CONCERTO RENOV

Feasibility Analysis of a Project to Expand the "Base de Données Nationale des Bâtiments- BDNB " Initiative Developed in France

VERSION 01

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Executive Summary

The acceleration of the energy transition within the European building sector, driven by the Green Deal and the "Renovation Wave" strategy, depends on the availability of reliable, interoperable, and continuously updated data infrastructures. The creation of well-organized national databases, such as the BDNB in France, is essential for an objective assessment of the building stock, the simulation of various renovation scenarios, and for enabling public policymakers to access transparent, accessible, and trustworthy information. The French model—characterized by the integration of multiple sources, comprehensive documentation, ongoing updates, and the dissemination of data under well-defined licences, including open data licences—now functions as a benchmark for the potential expansion of this approach across Europe.

This report, produced as part of the LIFE-2021-CET-HOMERENO project, investigates the feasibility of extending the BDNB model to additional Member States within the European Union. Through a comprehensive comparative analysis and systematic review of existing initiatives, it evaluates the maturity, accessibility, structure, and quality of open or licensed databases across seven nations: Germany, Belgium, Denmark, Spain, Italy, Luxembourg, and the Netherlands. For each country, the study delineates the necessary conditions for establishing an equivalent reference data layer, emphasizing both the benefits and the primary challenges associated with regulatory, technical, and institutional diversity.

Finally, this work proposes a reproducible methodological framework accompanied by operational and strategic recommendations, explicitly targeted at policymakers and stakeholders involved in national and European initiatives. The aim is to identify the most effective levers for action and to encourage a federated, progressive, and open approach to data building. This framework is presented as a vital foundation for the success of public policies focused on the renovation, adaptation, and sustainable management of Europe's building stock.

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1 Introduction

Improving energy efficiency and reducing the carbon footprint of the building sector lie at the heart of European ecological transition policies, driven by the Green Deal and the “Renovation Wave” initiative, with the aim of achieving carbon neutrality by 2050. In this context, the availability, consolidation, and utilisation of robust building databases at national or European level have become crucial levers for objectively assessing the state of the building stock, planning and guiding energy renovation, and supporting decision-making based on reliable and transparent data.

It is within this framework that the National Building Database (BDNB) was created in France. The BDNB catalogues and provides an identity record for every residential and tertiary building in mainland France, by combining data from more than 30 sources. This creates a rich information base for identifying the building stock, conducting simulations, and planning multi-scale strategies. The BDNB methodology stands out due to its integration of multiple attributes: morphological characteristics, uses, energy performance, materials, exposures, and risks, paving the way for cross-cutting data exploitation across numerous fields of analysis.

Building on these initiatives, the present report forms part of the European LIFE-2021-CET-HOMERENO project and aims to deliver a scientific and technical analysis of the feasibility of extending the BDNB model to other Member States of the European Union. The structure of this analysis is based on three main areas:

- a technical and comparative analysis of open data or restricted building databases across a panel of seven Member States, selected according to objective criteria (energy consumption, GHG emissions, climate risk, open data maturity), by conducting a thorough review of available data foundations, their volume, structure, and access conditions;
- an assessment of each country’s capacity to reproduce a foundational data layer compatible with a BDNB-type approach, analysis of database interlinkages, and proposals for methodological principles to stimulate and support the emergence of equivalent mechanisms across Europe;
- an investigation of the main European initiatives structuring knowledge of the building stock through a documentary approach (e.g. European Building Stock Observatory – BSO, EUBUCCO database, GISCO project);

At each stage, the report will endeavour to provide:

- systematic references (links, data sheets, official documentation),
- and, where necessary, explicit mention of any weaknesses, gaps, or uncertainties regarding the robustness of sources or existing systems.

This study therefore aims to provide a comparative analysis of the conditions required to generalise a national building database, in support of European public policies for the renovation and management of the building stock.

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2 Objectives

2.1 General objective

The general objective of this report is to evaluate, on scientific and technical grounds, the feasibility of extending the French BDNB approach to other European countries. This evaluation aims to support the acceleration of energy renovation within the building stock and to strengthen the capacity for monitoring, simulation, and planning of public policies as part of the European ecological transition and the LIFE-2021-CET-HOMERENO project.

2.2 Specific objectives

- Carry out an initial comparative analysis of all European Union Member States.

  This stage involves collecting and comparing the necessary information for identifying priority countries, based on objective criteria (energy consumption, GHG emissions, exposure to climate risk, and the maturity of open data policies).

- Assemble a focused panel of seven target countries for in-depth analysis.

  Within the project, five countries were predefined: Belgium, Luxembourg, Germany, Italy, and Spain. Two additional countries were selected from Member States with advanced open data policies, in order to complete the panel and maximise the representativeness and relevance of the comparative study.

- Investigate key European initiatives

  Conduct a documentary review of initiatives such as the European Building Stock Observatory (BSO), the EUBUCCO database, and the GISCO project. The objective is to clarify the level, quality, accessibility, and potential for pooling existing resources in relation to the requirements of a BDNB-type approach.

- Perform a comparative analysis of the building databases of the seven selected countries

  For each country, identify and characterise the existing databases (open data and restricted access), the possibility of constructing a foundational building data layer, their availability, coverage, and completeness rates, access rights, and assess their suitability for integration and exploitation within a building data strategy.

- Assess the capacity to establish a “core data layer” in each country of the panel:

  Identify the technical and organisational conditions required, as well as any potential obstacles, for constructing the initial simulation layer, similar to step 1 of the ‘Concerto Renov’ initiative, using the analytical framework developed for the BDNB.

- Propose a methodological framework to foster the creation of BDNB-like initiatives in Europe

  Present the scientific principles of interoperability and pooling, potential partnership scenarios, and European resources to be mobilised (cooperation platforms, technical support).

- Formulate operational and strategic recommendations

  Guide public decision-makers and stakeholders on the preferred directions for extending a harmonised BDNB-type approach, including identified limitations and opportunities for improvement.

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3 Context

3.1 Buildings at the heart of Europe's energy, environmental and digital transition

The building sector accounts for nearly 40% of final energy consumption and more than a third of CO_2 emissions in the European Union, making it a fundamental pillar of the decarbonisation strategy led by the European Green Deal and the "Renovation Wave." Over 97% of the building stock will require renovation before 2050 in order to meet the EU's climate targets (BPIE - Buildings Performance Institute Europe, 2020). In this context, the availability, structuring, and openness of building-related data are crucial for designing, managing, and dynamically adjusting public policies on the energy transition.

European regulations, particularly the Energy Performance of Buildings Directive (EPBD) - (European Union, 2024b), the Energy Efficiency Directive (EED) (EED) - (European Union, 2023) and the EU Data Act - (European Commission, 2024) require the establishment of comprehensive and interoperable national or European building data repositories. These repositories are intended to ensure the comparability, analytical reproducibility, and equal access to essential information for all sector stakeholders.

Among the key instruments for effectively scaling up renovations, the sharing and harmonisation of data are of paramount importance: energy performance certificates, consumption profiles, technical characteristics of buildings, and feedback from experience form a strategic information base. Such data enable the production of targeted analyses, the identification of priority segments, the orientation of actions, and the evaluation of impacts at various territorial levels.

Finally, the exploitation of these structured and shared data sets underpins the deployment of advanced digital services and the emergence of innovations dedicated to renovation and other essential themes. By promoting their integration, Europe will equip itself with the necessary tools to achieve the industrialisation of energy renovations and to support progress towards its climate objectives.

3.2 Buildings databases: multifunctional and structuring tools

3.2.1 Inventory and multi-scale knowledge of the building stock

Building databases have become indispensable for providing a detailed, structured, and updatable view of the building stock, with a multi-thematic (e.g., energy, environment, risks) and multi-scale representation. By centralising essential attributes (such as materials, uses, performance, etc.), they enable not only the precise identification of buildings to be renovated but also the monitoring of the dynamics and progress of renovation policies. Their granularity and reliability facilitate the proactive targeting of specific segments—for example, those with the highest energy consumption—the effective tracking of rehabilitation or conversion operations, and the production of robust indicators to guide public strategy and the effectiveness of incentive schemes supporting the energy and environmental transition.

3.2.2 Decision support for optimal urban management

As analytical and forward-looking management tools, building databases now serve as fundamental resources for decision-making and urban management, both for local authorities and national institutions, as well as for the private sector. Their integration into land management, local taxation, and urban development monitoring is decisive for effectively targeting, prioritising, and redirecting public interventions. These databases enable public actors to adjust social planning, strengthen the fight against energy poverty, and accurately designate priority sectors for renovation, in line with the recommendations of BPIE (BPIE - Buildings Performance Institute Europe, 2020) and national and European regulatory requirements.

Furthermore, the high level of detail in these descriptions and the increasing openness of interfaces (e.g. APIs, portals) provide support for regulatory compliance (such as calculating renovation rates and assessing performance—thermal, environmental, etc.) while reinforcing coordination between sectoral policies and various levels of governance.

3.2.3 Support for innovation, research, and collective intelligence

Structured and open access to building databases accelerates innovation by enabling widespread advanced analysis, large-scale simulations, the development of digital twins, and the dissemination of visualisation tools. These databases stimulate both academic research and technological entrepreneurship and also foster the emergence of citizen or community initiatives focused on transparency, shared governance, and contributing to public knowledge of the built environment. They make it possible to objectively assess energy potential, map risks, or enable shared governance of territories (Florio et al., 2023). This structuring of data turns building databases into the foundation of a digital common good and a driving force for urban and democratic transitions.

3.3 The central and strategic importance of open data

3.3.1 The fundamental role of open data

Open data represents a major driver for promoting transparency, innovation, and efficiency across a range of sectors. Its accessibility and reusability allow both public and private stakeholders to rely on trustworthy information and cross-reference different datasets in order to generate new knowledge. The intrinsic value of open data lies in its ability to democratise access to information, offering a wide variety of actors—including governments, businesses, researchers, and citizens—the opportunity to use it to inform decision-making, develop innovative services, and improve or optimise strategies and operations (Hein et al., 2023).

