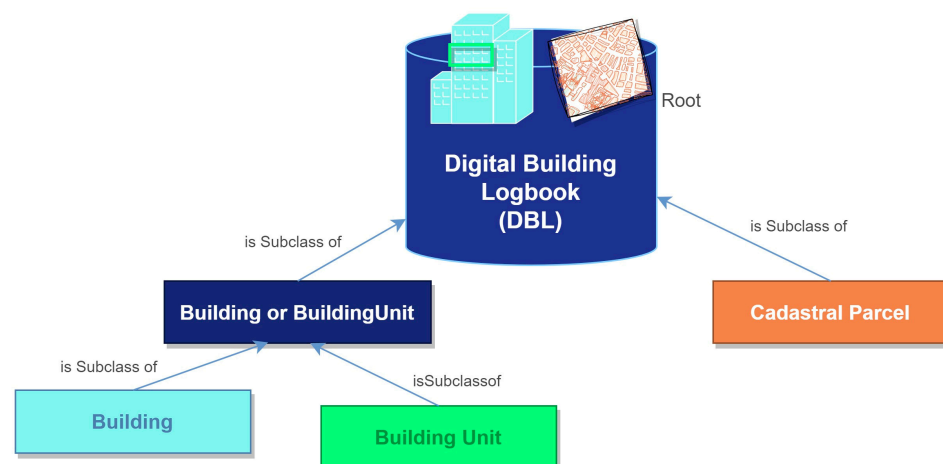


Figure 2. DBL levels, cadastral parcel, building and building unit, based on work from DG-Grow [18].

The report provides a set of meaningful properties/datasets for each level that should be fulfilled. Later, these will be detailed as part of the comparison in the section Demonstration, where figures with the datasets and the link with relevant existing elements are presented. Regarding the main components and DBL framework administration, the common repository is organised according to seven information layers, as presented in Figure 3. Although this organisation might raise discussions, what is relevant to consider is that this can be a default vision for the DBL, where others, more detailed or focused on different aspects, can be set. Considering the framework defined for the Level of Information Need (LOIN) standard, if multiple purposes are attached to a property/dataset, then it would be easy to define and set other layer-based organisations [36,37].

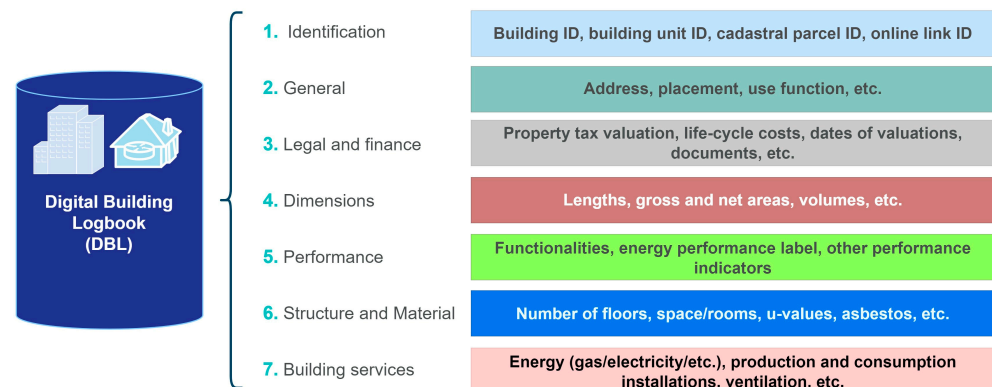


Figure 3. Main components/layers of the proposed DBL framework [18].

Despite the evolutions and continuous discussion around DBL, it should be recognised that these technical guidelines constitute a relevant basis on which all developments should be conducted, even if it means questioning some of the assumptions made.

4. Design and Development

This section explores and reviews a group of existing documents/deliverables in the Portuguese construction landscape that are considered relevant for the research. In this sense, the initial study, previous to the one presented in Section 3.2, constitutes the starting point here because one deliverable from Portugal was explored. This is now better contextualised regarding the information requirements and understanding of the surrounding legal framework. This follows the presentation and contextualisation of other elements, introducing the knowledge to demonstrate and analyse their datasets (Section 5).

4.1. Final Report of the Study on the Development of the EU Framework for DBLs (2021)

The study published in 2021 surveyed and analysed forty building logbook initiatives from different countries, EU and non-EU, to highlight key success factors and barriers [3]. Regarding Portugal, the “Livro de Obra” or construction workbook (LO/construction book) was identified as a potential logbook.

The LO/construction book is set in the legal framework for urbanisation and building construction (RJUE) [38] and is detailed by technical provisions [39] that have recently been updated [40] and are systematised in Table 1. The LO/construction book was set up to control the execution of licensed or authorised construction works, where the technician in charge must record all the relevant facts during the construction process. It is to be kept and maintained on-site for consultation by the authorities responsible for work supervision. In 2008, the technical provisions opened the way for adopting an electronic format. Despite the efforts to provide some guidance on the contents to be recorded, in practice, it is observed that the authorities and technicians in charge use different approaches to comply with the requirements. Most elements are paper-based or based on meeting minutes made using writing software. The adoption of an electronic LO/construction book is residual. When

that happens, it assumes the format of folders with PDF files stored in a standalone or cloud environment [41].

Table 1. Technical provisions/contents and LO/construction book organisation, as defined in the Portuguese legal framework.

Part I—Opening Term		Registry of the Construction Start: Site Opening, Date and Involved Stakeholders
Part II—Record of Facts and Observations Related to the Execution of the Construction Works		
Date	Stakeholders/ Roles	Observations
		Relevant dates: start, end and suspensions Measures applied to the contractor Changes to the design and approvals License for construction activity of all entities involved in the construction Accidents and other events, with impacts on the construction Deconstruction, alteration or other actions needed to comply with the design Technical assistance requests: third parties Non-compliance situations and instructions to solve them Tests or trials made on-site regarding materials or equipment
Part III—Record of the main characteristics of the building and the construction solutions impacting the quality and functionality		
Chapter 1: Building identification, structure and roof		Building ID in terms of location Characterisation of the type of foundations and description of the adopted solutions Characterisation of the building structure and description of construction methods and adopted solutions Characterisation of the type of roof (terrace, sloped roof or other), adopted solutions and rainwater drainage system technical solutions and products
Chapter 2: Façade and partition walls and floor finishes		Characterisation of the façade walls and description of construction methods and adopted solutions, including product characteristics and manufacturer identification Orientation of the façades Characterisation of the partition walls and description of construction methods and adopted solutions Characterisation of the floor finishes and description of the construction methods and adopted solutions
Chapter 3: Construction products used and manufacturers'		Identification of the construction products/materials used and their essential characteristics, namely those set by the CE mark, locations, replacement or repair needs and expected life
Chapter 4: Installed equipment and reduced mobility accessibility		Identification of all equipment installed in the building, such as lifts, escalators, heating, ventilation or HVAC, gas extraction systems and fire safety and their manufacturers and essential characteristics Identification and description of the access conditions for people with reduced mobility (stairs, ramps, heights and hall width) and the equipment specifically designed for their use, manufacturers and essential characteristics
Chapter 5: Doors, windows and openings protection systems and manufacturers' identification		Characterisation of access doors and garage doors, location, materials and main product characteristics External windows characterisation, type, materials, type of glazing, special characteristics and opening systems Entities responsible for inspection and maintenance
Part IV: Closing term		Registry of the provisional handover: end of construction, with data and inspection report signed by involved stakeholders

Although the range and meaningfulness of the LO/construction book for Portuguese construction can be recognised, in practice, it is observed that several gaps and overlaps remain, resulting in inconsistencies, the duplication of effort and, more importantly, data gaps and data loss. Other studies on the construction work phase in Portugal, focusing on the EU legal framework requirements for health and safety in construction sites, have evidenced a similar situation [42].

While it can be understood, from the contents presented in Table 1, why the LO/construction book was chosen for the DBL study, it can be recognised that it is not data driven. In addition, its practical implementation has suffered from uncertainty regarding support and the absence of supervision. However, there are other elements that, although with a scarce range, we interpret as providing better inputs for the DBL according to the EU framework and, from there, support changes that can make the LO/construction book a better instrument for the intended purposes.

4.2. Existing Deliverables in Portugal Relevant to the EU DBL Framework

From the idea of building something to the handover of the built object, several phases and processes exist that rely on producing critical deliverables for different purposes ranging from performance requirements to budget estimates, programming and control of construction works, compliance checks or safety and health reports. Considering the framework detailed in Section 3.2 and understanding the data requirements for the mentioned elements/deliverables, finding overlaps or, at minimum, similarities is possible. The EPC, as detailed in the Introduction, evidences clear overlaps. Although this will be later explored, it should be noted that the EPC is an outcome with a set of properties/datasets that will only come later in the construction process value chain. Without disregarding its importance, it is relevant to note that its materialisation implies that information and datasets from deliverables are produced earlier, namely at the beginning of the construction process. Assuming the DBL main components [18] and the process-based framework [15], its root corresponds to the cadastral parcel, meaning the deployment should occur once building an object is a go, and there is a terrain for it. Land property registry and tax information associated with the property/parcel constitute the initial datasets that need to be captured by the DBL.

During the design phases, several actions must be performed to detail the design of the object to be built and assess its compatibility/compliance with municipality plans and regulations. Permitting is the concept surrounding a set of processes that must be performed before and during construction, depending on the country's procedures [43]. Despite some doubts, even among communities of experts, there is a strong bond between DBLs and digital building permits (DBP) [44]. One of the most frequent permitting processes occurs during early design to perform regulation compliance checks, often described as licensing [45]. Together with a set of deliverables for the licensing process, a group of datasets must be fulfilled and submitted as part of the Portuguese Urban Planning Operations Indicator System (SIOU) governed by the Statistics Office (INE) [46]. Considering the scope, the principles expressed in Section 3 and the type of datasets collected, this process became one of the most interesting to explore and interpret. Before the handover, two main deliverables need to be produced. These are the EPC under a predefined model established by the Portuguese framework [47], translating to the national domain the prescriptions from the EU Energy Performance of Buildings Directive (EPBD) [48] and the technical housing datasheet (FTH). The FTH was established under the Portuguese legal framework defining the requirements for advertising information for purchasing residential properties [49].

Although it can be recognised that other elements/deliverables exist comprising other datasets, such as construction and usability licenses, construction site opening, reports for public procurement and health and safety in construction sites, for this study, it is found that their datasets and alignment will benefit from the clarification of the ones now explored, especially from the SIOU. Previous research already focused on the topic concerning public procurement for public works and health and safety aspects [42].

4.2.1. Matrix Certificate (CPU) and Property Registry (RP)

The matrix certificate or *Caderneta Predial Urbana* (CPU) and the property registry or *Certidão do Registo Predial* (RP) apply to cadastral parcels, buildings and building units and have different purposes. The first is defined for tax purposes [50]. The other is meant to prove the ownership of land parcels and built entities [51]. Although related, historically, they have been governed by two different public authorities, the *Autoridade Tributária e Aduaneira* (AT) for the matrix certificate under the Property Tax Code and the *Instituto dos Registos e do Notariado* (IRN) for the land property registry, under the Land Registry Code [51]. This has led to dataset misalignment, as some differences are common among them. In this respect, it is relevant to briefly contextualise the two initiatives taking place and involving these elements. The first is the *Balcão Único do Prédio* (BUPi), a simplified cadastral information system mainly devoted to implementing the cadastre of rural areas in Portugal. Launched in 2017, it gathered property registries, matrix certificates and geo-referenced information in a single online platform that liaises citizens with the public administration [51]. The BUPi has gone through tests and pilots, which have led to a general implementation in rural areas. Updates have been made to expand and improve the data governance (integration) and sharing. Through BUPi, initial steps were made to bring together IRN and AT databases and deliverables, improving data consistency and governance [51]. Although this is only meant for rural parcels, the process can evolve similarly for urban areas and building-related data.

In parallel and in articulation with BUPi developments, the National Cadastral Information System (SNIC) was established in 2023 as one of the updates to the cadastre's legal framework [52]. Governed by the Land General Directorate (DGT), the SNIC aims to integrate all the information relating to the land registries, including information on the administrative and geographical locations, geometric configuration and area of the cadastral parcels, ownership information from INR via interoperability protocols with BUPi and attributes and tax value from AT using interoperability through BUPi [52]. From this, it is possible to observe that relevant actions are being taken to strengthen the consistency and interoperability between the RP and the CPU registries and deliverables. In addition, SNIC development must be performed in articulation with INSPIRE Directive guidelines, which will strengthen another level of interoperability and assumptions for data governance and usage.

4.2.2. Urban Planning Operations Indicator System (SIOU)

Statistics play a crucial role in the EU. In articulation with EU bodies, member states have developed harmonised procedures to compare data from distinct aspects such as product trade (import and export), metrics on demography, energy production, characteristics of the built stock and urban planning operations [53]. The Portuguese Urban Planning Operations Indicator System (SIOU) was established in 2002 under the same legal framework as the LO/construction book. In opposition to the LO/construction book, an online platform was set up for the SIOU to collect the datasets from defined forms. The SIOU Q3 form, a survey on the design of buildings to be built or deconstructed, became part of the permitting process in all municipalities. The form is filled out for each process when a permit is required (mandatory for all private works) and is communicated to the statistics office (INE). Several updates have been made in the platform to accommodate changes in the legal framework, namely harmonisation with the EPC datasets, terminology harmonisation, the improvement of data accessibility and sharing and change in data collection methods [46]. It is worth mentioning that all datasets related to addresses are already compliant with the INSPIRE Directive's Addresses theme [54]. The SIOU requires the Q3 form to be updated at the end of construction. Given the most probable similarity of this system with those of other member states (as similar requirements should exist from specific statistics offices across the EU), demonstrating these datasets and evaluating them with the EU DBL framework is paramount for the aimed contributions.

4.2.3. Technical Housing Datasheet (FTH) and Energy Certificate (EPC)

As mentioned, the FTH was established in 2004 to make descriptions of the technical and functional characteristics of residential buildings and their units (dwellings) available in a single document for consumers. A specific template was produced as part of the supporting legal framework to help promoters provide the required data [55]. The FTH is a technical document built during construction and delivered in PDF or paper format at handover.

The EPC is an instrument derived from the Energy Performance of Buildings Directive to provide consumers with a classification of the energy performance of buildings or units. Different entities have researched and evaluated the progress in implementing EPCs over the last few years [9,56]. With the new goals set by the EU Green Deal, the EPC is gaining more and more importance, becoming one of the most relevant deliverables [57,58]. As it will be detailed, the EPC relies on data from the technical solutions used in the building, meaning that some overlap with the FTH and LO/construction book exists despite its specific purpose: energy. Each member state has implemented its own EPC based on shared principles. In Portugal, the EPC follows a template defined in the legal framework [59]. A design EPC must be part of the execution of design deliverables. Considering all changes made during construction, an update will be produced, leading to the final EPC.

4.2.4. Overview

As evidenced previously, elements in the construction-related Portuguese legal framework are considered relevant to the EU DBL. Despite the singularities, some result from EU directives or prescriptions. This means that the outcomes from the present exercise can be used for similar evaluations in other member states. To get a clearer perspective of the landscape of deliverables and to support the demonstration and evaluation that will follow, Figure 4 provides a summary of positioning in the construction process life cycle and evidencing the present gaps/silos in terms of integration.

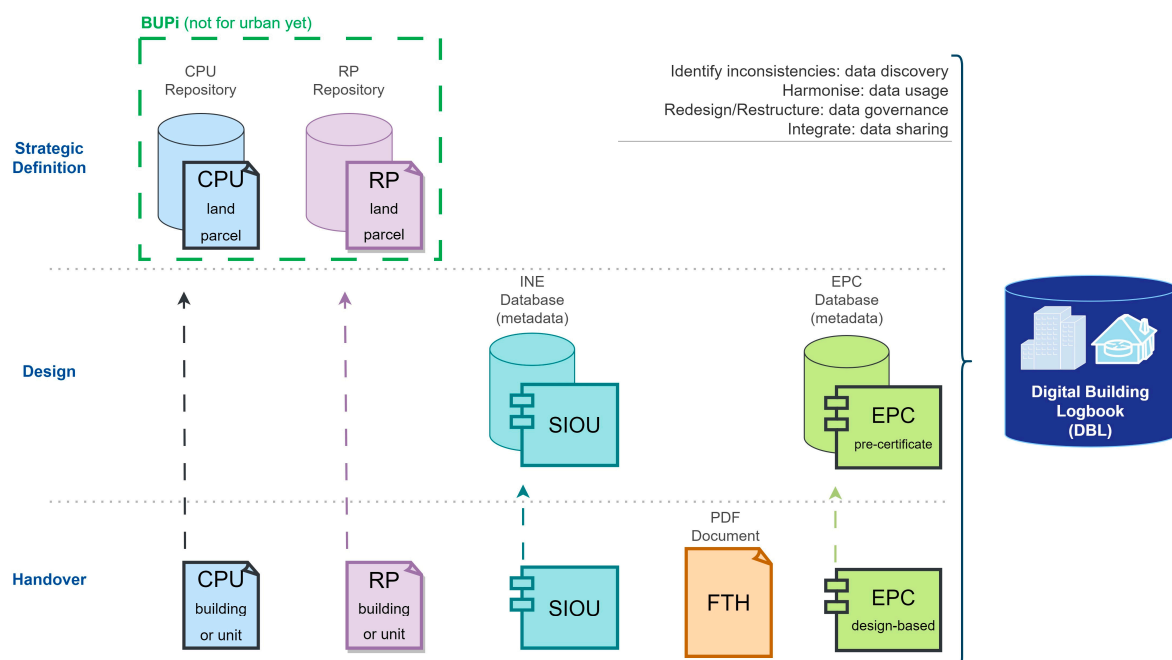


Figure 4. Overview of existing Portuguese deliverables considered in the study and relevant to the EU DBL framework and positioning in the construction process life cycle.

5. Demonstration

5.1. Portugal Datasets Landscape

5.1.1. Matrix Certificate (CPU)

The official models for the rural and urban matrix certificate registries in computer format are defined in the legal framework, specifically Portaria no. 894/2004 [60]. For the case of the urban matrix certificate, Figure 5 presents a knowledge graph summarising the landscape of datasets. These are clustered into topics to provide information on the parcel identification, location and description. The information on the source parcel is provided, as the parcel can have different origins, namely the aggregation of several or resulting from splitting. Parcel areas and tax data, such as previous and present values, are provided. It is interesting to note that the parcel central coordinates are provided here. The last group of datasets addresses the owner(s) identification. Datasets considered irrelevant were shortened to save space for better visualisation.