In today's context, where the volume of generated data is expanding exponentially, open data acts as a catalyst for innovation by encouraging collaboration and the sharing of knowledge. It helps break down information silos, thereby promoting interoperability between different datasets and systems. This is particularly relevant in complex fields such as the building sector and urban planning, where the combination of diverse data sources (socio-economic, environmental, urban) can reveal correlations and trends that would otherwise remain invisible. Moreover, making data open builds public trust in institutions by providing greater transparency around their activities and decisions. In doing so, open data lays the foundations for more open and participatory governance—a necessity for territorial development.

In the building sector, the adoption of open data principles carries strategic importance. Opening up data allows for the creation of precise and regularly updated inventories of the building stock, offering a detailed picture of the condition of the property portfolio. Beyond compiling such inventories, the availability and cross-linking of open data spur the development of innovative strategies and solutions to accelerate and optimise renovation, address adaptation challenges such as overheating and urban heat islands, and improve urban management, including responses to issues like urban heat exposure. By facilitating the pooling of information relating to buildings, open data serves as a major lever for improving urban planning, enabling more efficient resource allocation, and fostering the emergence of more sustainable and resilient built environments. The ability to aggregate, compare, and exploit multiple sources of information strengthens the relevance of analysis and the reach of public policies, while underpinning innovation in support of local stakeholders.

3.3.2 The need for standardisation in the building sector

The standardisation of open data is a strategic and structuring challenge for the building sector, given the diversity, heterogeneity, and complexity of the information involved—such as cadastral data, building attributes, energy diagnostics, environmental risks, or usage statistics. Standardising data involves establishing norms across the entire value chain: defining the attributes to be collected, structuring and organising datasets, storage and transfer protocols, as well as terminology and

semantic descriptions, in line with best practices established nationally and internationally (Gal & Rubinfeld, 2019).

Standardisation and normalisation of data respond to very real needs for fluidity, efficiency, and collaboration among stakeholders. This encompasses the entire value chain—not only the interfaces (e.g. APIs), but also dataset structures, exchange formats (e.g. GeoJSON, GML), shared attribute definitions, data organisation on geoportals and national platforms, as well as the enrichment and clarity of metadata. The use of interoperable portals and open catalogues guarantees semantic and technical alignment of reference systems, preventing fragmentation, reducing redundancies, and maximising reusability. Shared metadata provides users with the necessary keys to interpret and coherently utilise datasets, while ensuring portability and traceability. However, a diversity of needs, the lack of consensus on terminology, and the coexistence of open standards with proprietary solutions still create difficulties, particularly in terms of effective data sharing, data transformation, or the interconnection of heterogeneous systems. These obstacles highlight the importance of collective governance of standardisation and of the coherent deployment of data cycle tools, from formats to usage methods and documentation.

National structuring initiatives, such as the Référentiel National du Bâtiment (RNB, France) with its unique identifiers (ID-RNB), and European initiatives like the INSPIRE standard or CityGML, illustrate the current momentum towards a common language that guarantees the uniqueness, stability, and traceability of building data. In parallel, open source tools and adaptable or intermediary formats (e.g. GeoJSON) facilitate the translation and integration of data from various systems, even where sectoral governance is lacking. However, the widespread establishment of standards in the building sector still faces major barriers: diversity of business needs, resistance to change, an absence of consensus on terminology, fragmentation of technical solutions, and a lack of resources or support for system transformation. Added to these are the still uneven maturity levels of many sectoral standards, offset in part by the open source movement's collaborative documentation and shared experimentation.

To overcome these challenges, it is essential to strengthen collective governance, promote the co-construction of relevant standards, and actively support data producers as they evolve their practices. The participation of all stakeholders—local authorities, the State, the private sector, academia, and end users—as well as recognition of the importance of standardisation for everyone, are vital to fully exploit the potential of open data in the building sector, supporting innovation, resilience, and better services.

3.4 European strategies and European data spaces for shared data

European strategies regarding shared data are built on a legislative and technical foundation, spearheaded by Directive 2019/1024/EU on open data (European Union, 2019), which requires Member States to provide free access to, and facilitate the reuse of, high-value public datasets—particularly those classified as "High Value Datasets" (HVD) in sectors such as buildings, mobility, and the environment (European Union, 2022a). This momentum has been reinforced by the Data Governance Act (European Union, 2022b), which establishes the framework for secure, transparent, and ethical data sharing, including safeguards for personal data protection and the governance of shared data spaces.

The European Union structures its approach around shared initiatives and infrastructures designed to guarantee technical interoperability (open formats, standardised APIs, federated catalogues), and to standardise the entire chain of publication, access, and reuse of public data at the continental level. A core technical pillar is the INSPIRE Directive (European Commission, 2007), which sets out the harmonisation model and architecture for key European geospatial layers (administrative boundaries, land parcels, addresses, buildings), based on standard data models, multilingual metadata catalogues, geographic web services (WMS, WFS), and the federation of national geoportals (e.g. INSPIRE Geoportal ; geodati.gov.it ; pdok.nl). Thanks to INSPIRE, observers, public administrations, and businesses enjoy harmonised access to validated, standardised datasets, which facilitates cross-border comparisons and the flow of innovation at the European scale.

The practical application of these strategies in the building sector is grounded in this technical and regulatory foundation, promoting the creation of national and European databases covering essential layers: cadastre, addresses, Energy Performance Certificates (EPC), natural hazards, and other harmonised geodata. Legislation such as the Energy Performance of Buildings Directive (EPBD) (European Union, 2024b) makes the establishment of a national EPC register a prerequisite for the large-scale, managed renovation of Europe's building stock.

At the same time, initiatives such as the EU Building Stock Observatory (European Commission, 2025), GISCO/Eurostat - (Eurostat, 2025) and EUBUCCO (Milojevic-Dupont et al., 2023) aggregate, harmonise, and redistribute these datasets at the EU level to support comparative research, assessment of climate policies, urban planning, and monitoring of territorial inequalities. Innovation relies on effective coordination between national platforms and federated European infrastructures, ensuring the durability, accessibility, and transnational compatibility of key building data, while maintaining high standards in terms of standardisation, documentation, and control by data holders.

3.5 Base de Donnée Nationale des Bâtiments - BDNB

3.5.1 Origins and objectives

The BDNB (National Building Database in English) is a French project developed by the Scientific and Technical Centre for Building (CSTB), aiming to create a comprehensive, interoperable, and regularly updated building database for the French building stock. Its development responds to a dual need: to provide a reliable multi-source inventory supplying public knowledge, and to offer a technical foundation for the management of energy, environmental, and territorial policies. The initiative was launched with a digital commons approach, promoting standardisation, openness, transparency, and the cross-cutting use of data. To know more about the BDNB project, visit bdnb.io.

3.5.2 Data sources - socle data

The construction of the BDNB is based on the integration, consolidation, and cross-referencing of numerous public and non-public databases, all systematically documented and regularly synchronised. At the core of the system, the BDNB draws from several key national datasets:

- The National Address Database (BAN - ETALAB), used for standardising and geolocating addresses as well as merging spatial information from multiple sources – https://adresse.data.gouv.fr/
- Building footprints (BD-TOPO® - IGN), providing building ground coverage, building heights, and other essential data for morphological and cartographic analysis – https://www.data.gouv.fr/datasets/bd-topo-r/
- Land and property records – fiscal data (DGFiP - Cerema), which combine cadastral information, property value, legal status, usage, and taxation at both parcel and building level – https://datafoncier.cerema.fr/fichiers-fonciers
- Energy Performance Certificates (EPC), the official source for integrating standardised energy label information – https://observatoire-dpe-audit.ademe.fr/donnees-dpe-publiques
- The National Building Register (RNB – https://www.data.gouv.fr/datasets/referentiel-national-des-batiments/), designed to assign a unique and stable key to each building, is intended to become the foundation of national identification (see bdnb.io/blog/29/05/2024/article_rnb/).
- Specialised datasets that enrich records according to professional criteria: occupancy typology, year of construction, technical equipment, renovations, etc., and other open datasets or partner-contributed data integrating environmental, urban, natural, or technological risk, public amenities, and zoning layers.

Beyond standard descriptive data, the BDNB incorporates ongoing development of advanced indicators to support analysis, modelling, and territorial forecasting, such as:

- calculations of simulated energy consumption—simulated EPC—for each residential building,
- simulation of overheating indicators (including analysis of thermal risk at the building or dwelling unit level during heatwaves),
- estimation and cross-referencing of DVF (Demande de Valeur Foncière—property value requests) data for economic analysis of the building stock,
- Regular production of new composite indicators related to building status and performance, such as energy performance and renovation potential.

The BDNB's data enrichment is supported by an industrial-scale synchronisation and version management system, relying on:

- semi-automated exchanges with partner databases, occurring at least quarterly, but often continuously when possible.
- geospatial processing and algorithmic matching workflows between sources, ensuring information consistency at the individual building level.
- probabilistic imputation (machine learning) to fill any gaps or inconsistencies (e.g., complete morphology information, performance, or usage in the absence of explicit declarations). There is transparent management of data history, traceability, and metadata (including source, update date, and data status).

The methodology is fully documented and published (bdnb.io), ensuring reproducibility, transparency, and alignment with European best practices in data management.

3.5.3 Method and Innovations

The BDNB stands out thanks to an evolving methodological and technical approach, aimed at constructing an integrated and reproducible building data reference framework at the national level. At present, the BDNB coordinates the matching and cross-referencing of multiple heterogeneous datasets (such as the land registry, addresses, energy performance certificates, fiscal records, and statistical data) through processes involving geospatial aggregation, algorithmic processing, and systematic documentation.

One of the BDNB's key strategic perspectives is its gradual alignment with the National Building Register (RNB), which is intended to become the official central key for the unique identification of buildings in France. While a link with the RNB has already been established, the process of full integration remains ongoing. The medium-term aim is to improve reliability, avoid duplications, and ensure the highest possible level of interoperability with both national and European infrastructures (see: bdnb.io/blog/29/05/2024/article_rnb/).