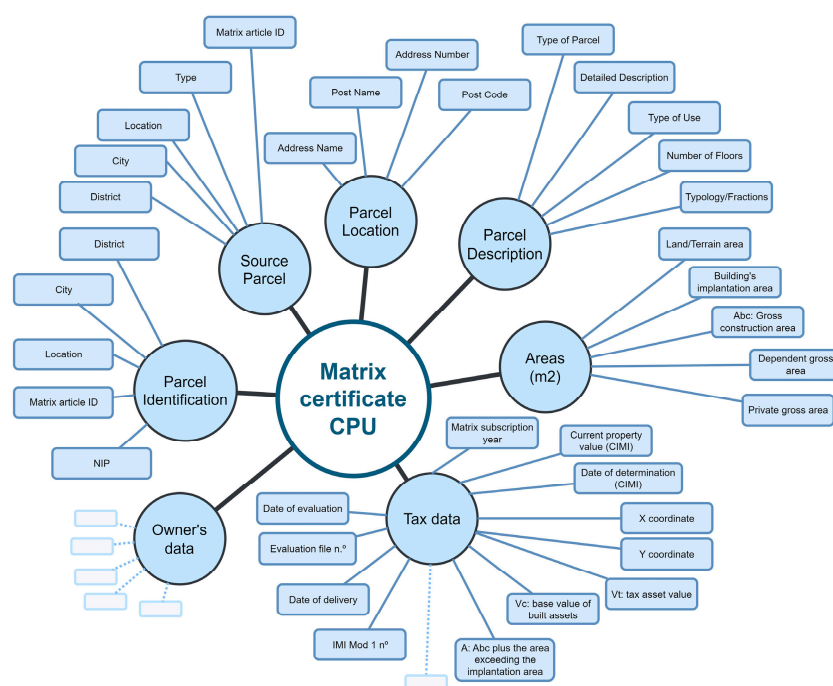


Figure 5. Urban matrix certificate (CPU) knowledge graph evidencing the relevant datasets.

5.1.2. Property Registry (RP)

The Land Registry Code governs the property registry (RP), and its main goal is to record all relevant facts [51]. Without entering too many details, these facts are primarily associated with changes in ownership, mortgages and parcel geometry. The system for recording is flexible, similar to what was previously mentioned regarding the LO/construction book. Looking at the datasets presented in Figure 6 and the results from the consultation of several real property registries, it is worth mentioning that for the parcel description, most datasets are compatible or overlap with datasets from the CPU. An exception applies to the areas where the covered area is different from the one presented in the CPU; doubts remain on the other. The registry book identification is specific to the property registry procedure. The owners' data and part of the other annotations comprise information from all recordable owners of the parcel due to selling or inheritance. It is relevant to mention that when a building exists and the partition in building units is set, the list of units, their identification, detailed description and per millage are described here. From the landscape, it is possible to observe that integration between the CPU and RP would bring consistency to the dataset management, namely those already structured. Inconsistencies would also

become more visible. In addition, this could constitute an opportunity for improving annotations standardisation.

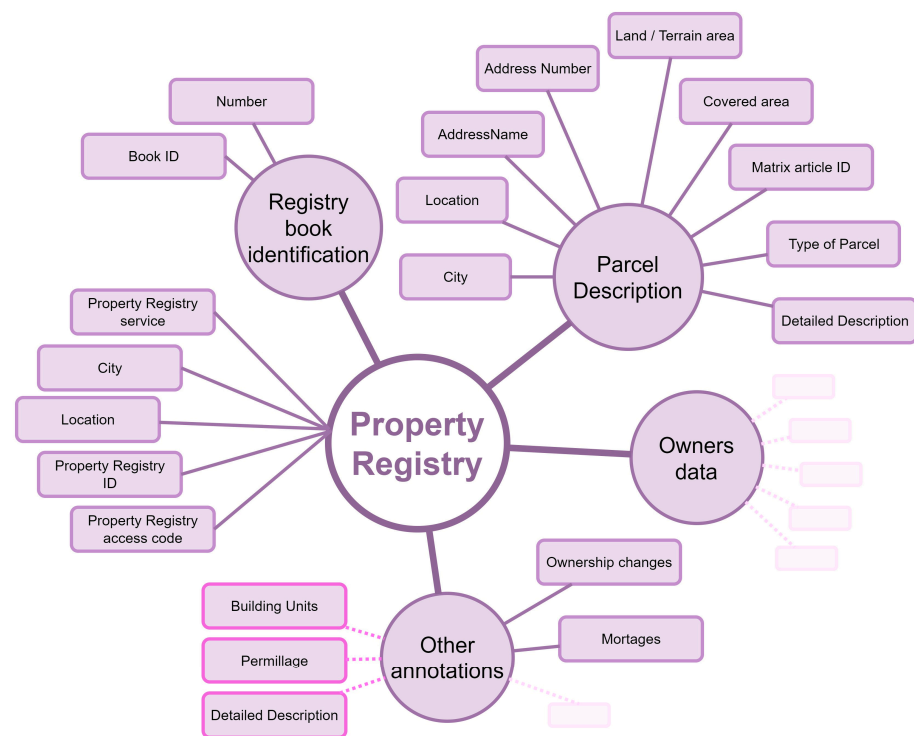


Figure 6. Property registry (RP) knowledge graph evidencing the relevant datasets.

5.1.3. Urban Planning Operations Indicator System (SIUO) Q3 Form

The Urban Planning Operations Indicator System (SIUO) is the most well-structured element under demonstration. This interpretation derives not just from the detail of the supporting documentation but mainly from the concern of setting classifications for all datasets presented, their sub-division and grouping in parts, as evidenced in Figure 7. Part A, the administrative process identification part and Part J, building identification and location, duplicate the datasets presented in the CPU but, more importantly, collect relevant information regarding the permits and project development forecast. This is shared with Part I, phase identification. In Part J, mentioning the different datasets addressing the coordinates is relevant. This is a relevant aspect when setting links with the INSPIRE Directive. Parts B, C and H endorse the identification of the promoter, its entity and the person responsible for completing it, respectively. They were omitted to save space because these datasets were interpreted as less relevant to the study. Part D, land management, articulated with the municipality master plan to observe the building potential. Part E reflects the parcel type relating to the CPU. Part F exposes the type of work and classifies the type of intervention and, in some cases, the extension. This is very relevant for statistical purposes. For example, the EU Renovation Wave accomplishment indicators rely on this classification, along with the building areas [12]. Without neglecting the previous parts, Part K, building characteristics, is very relevant for the building and building unit levels because many datasets associated with areas are defined here. In this part, it is worth denoting the statistics mindset of the element as one of the datasets requested is the number of cost-controlled dwellings to be built as part of the project. From the landscape of datasets presented in Figure 7, it is possible to discover how this element can be important for other purposes, surpassing statistics, and how improving shareability can be an added value for the value chain.

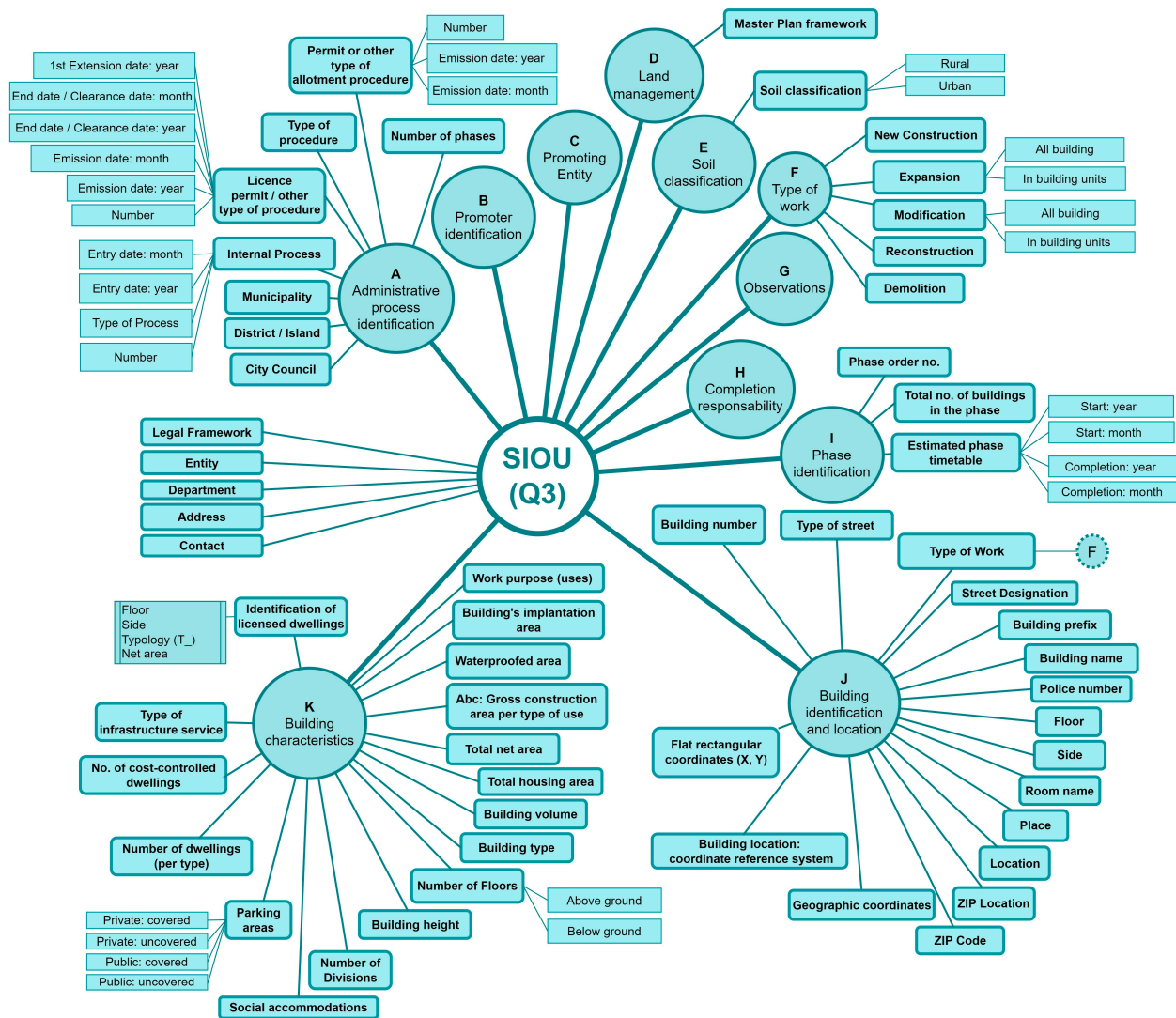


Figure 7. Statistical urban planning operations indicator system Q3 form (SIUQ) knowledge graph evidencing the relevant datasets.