From a technical perspective, the BDNB systematically adopts open standards, releasing its data in three main formats: CSV, GPKG (GeoPackage), and SQL dump. This trio covers the requirements of a wide range of users—from office software through to advanced GIS applications, and up to large-scale relational database integration.

Full traceability throughout the data cycle is ensured: every operation, transformation, or enhancement is publicly documented and historically recorded. The sources, the methods of interlinking, updates, technical documentation, and production scripts are all made publicly available. This scientific and technical transparency makes the BDNB an auditable, improvable, and reproducible model—see: data_model

Finally, the BDNB promotes a strategy of openness and differentiated governance:

- Public data are released under the Etalab Open Licence (Legifrance, 2017), and may be reused without restriction;
- Data with restricted access ("having rights") and results from advanced ("expert") models are disseminated in line with current legal and ethical requirements, particularly in compliance with the GDPR and statistical secrecy.

In summary, the BDNB methodology—combining open formats, comprehensive documentation, ongoing progress towards the RNB central key, and transparency—offers a reproducible blueprint for any digital commons building project elsewhere in Europe.

3.5.4 Uses and impacts

The BDNB is a structuring tool for all stakeholders in the sector, from territorial policy to the energy planning of the building stock. It enables the quantification, mapping, and precise management of the entire built environment at both national and subnational levels. By assigning an identity record to each building, the BDNB provides a foundation for territorial planning—such as the identification and simulation of the energy performance of the building stock and other indicators, as well as recognising trends in construction and transformation.

One of its main impacts lies in the targeting and operational monitoring of climate adaptation policies. By cross-referencing energy performance diagnostics (both modelled and observed EPCs), morphological data, and social criteria, the BDNB helps identify energy-saving opportunities, “energy-inefficient” buildings, and priority intervention areas. This analytical support is crucial for local authorities, providing data needed for the development of climate plans, allocation of grants, or planning of renovation incentives.

Furthermore, the integration of complementary layers (climate risks, networks, taxation, uses, creation/demolition of surfaces, among others) paves the way for cross-sectional analyses concerning urban planning, climate adaptation, and risk management. Public stakeholders, from local to national level, can therefore more effectively manage urban resilience, infrastructure programming, and the tracking of the energy transition.

Transversally, the BDNB maximises the evaluation of public policy impacts: its regular updates and comprehensive coverage may enable the measurement of progress (for example, in renovation rates or energy efficiency) and provide an objective foundation for long-term strategic decisions.

Finally, the BDNB fosters innovation, not just in the public sector but also in private and non-profit spheres: the availability of an API, its dedicated visualisation portal gorenove.fr (cited as an example in the Commission Notice providing guidance on new or substantially modified provisions of the recast Energy Performance of Buildings Directive (EU) 2024/1275 for Article 22), and downloadable datasets all support the creation of “digital twins” of the building stock, the deployment of artificial intelligence algorithms, and the development of additional visualisation platforms. This dynamic approach to data enhancement gives the BDNB a central role in France’s digital building ecosystem, and—through its transferability—acts as a powerful lever for innovation and sociotechnical impact throughout Europe.

3.5.5 The BDNB: a transferable model for Europe

The BDNB stands out as a reference model for structuring building data, which could readily be adapted by other European Union member states. In response to recurring sectoral challenges—fragmented sources, heterogeneous formats, difficulties in access, and the absence of a central pivot—the BDNB provides a systemic solution aligned with the interoperability, pooling, and transparency requirements advocated by the European Union and the OECD (OECD, 2025) .

Several factors explain the transferability and reproducibility of this model:

1. **Modular architecture and unique pivot**: at its core, the system relies on a “building identity card” soon based uniquely on a stable national identifier (RNB). This pivot facilitates the aggregation, cross-referencing, and enrichment of heterogeneous datasets, thus solving a central issue seen in many European national systems that lack such a common key.
2. **Rigorous and transparent methodology**: the BDNB promotes open, continuously enriched documentation, coupled with an algorithmic cross-referencing approach and systematic integration of various public sources and “entitled parties” (land registry, addresses, EPCs, taxation, urban planning, etc.). This self-documented reference base is therefore reproducible and open to audit, compatible with the European approach to constructing unique databases

at different scales (national, continental).

3. **An adapted dissemination framework**: by precisely distinguishing between open data, “entitled party” data and expert data, the BDNB allows for a fine adjustment of the level of openness, in coherence with national data management policies while maximising utility for all stakeholders.
4. **Native interoperability**: thanks to a harmonised data model, the use of unique identifiers, open formats, and standardised documentation, the BDNB enables automated linking with other national datasets and is immediately in line with European requirements for upward integration, thereby laying a solid foundation for the future single European market for building data.

4 Methodology

Before transposing the BDNB model into another national context, a feasibility study is essential. This is, therefore, the main objective of the present study. The methodology is based on a multi-step comparative approach, designed to ensure the objectivity and scientific reproducibility of the analysis: defining precise feasibility criteria (technical, data-related, and interoperability), the justified selection of target countries (panel), the collection and comparative evaluation through a multi-criteria framework (using institutional sources, literature, and exchanges with operators), and the systematic acknowledgement of limitations tied to the varying availability of data and the differing dynamics at national or European level.

4.1 Comparative analysis across all European Union member states

The initial stage of the process consists of a comparative analysis of all 27 EU Member States, aiming to provide an objective overview for the selection of priority countries. This selection is based on several key criteria: average energy consumption of buildings (residential and tertiary), greenhouse gas emissions from the sector, level of exposure to climate risks, and, crucially, the maturity of open data policies and infrastructures (accessibility, standardisation, frequency of updates).

The identification of the seven target countries (five of which were predefined) for in-depth study focuses on those where renovation challenges are significant and where open data initiatives are sufficiently advanced to enable the reproducibility of tools like the BDNB. The quality, interoperability, and documentation of building databases are decisive factors in assessing the potential for deploying a harmonised model similar to the BDNB at the national level.

This multi-criteria filtering will not only enable the analysis to focus on contexts where the BDNB approach will have the greatest structuring impact, but also maximise the chances of success for future Europe-wide roll-out by selecting countries that are leaders in public data policy and innovation within the building sector.

4.2 Choice of a restricted panel

The restricted panel includes five target countries predefined by the project mandate: Belgium, Luxembourg, Germany, Italy, and Spain. To complete this group and maximise the diversity of contexts, two additional countries were selected on the basis of the advancement of their open data policies and the maturity of their management of building databases, chosen from among the most innovative members of the European Union. The detailed selection process is based on a multi-criteria comparative table, derived from the information gathered in the previous stage.

4.3 Investigation of key European initiatives

The investigation phase begins with a targeted review of recent scientific publications and institutional reports, before focusing on the analysis of major structuring European initiatives—in particular, the European Building Stock Observatory (BSO), the EUBUCCO database, and the GISCO project—in order to assess their methodology, quality, and accessibility.

Where possible, direct exchanges (interviews or institutional contacts) with managers or responsible parties for these mechanisms have clarified the conditions of access, use, and associated best practices, enriching the analysis with practical and up-to-date field information.

4.4 Inventory, characterisation, and analysis of national databases

The inventory and national characterisation phase first aims to identify, in each country of the panel, all existing databases relating to the building stock that could serve as the foundation for a data core, whether open access or restricted. For each identified dataset, the analysis considers its potential compatibility with a BDNB-type approach, assessing coverage, available attributes, spatial and

temporal granularity, the existence of stable identifiers, and technical accessibility (government open data portals, APIs, standard formats, documentation).

This investigation will highlight, for each country, strengths (comprehensive coverage, rich documentation, interoperability), obstacles (missing essential attributes, regulatory limitations, fragmentation of databases, lack of interfacing services), and risks associated with integration. This detailed diagnosis prepares the subsequent stage, analysing feasibility conditions and identifying adaptations needed to align each ecosystem with a future "data core" logic based on the BDNB model.

4.5 Proposal of methodological principles and recommendations

The formulation of methodological principles and recommendations will first be based on the definition of a common framework, inspired by INSPIRE standards, the EU Data Act, EBSA recommendations, and the technical achievements of the BDNB, in order to guarantee the harmonisation, interoperability, and portability of building data at the European level. This framework takes into account lessons learned from practical experience in Switzerland, the Netherlands, and France, particularly in terms of collaborative governance, gradual standardisation, and the key role of trusted third parties or data-managing entities.

5 Results

5.1 Comparative analysis across all European union member states

The comparative analysis conducted across the 27 European Union Member States is based on a methodological selection of six key criteria, designed to objectively identify the countries where establishing a National Building Database (BDNB) would be most strategic. This approach combines, according to a weighted evaluation grid, the maturity of open data access, energy consumption specific to the residential building sector, national greenhouse gas (GHG) emissions linked to residential and tertiary energy use (notably heating and cooling), the proportion of floor area built before 1980, exposure to climate risks, and the size of the population potentially affected. Assigning differentiated weights to each criterion is intended to reflect their relative contribution to the successful, high-impact deployment of the BDNB.

Each criterion was weighted differently to reflect its specific contribution to the value creation of a BDNB. The maturity of open data policies emerges as the principal lever, with a weighting of 40%. Scientific literature and institutional analyses, notably from the European Commission and the annual "Open Data Maturity in Europe" (European Union, 2024a), report, confirm that successful open data policies are built on four pillars: political strategy, the presence of a national portal, the quality of datasets, and the real impact of their reuse. The aggregation of these dimensions enables the calculation of a synthetic comparative index, determining the maturity level of each Member State. A high score reflects better interoperability, greater sharing capacity, and optimal valorisation of public data—all of which are essential factors for the robustness of an infrastructure such as the BDNB. Beyond the existing European index, a specific qualitative assessment was made here, based principally on the relevance of open data in the building sector and its capacity to provide a foundation for a structured national database, similar to the BDNB.