5.1.4. Technical Housing Datasheet (FTH)

When analysing the landscape of datasets from the technical housing datasheet (FTH) presented in Figure 8, several aspects deserve immediate consideration. The first is the awareness that the datasheet sections match the EU DBL levels despite the different names. The following is that it is by far, but not surprisingly, the most technical document considered in the study. Lastly, it is worth mentioning that minor improvements in the FTH guidelines and the development of an information system support tool would easily provide added value for the industry and to clients. Looking at the details of the datasets and starting with the identification, several duplicate datasets are observed and, more relevant, this point sets a bridge with other elements not considered in the scope of the study. The reason mentioned was the intuition that there would be benefits from clarifying these aspects first. This observation confirms the intuition to some extent. Several points focus on identifying the relevant stakeholders involved, from the promoter/developer to the architect and the design disciplines authors, as well as the contractors and technical responsible. In Division I, allotment, supporting drawings and a general description comprise the datasets.

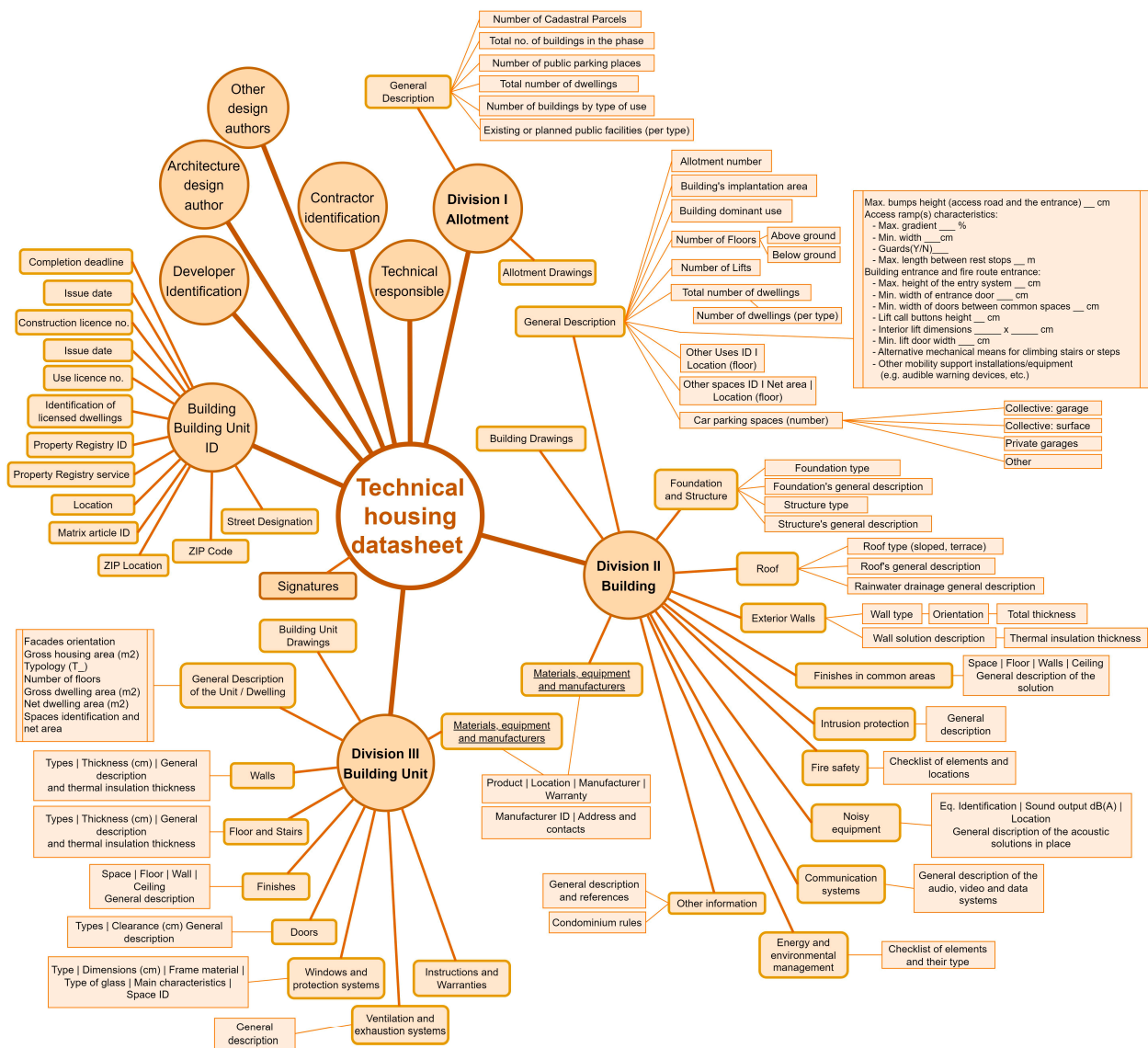


Figure 8. Technical housing datasheet (FTH) knowledge graph evidencing the relevant datasets.

Regarding this last part, these are well structured from an informatic systems perspective (this will be better explained when detailing Division II), and it can be observed that most datasets constitute duplicates from the CPU and SIOU forms. This means that FTH developments and system integration could promote immediate benefits. Division II addresses the building; again, drawings compose a relevant part. The building's general description comprises several well-organised datasets that overlap with the data provided for the SIOU to some extent. It was interesting to note how the difference in purposes leads to similar yet different datasets. One example observed is car parking. In the SIOU, all datasets address areas, while in the FTH, there are the same datasets but instead addressing the number of spaces. It is worth noting the concerns in organising all relevant datasets for accessibility and fire risk analysis. It could be interesting to become part of the FTH guidelines to be organised or provided previously for automated compliance checking during permitting [61]. This is relevant because it is observed that FTH production is carried out most of the time in a rush at the end of construction. However, looking at the details of the datasets, a lot could be set during the design and further developed as part of the supervision process, deriving the datasets automatically to the FTH. The EU DBL framework can be a game changer where opportunities for complementary/side information systems exist. The other parts of this section focus on specific construction

elements or systems, and the indication of types, solutions and general descriptions should be provided.

Despite some predefined organisation of some fields, the way to make the descriptions is very open. It is relevant not to forget that the FTH model was defined in 2004 [55], and since then, no updates have occurred. This is especially relevant to stress when framing a common element in Divisions II and III: the materials, equipment and manufacturers. The Digital Product Passport will provide all the data that meets the requirements established in the FTH and digitally. This means an update to make the FTH more digital would allow for significant gains for this accomplishment. The last point is Division III, building unit, where details of the construction elements used inside a dwelling are specified, similarly to what was mentioned in Division II. It is worth mentioning that the general description of the unit has some overlaps with the dataset of the SIOU, applying the same reasoning as mentioned before.

5.1.5. Energy Performance Certificate (EPC)

The last deliverable to describe is the EPC, as presented in Figure 9, partially because it comes in last with the FTH, and most datasets overlap with that deliverable. As previously mentioned, the EPC is framed as part of the energy performance regulations and is suffering significant push because it is identified as one of the key instruments for the Green Deal goals [62]. It applies to building units and, not surprisingly, contains many datasets specifically turned to the thermal characteristics of construction elements, complementing and overlapping the technical data from FTH, but also climate data, indicators, gains and losses in terms of heat, renewable energy, CO₂ emission estimation and, of course, the building unit energy class. In this respect, it is worth mentioning that for specific solutions, such as walls, roofs, pavements, windows, glazed surfaces and technical systems, significant improvements could derive from performing a data assessment value chain that could progress from the design through construction to feed the FTH and EPC. This deliverable has specific datasets related to the EPC system governance, namely the issue date and name of the qualified expert producing the certificate. The building/building unit is worth mentioning because it sets the bridge with datasets from the CPU and SIOU.

5.2. Dataset Comparison

In this sub-section, the datasets from the Portuguese existing deliverables previously detailed are confronted with the datasets or DBL ontology presented in the technical guidelines for DBLs explored in Section 3.2. The guidelines present one figure with applicable datasets for the three DBL levels: cadastral parcel, building and building unit. Figures 10–12 replicate the guideline figures by adding a colour schema representing the existing Portuguese elements and referencing the applicable dataset or group of datasets. A brief explanation for each figure is provided as an introduction to the evaluation section.

Regarding the datasets supporting the cadastral parcel level (Figure 10), it can be observed that all can be provided by the CPU, with one exception and one case, the clean soil statement, where the RP annotations are interpreted as relevant to be considered. The exception, or the case where no Portuguese datasets can provide the required inputs, concerns a geometric definition of the parcel. However, as previously exposed, the BUPi and SNIC developments and evolutions might easily accommodate this missing requirement.

More datasets are presented at the building level, with a total of 32, as visible in Figure 11.

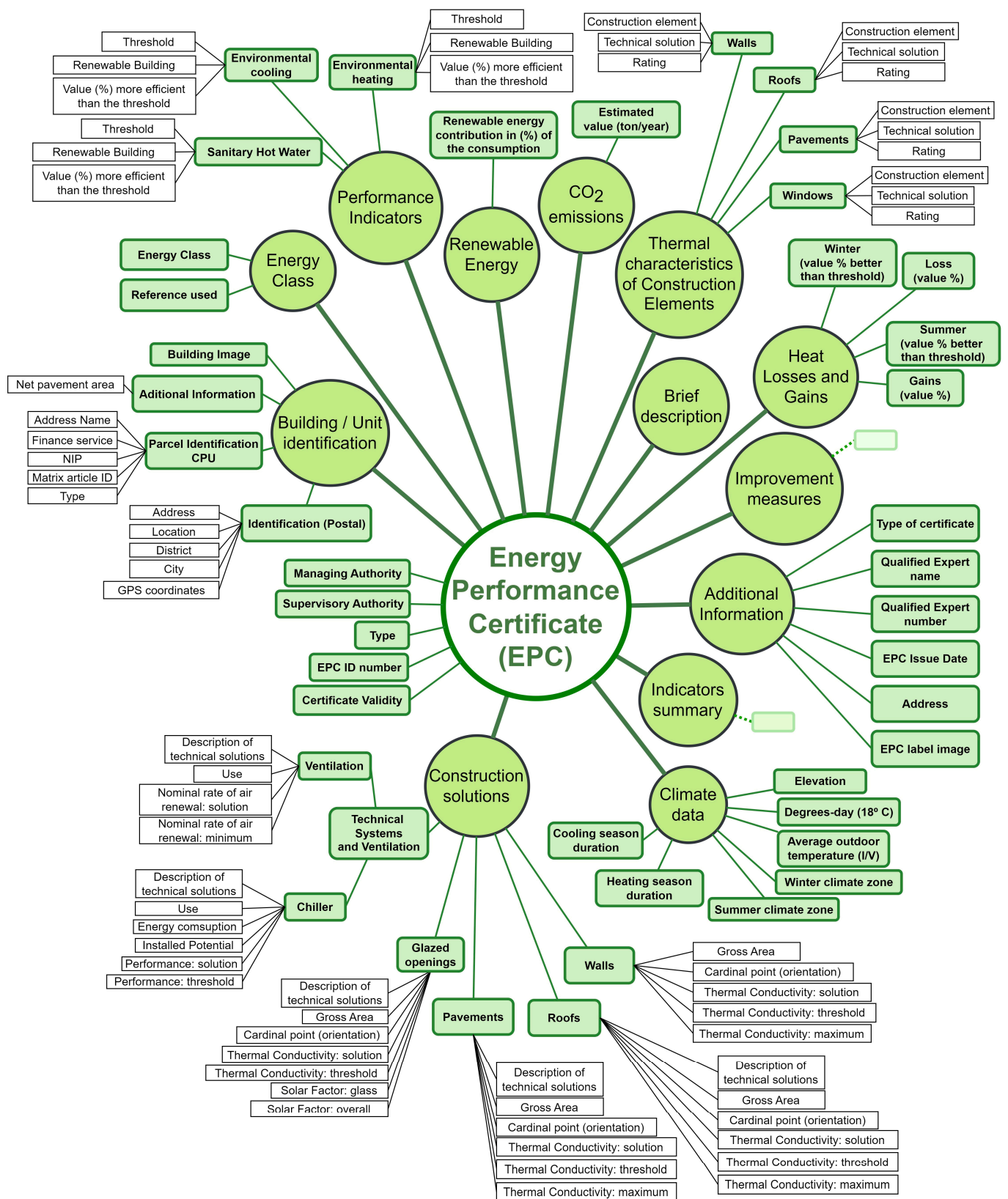


Figure 9. Energy performance certificate (EPC) knowledge graph evidencing the relevant datasets.

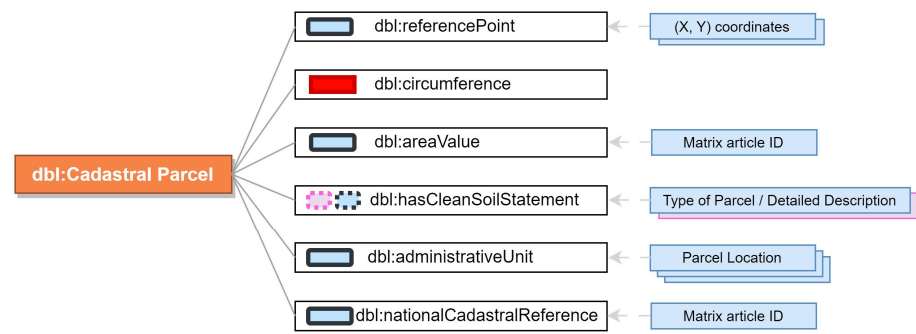


Figure 10. DBL cadastral parcel level with the datasets presented in the guidelines and comparison with those from studied Portuguese deliverables.

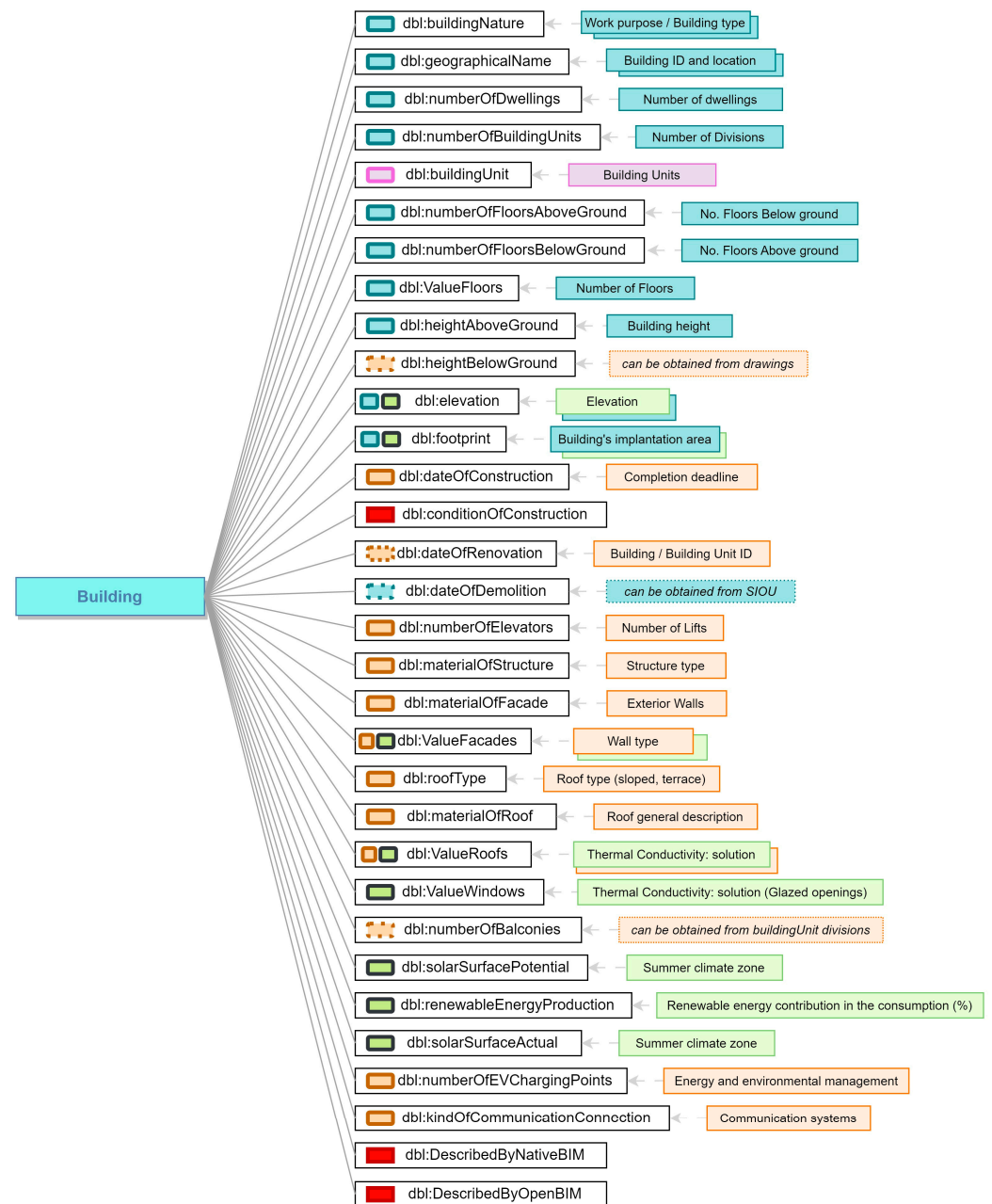


Figure 11. DBL building level with the datasets presented in the guidelines and comparison with those from studied Portuguese deliverables.