National GHG emissions (25%) and energy consumption (20%) from the building sector are central to Europe's energy transition. Ranking Member States along these axes focuses the analysis on those with the greatest decarbonisation potential, maximising the catalytic effect that the BDNB might have on achieving "Fit for 55" and "Net Zero Carbon" targets. These indicators are informed by Eurostat 2023 data: for energy consumption, the "households" category (https://ec.europa.eu/eurostat/databrowser/view/nrg_d_hhq__custom_17983966/default/table), and for GHG emissions from heating and cooling, the corresponding series (https://ec.europa.eu/eurostat/databrowser/view/ENV_AC_AINAH_R2__custom_17985819/default/table). All values were harmonised per capita to ensure international comparability, then integrated according to the selected weightings: 15% for emissions and 10% for final energy consumption. In addition, the proportion of floor space built before 1980 was also included (20%), as this ageing building stock is considered a priority for energy renovation works.

The analysis then factors in exposure to climate risks, assigned a weighting of 5%. This criterion is a key component of the multi-criteria grid, reflecting the vulnerability of territories to extreme climate events. The WorldRiskIndex (WRI)—$WRI = exposure * vulnerability$–, serves as the reference, combining around sixty variables to quantify the likelihood of seven main categories of natural disasters (earthquakes, tsunamis, cyclones, coastal and river flooding, droughts, sea level rise), also integrating national capacities for risk management and adaptation *(Bündnis Entwicklung Hilft, 2024).* The weighting for this criterion underlines the importance of prioritising territories where adaptation and risk management are crucial for national resilience.

Furthermore, the analysis incorporates demographic factors by evaluating the proportion of the population potentially susceptible to climate impacts within each territory. The inclusion of population data, with a designated weighting of 10%, emphasizes densely populated regions, where the implementation of a BDNB would yield the most substantial benefits for protection and adaptation. This demographic criterion aims to optimize the social efficacy of building data management initiatives by concentrating efforts on areas where human interests are most significant.

5.1.1 Summary of main results

The comparative study of the 27 European Union Member States reveals varied dynamics according to the principal indicators. Demographically, Germany, France, Italy, and Spain account for the majority of the European population, which naturally results in these countries having the greatest share of primary energy consumption and total greenhouse gas emissions from the residential sector. This demographic concentration heightens both energy and environmental challenges, making these regions strategically significant for any major intervention in the building stock.

When analysing residential energy consumption in relation to population, the hierarchy shifts: Finland, Austria, Denmark, and Luxembourg emerge as the countries with the highest final energy consumption per capita. This can be attributed to a combination of factors such as harsher climatic conditions, higher comfort standards, or a more energy-intensive building stock. The energy mix of each country also plays a key role in determining the amount of greenhouse gases produced per household, with notable differences depending on whether heating systems rely on fossil fuels or renewable energies.

For greenhouse gas emissions per capita, the results show significant disparities between EU Member States. Luxembourg records the highest levels of emissions related to heating and cooling per person, surpassing Belgium, Ireland, and Germany. The composition of the energy mix, alongside the overall efficiency of the building stock, explains this variation. Some countries may have high energy consumption but manage to contain emissions through substantial use of low-carbon energies—underlining the need to analyse consumption and emissions together.

Exposure to climate risks is highly variable across the European Union. According to the World Risk Index, Italy, Spain, and Greece are the most vulnerable countries, due to repeated exposure to major hazards such as earthquakes, floods, or droughts, combined with sometimes uneven risk management capacity at the local level. Taking this vulnerability into account is essential when planning and prioritising public policies aimed at building resilience.

The proportion of buildings constructed before 1980 remains a crucial criterion for identifying priority sites for energy renovation. Germany, France, Italy, and Spain together hold the majority of the EU's ageing building stock, thus intensifying the challenges associated with modernisation and reducing energy poverty. Incorporating these heritage buildings into renovation strategies is indispensable to achieving Europe's carbon neutrality goals.

Last but not least, the maturity of national open data systems is a key asset for developing national building databases. France, along with several northern European countries—such as Denmark, the Netherlands, and Finland—stand out for the quality, breadth, and advanced structuring of their building-related datasets. These nations have established comprehensive data governance policies that support reliable, up-to-date, and interoperable use of public information—a sine qua non for the successful implementation of a high-value national infrastructure.

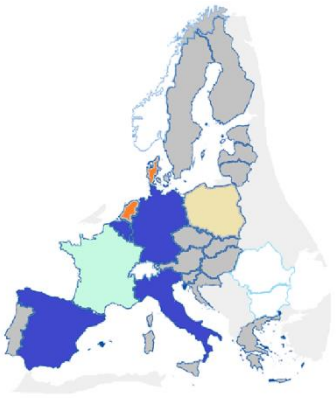
The national disparities observed for each of these criteria highlight the need to finely adjust strategies for deploying a national building database, taking into account each country's specific demographic, energy, informational, and climatic context, as well as its particular needs. For more details on the results and possible adjustments to the weightings, please refer to Table I in the Annex or the summary table below - Table 1.

Table 1. Summary of key factors and data availability in EU countries for the building sector

Country	Number of people (2021)	Normalised population score	Final residential energy consumption (Gigajoules) / person	Normalised final energy consumption score – residential	GHG emissions (kg CO_2 eq.) heating and cooling / person	Normalised GHG emissions score – heating/cooling per person	World Risk Index (%)	Normalised World Risk Index score	Floor area [Mm^2] – Built before 1980	Normalised score for floor area built before 1980	NOTE Building data (qualitative)	Normalised open data score – building data	Final score
France	67439568	0,82	22,494	0,41	485,06	0,36	7,54	0,66	2 305,14	0,57	4,50	1,00	0,73
Germany	81936440	1,00	27,037	0,55	940,17	0,72	4,1	0,33	4 008,78	1,00	3,00	0,40	0,64
Italy	59030133	0,72	19,567	0,32	696,20	0,52	11,11	1,00	2 129,38	0,53	3,00	0,40	0,50
Denmark	5840045	0,07	29,758	0,64	213,41	0,14	0,98	0,04	286,31	0,07	4,00	0,80	0,43
Netherlands	17475414	0,21	18,470	0,29	668,46	0,50	4,11	0,33	600,73	0,15	3,50	0,60	0,41
Poland	37019321	0,45	22,468	0,41	817,93	0,62	4,74	0,39	873,00	0,22	3,00	0,40	0,40
Belgium	11554767	0,14	25,194	0,50	1126,46	0,86	5,1	0,43	482,74	0,12	3,00	0,40	0,40
Spain	47400798	0,58	12,245	0,10	357,57	0,26	9,74	0,87	1 644,35	0,41	3,00	0,40	0,39
Finland	5533793	0,06	41,476	1,00	117,84	0,07	1,54	0,09	358,30	0,09	3,50	0,60	0,38
Luxembourg	643941	0,00	29,723	0,64	1300,39	1,00	0,61	0,00	23,84	0,00	3,00	0,40	0,37
Sweden	10452325	0,12	28,247	0,59	29,11	0,00	3,23	0,25	399,60	0,10	3,50	0,60	0,34
Ireland	5145710	0,06	20,693	0,36	1038,95	0,79	2,55	0,18	73,82	0,02	3,00	0,40	0,33
Czechia	10524167	0,12	25,811	0,52	767,54	0,58	1,09	0,05	306,43	0,07	3,00	0,40	0,33
Austria	8969068	0,10	30,777	0,67	566,92	0,42	1,16	0,05	449,70	0,11	3,00	0,40	0,33
Croatia	3871833	0,04	24,095	0,46	376,30	0,27	4,78	0,40	123,35	0,03	3,00	0,40	0,28
Slovakia	5449270	0,06	18,631	0,29	499,78	0,37	1,03	0,04	135,15	0,03	3,00	0,40	0,26
Lithuania	2810761	0,03	22,804	0,42	326,41	0,23	2,32	0,16	64,74	0,01	3,00	0,40	0,25
Cyprus	923382	0,00	15,260	0,19	460,92	0,34	3,5	0,28	72,29	0,02	3,00	0,40	0,25
Estonia	1331824	0,01	29,422	0,63	134,25	0,08	1,77	0,11	59,24	0,01	3,00	0,40	0,24
Latvia	1893223	0,02	23,700	0,45	228,04	0,16	3,01	0,23	45,23	0,01	3,00	0,40	0,24
Slovenia	2108977	0,02	20,651	0,36	317,59	0,23	2,1	0,14	56,93	0,01	3,00	0,40	0,24
Portugal	10343066	0,12	12,379	0,10	169,29	0,11	5,08	0,43	388,30	0,09	3,00	0,40	0,24
Greece	10482487	0,12	15,008	0,18	549,72	0,41	8,61	0,76	463,92	0,11	2,00	0,00	0,15
Hungary	9610393	0,11	23,382	0,44	689,57	0,52	0,95	0,03	251,68	0,06	2,00	0,00	0,15
Romania	19053815	0,23	16,497	0,23	311,62	0,22	3,22	0,25	309,67	0,07	2,00	0,00	0,11
Bulgaria	6519789	0,07	13,142	0,12	148,04	0,09	2,43	0,17	265,01	0,06	2,00	0,00	0,06
Malta	519564	0,00	9,154	0,00	81,39	0,04	1,03	0,04	10,40	0,00	2,00	0,00	0,01

Co-funded by the European Union

5.2 Choix of the restricted panel



In light of the detailed results presented above and in accordance with the project's requirements, the final panel selected for this study comprises seven countries: Germany, Belgium, Italy, Luxembourg, the Netherlands, and Denmark. This choice is not arbitrary; it is based on the detailed multi-criteria analysis described earlier, and on the search for a balance between statistical representativeness, sectoral relevance, and the potential for experience transfer. Collectively, these countries account for nearly 66% of the total population of the European Union, concentrate 65% of final residential energy consumption, and 71% of the sector's greenhouse gas emissions from heating and cooling activities recorded at the EU level. In addition, they include 71% of the building stock constructed before 1980, representing the most critical segment for the effectiveness of large-scale energy renovation in Europe.