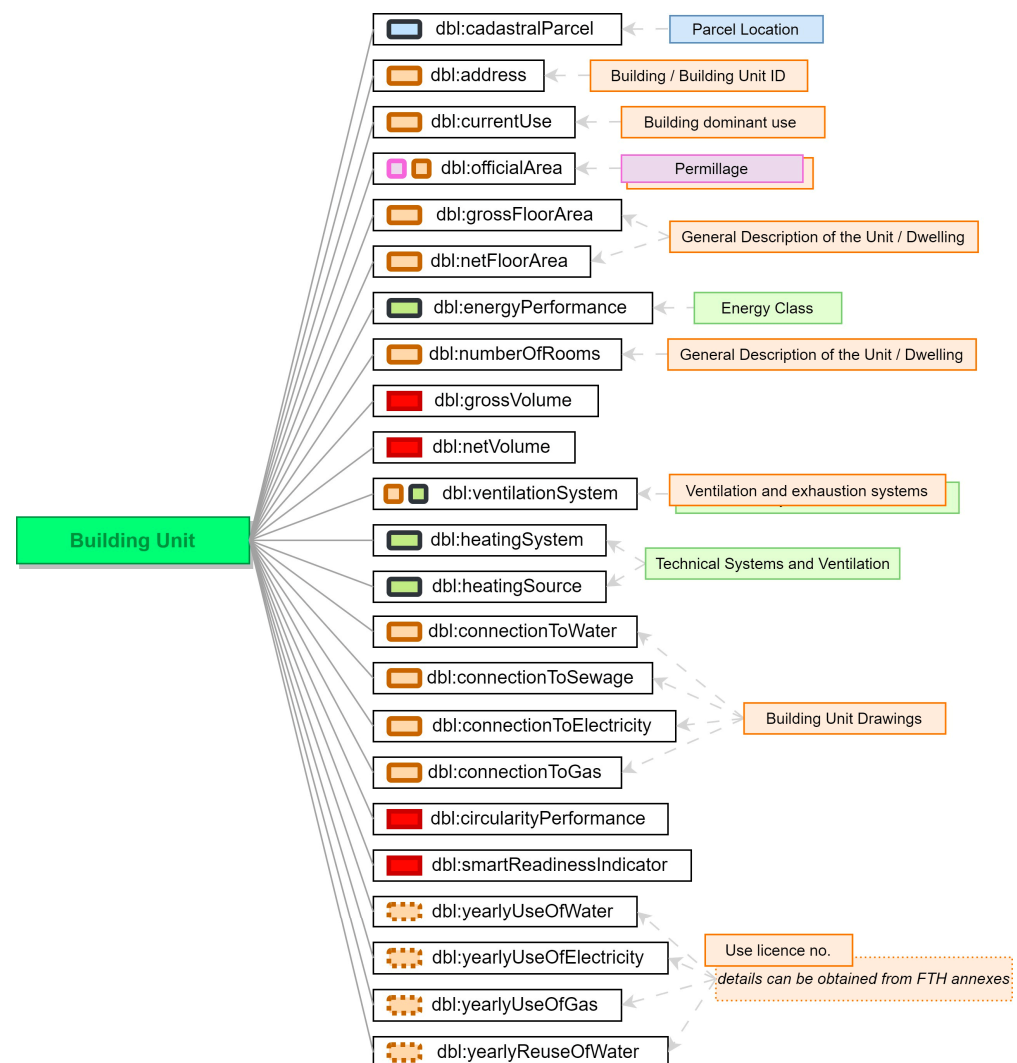


Figure 12. DBL building unit level with the datasets presented in the guidelines and comparison with those from studied Portuguese deliverables.

Only three datasets do not match the existing elements in Portugal, two of which are related to Building Information Modelling (BIM) and one of which is related to the general condition of the construction. It is worth mentioning that only recently BIM was introduced in the legal framework with a medium-term calendar for adoption for permitting purposes [40]. In what concerns the condition state, in practice, the CPU uses an index that concerns the building age and overall condition when determining the property value. However, this was not considered because the property evaluation can be pending for many years, and the principles to determine the index rely on the evaluator's experience. There is one method designed to assess building conditions prior to renovation actions that could provide the dataset. However, its applicability is not mandatory for housing building stock. Regarding the other, it is interesting to perceive the relevance of the SIOU in providing datasets and how, in many cases, duplicates are observed between the analysed documents. The value of the EPC is clear for the energy-related datasets, complementing the FTH responsible for the most significant part of the matches. More importantly, it is worth highlighting how this level can be easily accomplished in most datasets.

The interpretation was more difficult to perform at the building unit level, shown in Figure 12, due to difficulties in clearly understanding the range of the dataset's description. When working at the lowest level, the most relevant deliverables are, not surprisingly, the FTH and the EPC. Exceptions are made to the cadastral parcel reference, where CPU

datasets apply, and to the official area, where the RP and FTH share and should provide the value. It is worth mentioning that from the landscape of twenty-three datasets, four do not have a match, and the other four can only be obtained indirectly. Starting with the “red squares”, there are two different situations. One is related to volumes, where Portuguese elements only provide the volumetry for the entire building. This situation can be easily solved by adding the datasets. However, more importantly, the values will be more straightforward to estimate when BIM is implemented. The other relates to sustainability-related assessments, namely the circularity performance and the Smart Readiness Indicator. The increasing requirements will demand new datasets, signifying changes in the legal framework. These datasets and their estimation processes should be detailed and introduced in the elements where they are better framed.

6. Evaluation/Discussion

6.1. Contributions

The matches observed in Figures 10–12 demonstrate several aspects deserving of evaluation. The first is that almost all datasets have one or more matches within the existing deliverables. This leads to the awareness that if DBLs were mandatory in Portugal in the short term and the requirements were the presented datasets, it would be possible to build them based on the existing deliverables. The difficulty would rely mainly on collecting the deliverables, introducing the data and working on potential inconsistencies. From a data discovery perspective, it is interesting to note that the existing deliverables provide much more data than the ones established in the ontologies for the different levels. This topic deserves a separate evaluation further in this section.

Evaluating the outcomes from the figures, it is clear that different deliverables support most of the datasets depending on the level being worked. This is especially visible for the cadastral parcel with the CPU and the responsibilities shared when exploring the building level. A substantial part can be easily solved from the no-match datasets, except for the BIM- and sustainability-related datasets that rely on legal framework evolutions that are not expected to occur in the short term. From another perspective, the results prove that the criteria for choosing the deliverables were successful.

Looking at the different deliverables and summarising some of the observations made, it is clear that there would be substantial benefits if the data could be shared throughout the construction process value chain to streamline usage and fill in the different deliverables. Of course, the issue is not just data sharing, as governance aspects are also responsible for the observed situation. In this respect, one particular aspect that raises multiple concerns is associated with the ownership and security of the data in terms of accessibility. DBLs should collect and manage sensitive data that might be about the building characteristics or performance and is related to its occupants or its ownership. An in-depth study grounded on these observations and considering the visions for the common data spaces could be relevant to anticipate and draw strategies. If not, this topic should deserve attention from the research community. From the knowledge graphs, observing the alignment (today’s duplication) of datasets and their mismatches is also interesting. Of course, the duplicates can be justified as anchors ensuring the manual connection between processes and levels.

In contrast, the specific purposes can justify the mismatches without fading the absence of a crossed vision of the deliverables. This realisation is critical for future developments. Finally, it is worth emphasising that the deliverable for statistical purposes is meaningful in linking several deliverables and providing relevant datasets. As its digital maturity is higher than the others and there is an ongoing conciliation process of its datasets with INSPIRE, achieving this effort and in parallel work improved the guidelines for the FTH and LO/construction book, providing insights to be produced, since the design phase would be very relevant for building a DBL from the infancy of the construction process.

One last aspect that deserves evaluation in this sub-section is the relationship between the existing datasets and how they would be framed in the proposed DBL framework (Figure 3).

The CPU and RP fit in Point 3, legal and finance, despite their datasets being relevant for Points 1 and 2, identification and general, respectively. The SIOU form, not surprisingly, has a wide range, meaning that in addition to the already mentioned points, it would also provide datasets for Point 4, dimensions, mainly, and Point 6, structure and material, in more general aspects as the number of floors. The FTH would position itself in providing datasets, primarily for Points 6, 7 and 5, structure and material, building services and performance, respectively, without neglecting Points 3 and 4. Regarding others, the FTH mostly duplicates data from the previous elements. In the same perspective, the EPC would concentrate on providing additional datasets that are energy related to better accomplish the requirements for Points 5,6 and 7. It is relevant to mention that this is only a brief and overall evaluation of interpreting the deliverables, where a detailed and structured analysis makes sense as part of future research and to tackle some observed limitations, as described in the next sub-section.

From a data discovery perspective, this study and its evaluation provide interesting knowledge that allows the hypothesis to be redefined, adding more detail to the questions and new perspectives.

6.2. Limitations

This study was intentionally limited to specific aspects, mainly associated to data discovery, and is to be used as a knowledge base for future analysis. In this respect, all objectives set were accomplished, deserving, however, to leave some notes for consideration. The DBL ontologies used derive from the technical guidelines, where the main common elements were identified at each level, and strategic trends and requirements led us to foresee specific datasets. Despite the guidelines' merits, future developments should seek to extend the dataset framework at all levels by using the elements from statistical offices and the INSPIRE Directive. In brief, the reasoning is to replicate the exercise performed in this study but at an EU deliverables/elements level. When confronting the DBL framework organisation with the scope of documents, it is clear how the datasets spread throughout the points. Although this does not constitute any particular issue, it might not be very clear at the practical level, demotivating stakeholders for implementation. Future work should clarify the issue further to tackle resistance to changes.

7. Conclusions

The research aimed to effect changes in how the DBL is perceived in the construction industry, namely on the understanding that relevant data for its materialisation are already available.

The demonstration and evaluation evidenced this using five deliverables set in the Portuguese framework, where some are somewhat common to other member states, which made possible the achievement of high levels of matching between these datasets and those established in the EU DBL guidelines ontology. More precisely, the match is 83.3% for cadastral parcel, 90.6% for building and 82.6% for building unit. As presented, in some situations, duplicates were observed. The "no-match" situations were clearly identified in their origin, and most of them could be solved with adjustments to the existing landscape and processes. One of the examples progressing in that direction is the interoperability developments between the CPU and RP in the context of BUPi.

The landscape of deliverables defined for this work is only a part of the existing elements. However, and as observed, these constitute a relevant and representative sample to make significant progress in implementing DBLs under the EU common framework and guidelines, namely from a data discovery perspective.