This panel brings together a critical mass of dwellings (nearly 71% of the total housing stock and 62% of all buildings), offering strong potential for replicating the BNDB methodology. The selection also explicitly integrates a diversity of "open data" ecosystems: countries with advanced data accessibility and structuring sit alongside others with an intermediate maturity, making both comparison and the identification of good practices transferable across the European Union possible. This diversity enhances the scope of the lessons learned, facilitates extrapolation to other national contexts, and optimises the conditions for scaling up a future National Building Database.

5.3 Investigation of key European initiatives

5.3.1 General architecture of European action

The architecture of European policy is primarily built on an integrated regulatory framework, structured around the Open Data Directive (2019/1024/EU), the Data Governance Act, and the INSPIRE Directive (2007/2/EC), which together form the foundation for access, sharing, and harmonisation of data at continental scale. This body of regulation not only ensures the release of strategic datasets as open data (High Value Datasets), but also imposes strict requirements regarding interoperability, documentation, and dissemination in common formats, thereby supporting the creation of a coherent transnational digital infrastructure.

At the heart of this architecture, INSPIRE plays a central role as its backbone: it coordinates the common reference framework, structures metadata catalogues, establishes standardised models for core geographic layers (such as addresses, land parcels, buildings, administrative boundaries), and directs the alignment of national geoportals via federated services (WMS, WFS, REST API). This infrastructure enables smooth data flows, multi-scale data integration, and the reproducibility of analyses at the Union level.

European action is made tangible by the creation of sector-specific European Common Data Spaces, which bring together public and private data within a secure and interoperable framework. These initiatives facilitate widespread pooling of data and enable platforms such as the EU Building Stock Observatory, GISCO/Eurostat, and EUBUCCO to produce harmonised data sets for monitoring climate, energy, or urban policies.

The systemic integration of the construction sector is based on these principles: the Energy Performance of Buildings Directive (EPBD) requires the maintenance of open and compatible national public registers of Energy Performance Certificates (EPCs), which feed into both national and European planning. This semantic and technical linkage is reinforced by the adoption of international standards such as CityGML and GeoJSON, enabling innovations to migrate towards the European digital single market.

Finally, the European architecture is inherently oriented towards sustainability: it relies not only on technical and regulatory mechanisms, but equally on shared governance among institutions, agencies, Member States, and private ecosystems. These mechanisms are tested and improved through calls for projects, innovation laboratories, and consortia, ensuring constant adaptability to the rapid evolution of needs, uses, and data technologies.

5.3.2 Major European databases and observatories

5.3.2.1 EU Building Stock Observatory (BSO)

The EU Building Stock Observatory (BSO) is the European Commission's central platform dedicated to collecting, aggregating, and disseminating statistical data on the building stock of Member States. Its aim is to provide a unified, regularly updated dashboard enabling the monitoring of key indicators: number and types of buildings, energy performance classes, renovation rates, CO_2 emissions, equipment, usage, and other parameters essential for managing the sector. The BSO relies primarily on aggregated national data and statistical surveys, which grants it robust analytical capabilities at the macro level, while ensuring the comparability and traceability of European indicators.

However, the BSO's current remit does not include collecting or disseminating detailed data at the level of individual buildings or parcels. It mainly operates with statistical or synthetic data, compiling and consolidating results from national registers (such as Energy Performance Certificate databases), construction censuses, and sectoral surveys. This approach aims to provide European decision-makers with a robust monitoring and decision-support tool for the development, tracking, and adjustment of energy, climate, and urban policies. However, it also limits the Observatory's ability to support highly operational uses or micro-spatial analyses, which would require access to more detailed and georeferenced underlying databases.

In the future, the EU Building Stock Observatory intends to move towards greater granularity and the progressive integration of harmonised building-level data, to better meet the needs of public policy impact assessment and territorial planning. Current prospects include strengthened standardisation of national data flows, automation of reporting, and interconnection with European Common Data Spaces and other regular infrastructures such as EUBUCCO. The strategic objective is to equip Europe with a pan-European observation system, capable of providing multidimensional, dynamic, and open monitoring of the building stock, while also facilitating convergence with research, the private sector, and innovation in urban data.

5.3.2.2 European Building Stock Characteristics in Open Data (EUBUCCO)

EUBUCCO is, at the European scale, the first georeferenced database with building-level granularity covering all twenty-seven Member States. Designed as a pan-European resource, it aggregates, harmonises, and distributes information on more than two hundred million buildings, drawing on open data from national registers, cadastral systems, orthophotos, and other public inventories. The employed methodology ensures compliance with open standards and creates a harmonised model that overcomes the usual fragmentation in the European building heritage data landscape (Milojevic-Dupont et al., 2023).

EUBUCCO's notable feature is its level of granularity, providing attributes down to each individual building: year of construction, usage, height, and ground area. This level of detail offers significant analytical potential for research in urban morphology, density studies, vulnerability analysis, or modelling detailed territorial planning scenarios. Thanks to its comprehensive coverage and harmonised unique identifiers, EUBUCCO serves as an applied analytics tool previously inaccessible to researchers, planners, and decision-makers relying solely on aggregated European statistical observatories.

However, a current limitation of the database lies in the limited range of available attributes. EUBUCCO currently offers only four main variables per building, owing to the heterogeneity and availability of national sources, disparities in data models, and regulatory or technical obstacles to

accessing more detailed information (such as energy performance or materials). This restriction is accepted by the project team to ensure harmonisation and maintain transnational comparability, given the current stage of open data maturity across various countries.

The next priorities for EUBUCCO are to broaden thematic coverage: the goal is to add new attributes such as energy performance, structural typology, renovation index, and environmental exposure, while improving the frequency of updates to reflect the evolving dynamics of Europe's built environment. The team is also working to strengthen interoperability with other European databases (examples: GISCO Eurostat, INSPIRE, EPC registers) and to develop more advanced linkage tools, notably through the standardisation of identifiers and usage codes.

EUBUCCO's primary challenge lies in ensuring the convergence of standards, reliability, and sustainability of the data collection and processing chain, while balancing openness and quality with the sometimes fragmented or restrictive practices of public data producers. This requires establishing sharing agreements, developing integration protocols, and consolidating truly shared data governance at the European scale. EUBUCCO thus represents a crucial step towards open science applied to urbanism and energy, fostering innovation, planning, and the governance of housing and ecological transition policies across the EU.

5.3.2.3 Geographical Information System of the COmmission (GISCO)

GISCO, managed by Eurostat, is the benchmark platform for mapping and georeferencing within the European statistical information system. It systematically collects, structures, and publishes the essential spatial layers needed to produce European statistics: administrative boundaries, NUTS and LAU statistical units, networks, demographic and urban layers, land use, and territorial infrastructure. All data made available are based on models compliant with INSPIRE requirements, offering vector files, web services (WMS, WFS), and comprehensive multilingual metadata catalogues, which facilitate integration at every level of analysis and governance.

GISCO thereby serves as a crucial "pivot" for interoperability across the European Union: it brings together various reference systems from Member States, acts as a trusted interface for statistical comparison and data cross-referencing, and provides a common basis for monitoring European policies (cohesion, planning, energy, urban transition). The regular updating of reference layers (such as NUTS, LAU, Urban Audit) and high-level methodological documentation reinforce the reliability and authority of its datasets, whether for institutional statistics, territorial monitoring, or open research.

Nonetheless, GISCO faces several structural challenges. The first is its dependence on the cycle, quality, and harmonisation of national data reporting: the frequency and currency of updates vary significantly from one country to another, which can cause lags or discrepancies in the most detailed layers. Thematic integration is also conditioned by the maturity, availability, and actual standardisation of source datasets: the full incorporation of harmonised building data or energy performance streams remains an ambition to be consolidated in the years ahead. Synchronising temporal updates, managing institutional changes (such as changes in boundaries or municipal mergers), and local specificities also pose hurdles for ensuring perfect coherence at every scale.

Moreover, GISCO's evolution demands increased coordination among institutions, researchers, and Member States—especially regarding the adoption of new data models, the merging of metadata catalogues, and the development of common protocols for the automated integration of urban, building, or energy-related Big Data. Finally, to meet the challenges of urban planning, energy transition, and territorial resilience, GISCO will need to strengthen its interoperability with other key European initiatives such as INSPIRE, the EU Building Stock Observatory, and EUBUCCO, and incorporate the advances of "European Common Data Spaces" into its technical and regulatory architecture.

5.4 Comparative Analysis of Building Databases in Seven Selected Target Countries

5.4.1 Germany

5.4.1.1 Building data infrastructures and existing data sources

The foundation of Germany's national building data is structured around the official ALKIS system (Amtliches Liegenschaftskataster-Informationssystem), developed by the Association of State Surveying Authorities (AdV). ALKIS combines the automated land register (ALB) and the automated cadastral map (ALK) into a single, unified information system. ALKIS consists of three modules (acquisition/qualification, storage, dissemination), ensuring continuous updating, integrity, and distribution of cadastral data. The data model can include attributes in the following areas: parcel, owner, building, use, installations, topography, legal regulations, and territorial units (ADV-ALKIS). The full catalogue can be consulted on the ADV website.

Access licences for cadastral data are determined by the relevant authorities and sometimes require proof of legitimate interest to obtain specific information. Users can obtain extracts from the cadastre and other products via web services (e.g. : Geoportal allemand) or by visiting local offices. Data are generally available in various formats, such as XML, Shapefile, and CSV. Nevertheless, access to the data remains the main obstacle to its use. Various authors (Blanco et al., 2024; Dabrock et al., 2024, 2025; Hörner et al., 2024), particularly within the research sector, tend to use or supplement their studies with OpenStreetMap (OSM Germany) as an alternative data source.

Figure 1. Non-exhaustive visual from the German Geoportal: geoportal.de

Regarding the address register (HK-DE), it is also managed by the land registry. These data are regularly updated by the cadastral authorities of the different Länder. The "Central Office House Coordinates and Building Polygons" (ZSHH) collects and provides HK-DE data from the topographic administrations of the Länder, according to standardised fee and licensing models. ZSHH currently provides a HK-DE database updated twice a year. To date, more than 23 million buildings in Germany have registered addresses.

Regarding Energy Performance Certificates (EPCs), these are regulated by the European Energy Performance of Buildings Directive (EPBD) and are categorized into two types: the "Bedarfsausweis" (based on calculated performance) and the "Verbrauchsausweis" (based on actual consumption over the previous three years). This distinction may complicate comparisons between buildings. The

issuance and renewal of EPCs, which occurs every ten years, are conducted by authorized experts in accordance with stringent quality standards. At the regulatory level, EPC management is overseen by a central body, the GEG-Registrierstelle of the DIBt; this entity assigns a registration number to each EPC but does not maintain a public database containing all certificates or their details—only administrative information is recorded. Consequently, public access to EPCs is limited: there is no national register accessible to the public, nor is it possible to consult or download certificates in bulk; the process remains individual and conditional, especially during sales or rental activities. Random inspections are conducted, and German legislation envisions strengthening digitalization through the development of a "digital building logbook," designed to better organize and improve these data, particularly in the context of renovations and compliance with new European energy standards.

5.4.1.2 Data quality and interoperability

The quality of building data in Germany is primarily ensured by ALKIS, which provides cadastral geometries and regular update tracking. However, the granularity and timeliness of information vary between the Länder, as each applies its own administrative practices for attribute entry and data distribution. Datasets from ALKIS are comprehensive regarding land use, parcel identification, and legal status. Some Länder offer 3D datasets (LoD2/LoD3) and are experimenting with CityGML standards (notably for INSPIRE integration), but national harmonisation remains underway and is still a complex process. On the technical side, progress has been achieved through the adoption of GML formats and compatibility with INSPIRE. However, open data access or centralised APIs remain rare, and in most cases access is via regional portals or through paid licences. The documentation associated with datasets varies greatly: some Länder provide detailed datasheets and standardised metadata, while others are much more fragmentary. Ultimately, the main challenge remains the heterogeneity of the standardisation process, making the creation of a uniform and interoperable reference system at the federal level complex.

5.4.1.3 Governance, openness, and legal framework

In Germany, governance of building data is inherently decentralised, with each Land possessing significant autonomy over the publication, licensing (e.g. Datenlizenz Deutschland), and data flow management. At the federal level, the AdV harmonises specifications, while the BKG/ZSGT coordinates, aggregates, and distributes data nationally, and agencies such as Destatis produce statistical aggregates. There has been progress in data openness and increased interoperability among the Länder, but a fully functional national "one-stop shop" for all building stock (construction, usage, performance data) does not yet exist.

Consequently, access to data is mostly via the geoportals of the Länder (see Table 2), resulting in marked disparities in accessibility, available formats, and documentation standards. Major foundational datasets, such as fiscal or energy files, or sensitive data, remain unavailable or are only accessible with special authorisation, often reserved for institutional actors. Administrative coordination between the Länder presents a significant challenge for deploying a national building database, though initiatives like GDI-DE (dgi-de.org) aim to support greater interoperability and data sharing.

Table 2. Federal Geoportal and by Länder

Federal state	Link to geoportal
Géoportail Fédéral	https://www.geoportal.de
Bade-Wurtemberg	https://www.daten-bw.de
Bavière	https://www.bayernportal.de

Berlin	https://fbinter.stadt-berlin.de/fb/index.jsp
Brandebourg	https://geoportal.brandenburg.de/de/cms/portal/start
Brême	https://www.geo.bremen.de/
Hambourg	https://serviceportal.hamburg.de
Hessen	https://www.geoportal.hessen.de/
Mecklembourg-Poméranie-Occidentale	https://www.geoportal-mv.de/portal/
Rhénanie-du-Nord-Westphalie	https://www.bezreg-koeln.nrw.de/geobasis-nrw
Rhénanie-Palatinat	https://www.geoportal.rlp.de/
Saarland	https://geoportal.saarland.de/
Saxe	https://www.geodaten.sachsen.de/
Saxe-Anhalt	https://geodatenportal.sachsen-anhalt.de/gfds/
Schleswig-Holstein	https://geodatenportal.sachsen-anhalt.de/gfds/
Thuringe	https://geoportal.thueringen.de/
Basse-Saxe	https://www.geodaten.niedersachsen.de/startseite/

5.4.1.4 Usage potential and digital maturity

Germany demonstrates a high level of digital maturity, with a dense network of consultancies, open data initiatives, GIS platforms, and pilot projects on smart cities and digital twins. The introduction of 3D visualisations, CityGML/INSPIRE integrations, and Smart Region Digital infrastructures are evidence of strong innovation capacity, although these advances often remain limited to the regional or urban scale. Information pooling at the federal level is hindered by the diversity of approaches and the proliferation of regional portals, which restrict the emergence of comprehensive and fully interoperable platforms for the entire German building stock. Use cases in urban planning, energy renovation, and land management are particularly advanced in metropolitan areas and Länder with a strong technical tradition—such as Berlin and other major cities—but remain more varied in rural areas or for cross-national initiatives.

5.4.1.5 Challenges

The main challenge lies in the federal nature of governance: disparities in access, formats, update frequency, and attributes; the absence of a unique national key; administrative silence or slowness regarding standardisation; and restrictions on the use of certain fields (taxation/energy/consumption). Legal barriers may limit the immediate establishment and dissemination of a database similar to the BDNB in France. The cost of technical harmonisation and the obstacles related to inter-Länder coordination are substantial, even though INSPIRE initiatives and European open data projects are creating a favourable context in the medium term.

5.4.2 Belgium

5.4.2.1 Building data infrastructures and existing data sources

Belgium, characterised by its federal and regionalised structure, relies on a diverse range of platforms and reference systems for its building data.

The foundation of Belgian building data rests on a highly structured federal and regional institutional architecture, coordinated by the National Geographic Institute (IGN/NGI), which centralises, produces, and distributes the country's official geodata as the national "geobroker". The IGN manages core reference datasets: topographic maps, aerial photographs, digital mosaics, as well as the synchronisation of the "parcels" and "buildings" layers across all levels of governance. All of these datasets are documented, distributed, and viewable via the specialist geoportal geo.be, the national one-stop site for official geospatial datasets, which offers various formats (shapefile, geopackage, etc.) and advanced visualisation services.

Regarding the cadastre, the main reference is managed by the SPF Finance – General Administration of Patrimonial Documentation (financien.belgium.be), which provides the national parcel map, cadastral identifiers, and administrative units as open data (also available on geo.be). Unlike Germany (where ALKIS integrates geometry, usage, and ownership in one flow), the Belgian model separates federal land management (cadastre, addresses, administrative units) from specialised property management, which is delegated to the Regions for publication and updates:

- Walloon Region : the Wallonia Geoportal publishes the continuous mapping database (Projet Informatique de Cartographie Continue - PICC), address registries and cadastral history (ICAR).
- Brussels-Capital region : the UrbIS platform offers a precise reference for parcels, buildings, networks, land use, points of interest (POI), and includes a 3D component..
- Flemish region : manages its geospatial datasets on the Flemish geoportal – Geopunt, covering addresses, buildings, and sector-specific data.

For building energy certificates (EPC in Belgium, equivalent to DPE in France), each region maintains its own EPC database, reflecting the country's federal structure. EPCs (PEB certificates) are accessible for consultation via regional online platforms, allowing owners, buyers, or tenants to verify a property's energy performance. To retrieve a certificate, the exact address or EPC code is required, with the process managed mainly through secure online forms. Although these databases are robust regionally, they are not yet fully interoperable, even if efforts towards harmonisation are ongoing.

- Flanders: Energieprestatiedatabank VEKA
- Wallonia: Registre des certificats PEB
- Brussels: Registre PEB-EPB and Environnement Bruxelles

Environmental risk indicators (floods, vulnerability, etc.) are mainly collected and published by the regional environmental authorities; a portion of these datasets is aggregated and documented on geo.be. Data on energy or water consumption are primarily managed by regional operators (Sibelga, ORES, Fluvius, etc.) and are available in aggregated or restricted form, depending on each region's dissemination policies.

Finally, datasets relating to social housing, co-ownership, or other building specifics are fragmented, dispersed among regional operators, municipal services, and statistical portals; the centralisation or publication of a homogeneous national open data base on these topics is still to be built—though some statistics are available on the Statbel website. In general, the drive for data pooling, harmonisation, and dissemination remains dependent on the periodic synchronisation of data produced at the regional level, even though technical centralisation (IGN/NGI, geo.be) and federal cataloguing (data.gov.be) are providing increased visibility, robustness, and accessibility for institutional, scientific, economic, and private users alike.