Making DBL implementation more straightforward relies on in-depth research to consolidate and better evaluate some of the findings. Still, from the data discovery perspective, it is worth investigating the duplicate datasets in the different deliverables and adding others to the landscape. Harmonising these datasets with existing systems, such as the INSPIRE Directive, constitutes another research direction. Finally, aligning the evaluated

datasets with the DBL framework is also relevant to improving data organisation and governance, where security should be a priority. Straightforward DBL implementation requires a systematic approach to data sharing and governance, as major changes need to be performed in the legal framework and deliverables supporting systems to make them more digital or improve the interoperability characteristics. In practice, merging the CPU and RP, opening an SIOU database to improve links with other tools and systems and reconfiguring the FTH and its background legislation to become digital are some initial and key actions. Despite or in articulation with these actions, insights from the data spaces strategy and its requirements should be considered for the pathway definition. However, working boundaries and overlaps of the data spaces can become a concern, and the DBL positioning should be carefully evaluated. As mentioned, profile definition for data accessibility should also be a central concern for DBL development.

The EPC is a well-established process; many stakeholders consider it the most trustworthy deliverable. The lessons learned should be used for other processes. In addition, there must be an understanding that the SCE should be primarily automatically fulfilled with datasets from all documents. This does not withdraw the technical responsibility of assessing the building's energy efficiency. It strengthens that role and brings efficiency to the process.

Similarly, the work performed for statistical purposes should find a way to become more relevant in the construction value chain. The digital maturity of this process and its systematisation can be relevant for many processes, from permitting to DBLs. From this investigation comes a vision that improving the data shareability of these elements is paramount for DBL implementation in member states.

The research is limited to the deliverables under evaluation, although recognising that others exist and that other suggestions could have been made.

The definition of the Digital Building Logbook makes it a game changer in the construction industry, namely in building construction. The trends and goals will lead to its implementation across member states and boost practices outside the EU. Although it can be recognised that many changes need to occur, from a data discovery perspective, it is now more evident that many existing deliverables provide the information or datasets that are needed for DBL materialisation. The path towards a smart build environment must be built with a strategy that uses and improves existing practices, when they exist, to concentrate the efforts on bridging real gaps and streamlining the way goals can be accomplished.

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References

- Bernstein, P. *Architecture | Design | Data: Practice Competency in the Era of Computation*; Birkhäuser: Berlin, Germany; Boston, MA, USA, 2018; ISBN 978-3035611885. [\[CrossRef\]](#)
- GABC; UNEP. *The Building Passport: A Tool for Capturing and Managing Whole Life Data and Information in Construction and Real Practical Estate*; Global Alliance for Buildings and Construction: Nairobi, Kenya, 2021.
- Dourlens, S.; Carbonari, G.; De Groote, M.; Borragán, G.; De Regel, S.; Toth, Z.; Volt, J.; Glicker, J.; Lodigiani, A.; Calderoni, M. *Study on the Development of a European Union Framework for Digital Building Logbook—Final Report*; European-Union: Brussels, Belgium, 2021.
- Gómez-Gil, M.; Sesana, M.M.; Salvalai, G.; Espinosa-Fernández, A.; López-Mesa, B. The Digital Building Logbook as a gateway linked to existing national data sources: The cases of Spain and Italy. *J. Build. Eng.* **2022**, *63*, 105461. [\[CrossRef\]](#)
- Couto, P.M. *Universidade do Porto Faculdade de Engenharia, Avaliação Patrimonial De Imóveis Para Habitação*. Ph.D. Thesis, Faculty of Engineering, University of Porto, Porto, Portugal, 2007.
- Alonso, I.-N.C.; Sahebzamani, E.; Lendinez, F.; Forcada, N. Circular Economy and Digital Twins in the Construction Sector. In *Proceedings of the International Congress on Project Management and Engineering*, Terrassa, Spain, 5–8 July 2022; pp. 444–456.
- Muench, S.; Stoermer, E.; Jensen, K.; Asikainen, T.; Salvi, M.; Scapolo, F. *Towards a Green and Digital Future*; European Union: Brussels, Belgium, 2022. [\[CrossRef\]](#)
- JRC. *Summary Report on Status of Implementation of the INSPIRE Directive in EU*; European Union: Brussels, Belgium, 2017. [\[CrossRef\]](#)
- Arcipowska, A.; Anagnostopoulos, F.; Mariottini, F.; Kunkel, S. *Energy Performance Certificates (EPC) across the EU—A Mapping of National Approaches*; European Commission: Brussels, Belgium, 2014. Available online: http://bpie.eu/publication/energy-performance-certificates-across-the-eu/#.VDZi_vmSx9V (accessed on 22 May 2024).
- Papadaki, I.; Moseley, P.; Staelens, P.; Horvath, R.; Sanz, O.; Lipari, M.; Velayos, P.; Vaananen, H. *Transition Pathway for Construction*; European Commission: Brussels, Belgium, 2023. Available online: <https://ec.europa.eu/docsroom/documents/53854> (accessed on 10 January 2024).
- Gonçalves, J.D.S.; Lam, W.C.; Ritzen, M. The Role of Digital Building Logbooks for a Circular Built Environment. In *A Circular Built Environment in the Digital Age*; De Wolf, C., Çetin, S., Bocken, N., Eds.; Springer: Cham, Switzerland, 2024; pp. 229–243. ISBN 9783031396755. [\[CrossRef\]](#)
- European Commission. *A Renovation Wave for Europe*; European Commission: Brussels, Belgium, 2020.
- Gómez-Gil, M.; Espinosa-Fernández, A.; López-Mesa, B. Review and Analysis of Models for a European Digital Building Logbook. *Energies* **2022**, *15*, 1994. [\[CrossRef\]](#)
- Malinovec Puček, M.; Khoja, A.; Bazzan, E.; Gyuris, P. A Data Structure for Digital Building Logbooks: Achieving Energy Efficiency, Sustainability, and Smartness in Buildings across the EU. *Buildings* **2023**, *13*, 1082. [\[CrossRef\]](#)
- Mêda, P.; Calvetti, D.; Kifokeris, D.; Kassem, M. A Process-Based Framework for Digital Building Logbooks. In *Proceedings of the 2022 European Conference on Computing in Construction*, Rhodes, Greece, 24–26 July 2022; pp. 1–8. [\[CrossRef\]](#)
- Gómez-Gil, M.; Espinosa-Fernández, A.; López-Mesa, B. Contribution of New Digital Technologies to the Digital Building Logbook. *Buildings* **2022**, *12*, 2129. [\[CrossRef\]](#)
- Mêda, P.; Calvetti, D. Exploring the Potential of iPad-LiDAR Technology for Building Renovation Diagnosis: A Case Study. *Buildings* **2023**, *13*, 456. [\[CrossRef\]](#)
- Grow, D. *Technical Guidelines for Digital Building Logbooks—Guidelines to the Member States on Setting up and Operationalising Digital Building Logbooks under a Common EU Framework*; European Commission: Brussels, Belgium, 2023.
- Adelman, C. Kurt Lewin and the Origins of Action Research. *Educ. Action Res.* **1993**, *1*, 7–24. [\[CrossRef\]](#)
- Nogeste, K. Dual Cycle Action Research: A Doctor of Project Management (DPM) Research Case Study. In *Design Methods and Practices for Research of Project Management*; Routledge: Beverly, PA, USA; Gower Publishing: New York, NY, USA, 2015; ISBN 978-1-138-46108-6.
- Goldkuhl, G. Pragmatism vs interpretivism in qualitative information systems research. *Eur. J. Inf. Syst.* **2012**, *21*, 135–146. [\[CrossRef\]](#)
- Overmars, K.P.; Verburg, P.H.; Veldkamp, T. Comparison of a deductive and an inductive approach to specify land suitability in a spatially explicit land use model. *Land Use Policy* **2007**, *24*, 584–599. [\[CrossRef\]](#)
- Kifokeris, D. Variants of Swedish Lean Construction Practices Reported in Research: Systematic Literature Review and Critical Analysis. *J. Constr. Eng. Manag.* **2021**, *147*, 1–14. [\[CrossRef\]](#)
- Parameswaran, A.; Ranadewa, K.A.T.O. Learning-to-learn sand cone model integrated lean learning framework for construction industry. *Smart Sustain. Built Environ.* **2024**, *13*, 856–882. [\[CrossRef\]](#)
- Fellows, R.; Liu, A. *Research Methods for Construction*; Wiley-Blackwell: Oxford, UK, 2022; ISBN 978-1-119-81473-3.
- Tong, M.; Thomson, C. Developing a Critical Literature Review for Project Management Research. In *Design Methods and Practices for Research of Project Management*; Pasian, B., Ed.; Routledge: London, UK; Gower Publishing: Oxon, UK, 2017; pp. 153–172; ISBN 978-1-138-46108-6.
- Moore, N. Desk research. In *How to Do Research: The Practical Guide to Designing and Managing Research Projects*; Press, C.U., Ed.; Facet Publishing: Cambridge, UK, 2018; pp. 106–111.