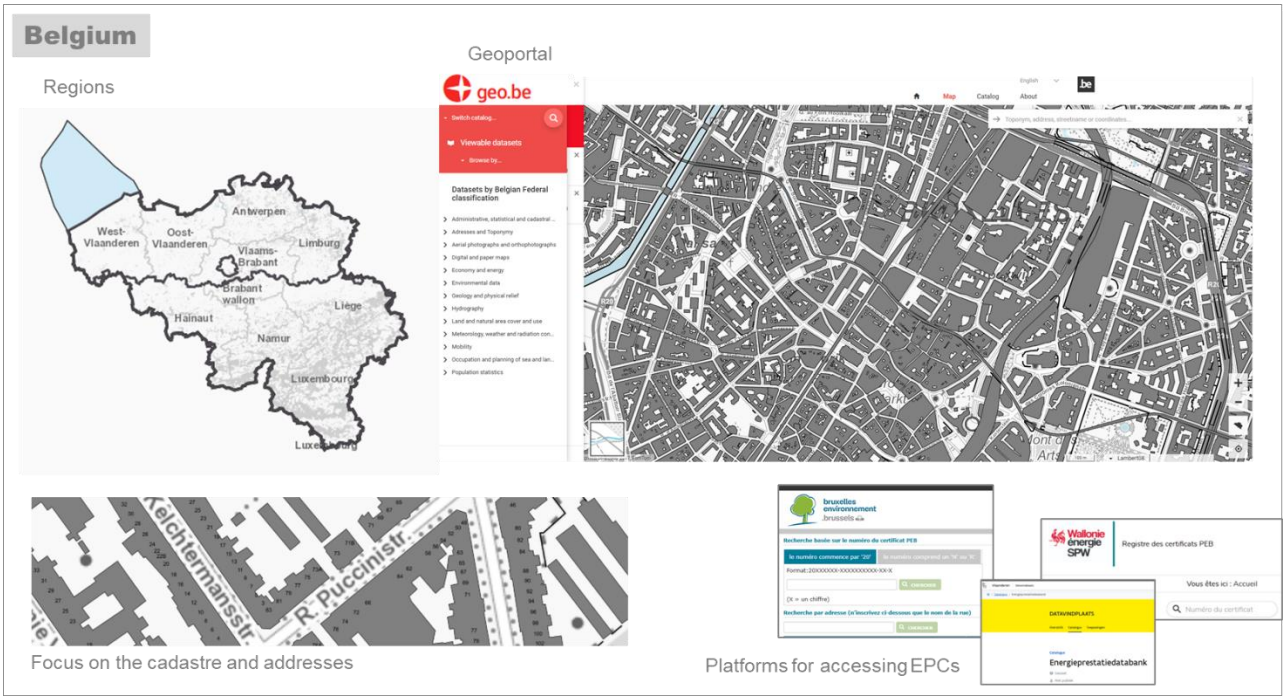


Figure 2. Non-exhaustive overview of building data in Belgium

5.4.2.2 Data quality and interoperability

The quality of building data in Belgium varies depending on the region, the data managers, and the nature of the datasets. The cadastre (SPF Finances) provides parcel geometries that are frequently updated, with accessible documentation and a well-established update chain. As for the building datasets produced by the IGN/NGI, while their national coverage ensures comprehensive morphological data (footprint, height, main use), recency and granularity can vary: the integration of new constructions or demolitions depends on regional and municipal data flows, sometimes resulting in significant discrepancies in areas experiencing strong urban dynamics.

At the regional level, Wallonia (via PICC/ICAR), Brussels (via UrbIS), and Flanders (GRB, CRAB) each maintain their own building/address registers, often enriched with metadata (typology, storeys, local attribute codes) and occasional 3D models (Brussels, Antwerp). The quality, update frequency, and completeness of these datasets depend on the resources, investments, and technical maturity of each region, leading to heterogeneous situations in terms of attribute density, geometric reliability, and documentation.

Interoperability suffers from the plurality of attribute models, naming conventions, and differences in spatial granularity. Efforts are being made to harmonise geodata structures (INSPIRE, GeoPackage, Shapefile, etc.), and most datasets are accompanied by metadata compliant with European standards (ISO 19115), which makes integration and cross-referencing easier (e.g. the “Capakey” national parcel identifier). Nonetheless, building datasets are often isolated from the strict cadastre (no universal building identifier), which can limit cross-analyses between parcel/building/use. The consultation of EPC/PEB certificates illustrates this diversity: each region manages its own database, the data formats, the granularity of public information (display, download, anonymisation), and access procedures differ greatly, although migration towards a harmonised common interface (such as Belgian Buildings under INSPIRE) is underway.

Finally, reusability and openness remain uneven: while most cadastral, geographic, administrative unit, and even some building datasets are open data (often via geo.be or regional portals), “professional” layers (energy, risk, water, social housing) are distributed according to specific access policies, often under licence or at aggregation levels that limit analysis at the property unit level.

In summary, the overall quality and interoperability of building data are improving in Belgium thanks to the national infrastructure and the growing enrichment of regional platforms. However, structural

differences, update publication rates, and the articulation between cadastre and building data remain challenges to be overcome to ensure smooth and homogeneous integration in a pan-Belgian or European context.

5.4.2.3 Governance, openness, and legal framework

The governance of building data in Belgium is organised at the federal level—through the SPF Finances and the IGN/NGI—which retain control over national geometric and cadastral reference datasets. Meanwhile, each Region (Flanders, Wallonia, Brussels) independently manages regulation, planning, energy policy, and all certification and renovation systems. Regional strategies reflect this autonomy, with different objectives, labels, obligations, and EPC/PEB systems, and multiple types of public operators (energy agencies, regional housing authorities, cities, intermunicipal bodies).

Data openness varies by information type: morphological and cadastral layers benefit from open data policies, supported by the national geo.be portal, whereas energy or professional data (EPC certificates, consumption, renovation) often remain under regional compliance, with access subject to varying modalities (consultation, licences, restricted access). The absence of a unique national building identifier, the protection of personal data, and legal requirements foster structural fragmentation, which slows the creation of an integrated, pan-Belgian one-stop site.

Alignment with the European Union (e.g. INSPIRE) and national green transition initiatives promote greater openness, sharing, and standardisation. Despite progress, governance remains marked by strong regional autonomy and the lack of full integration between bureaucratic, operational, and access systems for the key professional layers of the building sector.

5.4.2.4 Usage potential and digital maturity

The potential for a national building database in Belgium could rely, at its core, on existing cadastral and morphological reference datasets, which are already open and regularly updated at the national level (geo.be, financien.belgium.be, ngi.be). However, energy and “professional” data (EPCs, renovation, consumption, risks) are fragmented, regionally managed, and lack interoperability; this currently limits automation and national aggregation at the building-unit level (energie.wallonie.be, vlaanderen.be, environnement.brussels).

Digitalisation is progressing significantly, with online EPC platforms, the emergence of thematic clusters and portals (e.g. TOTEM), and tools to support renovation and usage monitoring—stimulating data use for urban planning, renovation, or climate reporting. Still, these applications remain highly varied and partially divided by region, asset type, or regulatory purpose.

Nevertheless, this fragmentation restricts the automated aggregation at building level, national standardisation, and cross-data exploitation, especially as access regimes (licences, usage rights) remain restrictive or uneven.

The current absence of a common data and building language, the diversity of regional models and regulations, fragmented access to energy, risk, and other professional data, as well as unequal “smart” coverage (further advanced for new/non-residential than for dispersed residential stock) all hinder the smooth deployment of a comprehensive, interoperable BDNB capable of unified or automated management of Belgium’s building assets. Despite significant potential, the full feasibility of a national register suitable for efficient and sustainable monitoring thus requires much greater convergence in synchronisation, standardisation and governance practices, and a strengthening of openness for digital professional layers.

5.4.2.5 Challenges

The main challenge in creating a fully functional and interoperable national building database in Belgium lies in institutional fragmentation: the management of building, energy, and renovation data remains highly regionalised, with each region having its own reference systems, standards, formats, update frequencies, and portals. This plurality complicates metadata alignment, attribute standardisation, linkage with the cadastre, and automated merging at the building-unit level—thus hindering the establishment of a single, pan-Belgian identifier for each building.

The diversity of EPC models, regulatory criteria, declaration cycles, and disparities in access rights (licences, open data levels, GDPR obligations) create inequalities in coverage, accessibility, and reusability, particularly for "professional" data (actual consumption, diagnostics, risks, performance). Detailed information often remains incomplete or is only accessible through institutional channels or for regulatory reporting—impeding the development of national integration services and limiting the potential for automated, prospective, or data-driven monitoring.

Finally, reliance on variable data flows, the lack of systematic synchronisation between technical/federal bodies and regional platforms, and the absence of a national certification or cross-governance process for building data expose any future national building database to structural risks: redundant or contradictory data, lack of traceability in case of new uses (circularity, renovation, etc.), and difficulty in meeting growing European reporting requirements (climate, biodiversity, building stock mapping). These obstacles do not question the robustness of the cadastral or morphological foundation, but they do limit the feasibility of a homogeneous, up-to-date, open, and truly usable national database for the climate transition and integrated management of Belgium's building stock.

5.4.3 Denmark

5.4.3.1 Building data infrastructures and existing data sources

Denmark offers a model building and land data infrastructure, distinguished by its degree of centralisation and interoperability. This coherence is based on a set of reference registers, each administered by public agencies and synchronised through centralised portals such as Datafordeler, Dataforsyningen, and the Geodatastyrelsen (GST).

All Danish land and building entities are assigned unique identifiers, forming the backbone of interoperable and traceable systems. Each unique property (fast ejendom) receives a BFE number (Bygnings- og Boligregister Ejendomsnummer), assigned in the Ejendomsbeliggenhedsregistret (EBR), and a standardised address as per the address register (DAR). The matrikelnummer (cadastral number), defined in the Matrikelregistret, identifies each parcel in connection with its "ejerlav" (historical cadastral unit), ensuring granularity and continuity in the legal monitoring of land.

Every building or constructed unit is assigned a BBR-ID in the BBR (Building and Housing Register), which is the key for temporal, energy, and physical tracking of the building stock at a national level. The property register (EJF), collects all information on property rights, transfers, mortgages, and charges, enabling the association of events (transactions, inheritance, subdivisions, etc.) with the main identifiers of land (BFE-nr., matrikelnummer) and buildings (BBR-ID). Administrative divisions (DAGI), property taxation (VUR) and other datasets are automatically integrated thanks to the structural coherence of these identifiers. This system guarantees alignment and traceability between geographic location, legal status, and the administrative or energy reference base of a property.

Regarding the EPC management system (known as "energimærke"), the country is likewise exemplary for its centralised national approach and transparency. The public portal SparEnergi.dk provides easy access to the energy label of any building simply by entering its address, offering a clear and immediate performance overview. While individual consultation is free, access to bulk data for research or policy-making requires specific authorisations. This robust infrastructure serves as a model for EPC data collection, analysis, and dissemination, in line with Denmark's goals for energy efficiency and carbon emissions reduction.