28. Pauwels, P.; Costin, A.; Rasmussen, M.H. Knowledge Graphs and Linked Data for the Built Environment. In *Industry 4.0 for the Built Environment*; Springer International Publishing: Cham, Switzerland, 2022; Volume 20, pp. 157–183; ISBN 9783030824303.
29. Chaudhri, V.K.; Baru, C.; Chittar, N.; Dong, X.L.; Genesereth, M.; Hendler, J.; Kalyanpur, A.; Lenat, D.B.; Sequeda, J.; Vrandečić, D.; et al. Knowledge graphs: Introduction, history, and perspectives. *AI Mag.* **2022**, *43*, 17–29. [CrossRef]
30. European Commission. *A European Strategy for Data*; European Commission: Brussels, Belgium, 2020.
31. European Commission. *Commission Staff Working Document—On Common European Data Spaces*; European Commission: Brussels, Belgium, 2022; SWD(2022). Available online: <https://digital-strategy.ec.europa.eu/en/library/staff-working-document-data-spaces> (accessed on 23 May 2024).
32. European Commission. *Commission Staff Working Document—On Common European Data Spaces*; European Commission: Brussels, Belgium, 2024.
33. Noardo, F.; Ellul, C.; Harrie, L.; Overland, I.; Shariat, M.; Arroyo Otori, K.; Stoter, J. Opportunities and challenges for GeoBIM in Europe: Developing a building permits use-case to raise awareness and examine technical interoperability challenges. *J. Spat. Sci.* **2020**, *65*, 209–233. [CrossRef]
34. Al-Sadoon, N.; Fauth, J.; Menzel, K. Digital Twins as Enabler for Long Term Data Management Using Building Logbooks. In *Collaborative Networks in Digitalization and Society 5.0. PRO-VE 2023*; IFIP Advances in Information and Communication Technology; Springer: Cham, Switzerland, 2023; Volume 688, pp. 673–686. [CrossRef]
35. Mêda, P.; Calvetti, D.; Hjelseth, E.; Sousa, H. Incremental Digital Twin Conceptualisations Targeting Data-Driven Circular Construction. *Buildings* **2021**, *11*, 554. [CrossRef]
36. ISO 7817; Building Information Modelling—Level of Information Need—Concepts and Principles. International Organization for Standardization (ISO): Geneva, Switzerland, 2023; p. 39.
37. Noardo, F.; Malacarne, G.; Mastrolembro Ventura, S.; Tagliabue, L.C.; Ciribini, A.L.C.; Ellul, C.; Guler, D.; Harrie, L.; Senger, L.; Waha, A.; et al. Integrating Expertises and Ambitions for Data-Driven Digital Building Permits—The EUNET4DBP. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* **2020**, XLIV-4/W1-2020, 103–110. [CrossRef]
38. Conselho de Ministros. *Decreto-Lei n.º 555/99—RJUE—Regime Jurídico da Urbanização e Edificação*; Diário da República: Lisboa, Portugal, 1999; p. 8. Available online: <https://dre.pt/dre/legislacao-consolidada/decreto-lei/1999-34567875> (accessed on 4 June 2024).
39. Ministério do Ambiente do Ordenamento do Território e do Desenvolvimento Regional; Ministério das Obras Públicas Transportes e Comunicações. *Portaria n.º 1268/2008, 6 de Novembro—Livro de Obra*; Ministério do Ambiente do Ordenamento do Território e do Desenvolvimento Regional Ministério das Obras Públicas Transportes e Comunicações: Lisboa, Portugal, 2008; p. 7749. Available online: <https://dre.pt/dre/detalhe/portaria/1268-2008-439147> (accessed on 4 June 2024).
40. Presidência do Conselho de Ministros. *Decreto-Lei n.º 10/2024—Reforma e Simplificação dos Licenciamentos no Âmbito do Urbanismo, Ordenamento do Território e Indústria*; Diário da República, 1.ª Série, n.º 5; INCM—Imprensa Nacional Casa da Moeda Lisboa: Lisboa, Portugal, 2024; pp. 5–52. Available online: <https://diariodarepublica.pt/dr/detalhe/decreto-lei/10-2024-836222484> (accessed on 4 June 2024).
41. Vieira, J.A.C. Cadastro Nacional de Edifícios—Proposta de um Bilhete de Identidade Para Imóveis. Master’s Thesis, Faculty of Engineering, University of Porto, Porto, Portugal, 2018.
42. Mêda, P.; Sousa, H.; Calvetti, D. The Anatomy of the Digital Building Logbook embodied with Health and Safety data requirements. In *Digital Transformation of Health and Safety in Construction (CIBW099W123): Book of Proceedings*; Emuze, F., Sherratt, F., Soeiro, A., Eds.; FEUP Edições: Porto, Portugal, 2023; pp. 319–328.
43. Fauth, J.; Bloch, T.; Noardo, F.; Nisbet, N.; Kaiser, S.; Peter, N.; Tekavec, J. Taxonomy for building permit system—Organizing knowledge for building permit digitalization. *Adv. Eng. Inform.* **2024**, *59*, 21. [CrossRef]
44. Mêda, P.; Fauth, J.; Schranz, C.; Urban, H.; Sousa, H. Digital Building Permits and Digital Building Logbooks—Clustering the Challenges and Requirements for alignment. In *Proceedings of the 2024 EC3—European Conference on Computing in Construction*, Chania, Greece, 14–17 July 2024; pp. 1–8.
45. Bellos, C.V.; Petroulatou, K.; Anthopoulos, L. Electronic Building Permission System: The Case of Greece. *Procedia Eng.* **2015**, *123*, 50–58. [CrossRef]
46. INE—Instituto Nacional de Estatística. *SIOU—Sistema de Indicadores de Operações Urbanísticas*; Lisbon, Portugal, 2024.
47. Presidência do Conselho de Ministros. *Decreto-Lei n.º 101-D/2020—Sistema de Certificação Energética dos Edifícios*; Presidência do Conselho de Ministros: Lisboa, Portugal, 2020; pp. 7–(21)–7–(45). Available online: <https://dre.pt/application/file/a/150570803> (accessed on 4 June 2024).
48. European Parliament. *Directive (EU) 2018/844—Energy Efficiency and Energy Performance of Buildings*; European Union: Brussels, Belgium, 2018; pp. 75–91.
49. Presidência do Conselho de Ministros. *Decreto-Lei n.º 68/2004—Ficha Técnica da Habitação*; Presidência do Conselho de Ministros: Lisboa, Portugal, 2004; pp. 1799–1804.
50. Presidência do Conselho de Ministros. *Decreto-Lei n.º 287/2003—Imposto Municipal Sobre Imóveis*; Presidência do Conselho de Ministros: Lisboa, Portugal, 2003; p. 178.
51. Presidência do Conselho de Ministros. *Decreto-Lei n.º 90/2023—Código do Registro Predial—Alterações ao Balcão Único do Prédio (BUPi) e Sistema de Informação Cadastral Simplificado*; Diário da República n.º 197/2023, 1.ª Série; INCM—Imprensa Nacional Casa da Moeda Lisboa: Lisboa, Portugal, 2023; pp. 31–47.

52. Presidência do Conselho de Ministros. *Decreto-Lei n.o 72/2023—Sistema Nacional de Informação Cadastral e Regime Jurídico do Cadastro Predial*; Diário da República n.o 163/2023 1.a Série; INCM—Imprensa Nacional Casa da Moeda Lisboa: Lisboa, Portugal, 2023; p. 44.
53. Ustaoglu, E.; Williams, B. The Inter-Relationships of Territorial Quality of Life with Residential Expansion and Densification: A Case Study of Regions in EU Member Countries. *Urban Sci.* **2024**, *8*, 22. [[CrossRef](#)]
54. European Commission. *INSPIRE—D2.8.I.5 Data Specification on Addresses—Technical Guidelines*; INSPIRE Maintenance and Implementation Group (MIG): Seville, Spain, 2014.
55. Presidência do Conselho de Ministros e Ministérios da Economia e das Obras Públicas Transportes e Habitação. *Portaria n.o 817/2004—Modelo da Ficha Técnica da Habitação*; Diário da República n.o 166—16 de Julho de 2004 I Série-B; INCM—Imprensa Nacional Casa da Moeda Lisboa: Lisboa, Portugal, 2004; p. 1.
56. Zangheri, P.; Castellazzi, L.; D’Agostino, D.; Economidou, M.; Ruggieri, G.; Tsemekidi-Tzeiranaki, S.; Maduta, C.; Bertoldi, P. *Progress of the Member States in Implementing the Energy Performance of Building Directive*; European-Union: Luxembourg, 2021. [[CrossRef](#)]
57. Koltisios, S.; Katsaros, N.; Mpouzianas, N.; Klonis, P.; Giannopoulos, G.; Pastaltzidis, I.; Chatzipanagiotidou, P.; Klumbvte, E.; Jurelionis, A.; Sedukvte, L.; et al. Digital Twin application on next-generation Building Energy Performance Certification scheme. In Proceedings of the 2022 IEEE International Smart Cities Conference (ISC2), Pafos, Cyprus, 26–29 September 2022. [[CrossRef](#)]
58. Gómez-Gil, M.; Espinosa-Fernández, A.; López-Mesa, B. A new functionality for the digital building logbook: Assessing the progress of decarbonisation of national building sectors. *Environ. Impact Assess. Rev.* **2024**, *105*, 107393. [[CrossRef](#)]
59. Direção-Geral de Energia e Geologia. *Despacho n.o 6476-A/2021—Conteúdo Obrigatório dos Certificados Energéticos*; Diário da República n.o 126, 2.a Série—Parte C; INCM—Imprensa Nacional Casa da Moeda Lisboa: Lisboa, Portugal, 2021; pp. 1–7.
60. Ministério das Finanças. *Portaria n.o 894/2004—Modelos Oficiais da Matriz Predial Urbana Informatizada e da Caderneta Predial de Prédio Urbano*; Diário da República n.o 171/2004, Série I-B de 2004-07-22; INCM—Imprensa Nacional Casa da Moeda Lisboa: Lisboa, Portugal, 2004; pp. 4581–4582. Available online: <https://diariodarepublica.pt/dr/detalhe/portaria/894-2004-507421> (accessed on 4 June 2024).
61. Hansen, H.T.R.; Lynge, K. Redesigning public governance of the Danish built environment from relative to absolute metrics. *Proc. IOP Conf. Ser. Earth Environ. Sci.* **2020**, *588*, 022006. [[CrossRef](#)]
62. European Commission. *The European Green Deal*; European Commission: Brussels, Belgium, 2019.

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