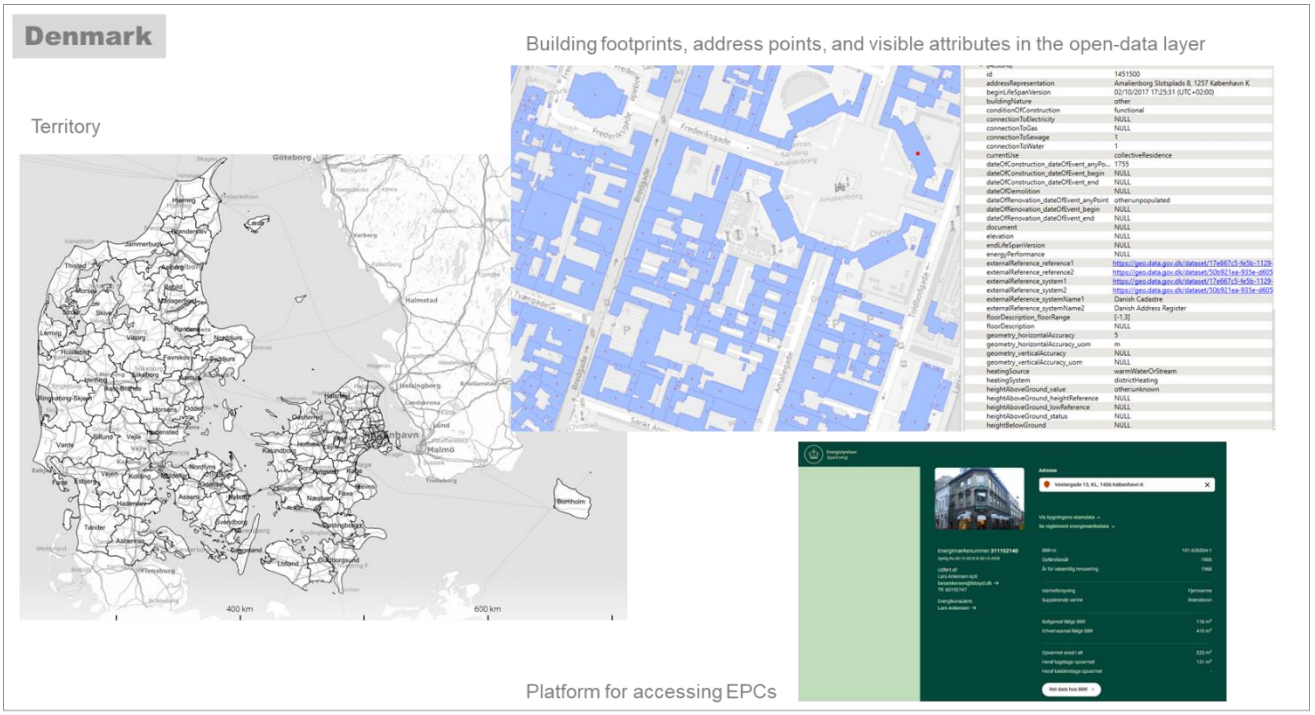


Figure 3. Non-exhaustive overview of building data in Denmark

5.4.3.2 Data quality and interoperability

Denmark stands out for the high quality and interoperability of its building and land data, supported by the uniqueness, reliability, and systematic standardisation of the identifiers used in each of its national registers. The structuring around robust identifiers—the matrikelnummer for parcels, BFE-nr. for properties, BBR-ID for buildings, and the DAR address code—guarantees non-ambiguity, traceability, and a complete chain from land to building, making the country a benchmark for integrity, documentation consistency, and automation in data linkage.

Data quality is reinforced by harmonised national procedures for data entry, validation, and updating, carried out by public agencies such as the Danish Geodata Agency, Datafordeler, or the Danish Energy Agency. The key registers are frequently updated, whether for cadastral changes, property transfers, building alterations, or energy certificate updates. This process is underpinned not only by the systematic transmission of information by professionals (surveyors, notaries, authorities), but also by error reporting or corrections from citizens themselves: any individual (owner, occupant, professional, etc.) can request a correction or report an anomaly directly to the registers, further enhancing the reliability and continuous updating of the national system. While errors, redundancies, or discrepancies may rarely occur, Denmark's ecosystem—rooted in a culture of official records, proactive oversight, and active participation by end users—means these are minimised.

The Danish model likewise guarantees technical interoperability through the systematic adoption of international standard formats (e.g. JSON, XML, GeoJSON, GPKG), the provision of open APIs, the existence of well-documented catalogues, and compatibility with the European INSPIRE directive. This foundation makes it possible to cross-reference, aggregate, and combine all layers (cadastre, building, fiscal, EPC, addresses, etc.) without loss of quality or meaning. More broadly, Denmark succeeds in offering both granular quality of data—down to parcel or building level—and the ability to aggregate and publish in bulk for spatial, territorial, or energy analysis, while ensuring source integrity and complete historical records for every operation.

5.4.3.3 Governance, openness, and legal framework

Governance of building and land data in Denmark is based on a centralised organisation, led by national agencies: Geodatastyrelsen for cadastre, land, and addresses; the Energy Agency for EPCs; and overall data flow coordination through the Datafordeler and Dataforsyningen portals. This

centralisation facilitates regulatory synchronisation, uniform application of standards, and controlled information flow for all institutional, professional, and individual uses.

The openness policy is highly advanced for all cadastral layers, parcels, and administrative reference datasets: nearly all of this data is available for free as open data. This model allows public, private, and research actors to download, interconnect, and make wide use of the data.

However, a strict distinction is maintained for personal data: all nominative information regarding landowners and property rights (from the EJF register) is not open to the public. Access requires authorisation and may be subject to a licence, in strict compliance with GDPR and Danish data protection laws. Only specific users (authorities, regulated professionals, certain research services) are permitted to access these complete or personally detailed datasets.

The same restriction applies to access to the national EPC database ("energimærke"): while any citizen can freely view the energy label of a building via a public interface (SparEnergi.dk), obtaining the full database for scientific, operational, or policy use requires formal authorisation, to prevent misuse for commercial purposes or breaches of confidentiality.

National portals specify access arrangements, usage rights, and application and licensing processes, ensuring transparency in governance and the security of sensitive data.

5.4.3.4 Usage potential and digital maturity

Denmark has an environment highly conducive to the development of a unique national building database (BDNB). The existence of robust and interlinked identifiers for each entity—property (BFE-nr.), parcel (matrikelnummer), building (BBR-ID), address (DAR)—and their systematic standardisation natively enable the creation of a federated and scalable structure, perfectly aligned with the BDNB concept. The chaining of existing registers (BBR, EBR, EJF, VUR, DAGI, etc.) already offers granularity from parcel to housing unit, which is essential for constructing a comprehensive, reliable, and scalable database.

Operationally, the centralisation of portals (Datafordeler, Dataforsyningen), the presence of interfaces, exhaustive documentation, and the progressive opening of datasets position Denmark at the forefront of infrastructures ready for massive, multi-purpose exploitation. This organisation supports automated data cross-referencing (parcel, building, use, energy, taxation), the development of digital twins, and the emergence of a genuine service ecosystem (asset analysis, urban planning, energy tracking, risk management, smart home management, climate reporting, etc.).

A culture of innovation and open, accessible data—combined with the ability for citizens to make corrections and fast access to verified information—ensures responsiveness and system robustness. All stakeholders—local authorities, private operators, researchers, citizens—benefit from a unique potential to develop new uses, improve the management of the building stock, and create synergies between registers and services.

In summary, Denmark's digital maturity and open architecture, underpinned by centralised governance, make not only possible, but readily achievable, the creation and maintenance of an integrated, comprehensive, and reliable national building database.

5.4.3.5 Challenges

The transition towards a single database centralising all building information in Denmark, although technically achievable, comes with specific challenges that must be anticipated.

One major challenge concerns fine-grained access management: the Danish system already distinguishes between open data and sensitive data (owner-related data, governed by the EJF register, or energy performance data from SparEnergi.dk at large scale). A fully unified BDNB would require the definition of precise access policies—differentiating rights by user profile (general public, administrations, researchers, private actors, etc.), type of data (anonymised or nominative), and intended use. The granting of licences, traceability of consultations, and ex post controls would all become central to ensure GDPR compliance and stakeholder trust.

A second key point: consolidating such a database would require a dedicated budget to guarantee

ongoing maintenance, cybersecurity, technical scalability, and long-term data quality. Existing portals, although efficient, would need additional human resources and infrastructure enhancements to support expanded, responsive, and secure usage.

Finally, moving to a national building database would require dedicated services to assist users: help interfaces, technical support, licence request and approval procedures, training, and support for integrating the data into existing professional tools. It would be essential to guarantee transparency around access conditions, comprehensive documentation, robust APIs and data access points, and active mediation to avoid inequalities in access or use.

In summary, the success of a Danish BDNB will depend on precise governance of access and licences, sufficient resource allocation to ensure its viability and security, and the ability to provide support and guidance services to all stakeholders. Only in this way will the country be able to maintain the robustness, trust, and usefulness of this infrastructure for the benefit of its digital and environmental transition.

5.4.4 Spain

5.4.4.1 Building data infrastructures and existing data sources

Spain has a building and land data architecture built around central portals with shared governance. The national cadastre, managed by the Ministerio de Hacienda via the sedecatastro.gob.es portal, is the foundation for access to geometric, administrative, and attribute information on parcels and buildings. Its openness is partial: while certain datasets or statistical aggregates are freely available, any full access, bulk download, or detailed attribute extraction requires identification via Cl@ve and, where applicable, a licence in accordance with national data protection regulations. Land taxation, integrated within the cadastre, remains subject to strict access rights. While some extracts or statistical aggregates are published, access to nominative, asset, or detailed data requires authorised professional status and the acquisition of a permit or licence, in line with national regulations and the GDPR.

Postal addressing is handled by the Instituto Geográfico Nacional (IGN) and the Centro Nacional de Información Geográfica (CNIG). Data, structured and compliant with European standards, are available on datos.gob.es and Cartociudad (collection d'adresses). Depending on the layer and intended use, access may be open or subject to licensing, especially for bulk downloads or the use of dedicated APIs.

Administrative units—municipalities, provinces, regions—are accessible via the centre of downloads (centrodedescargas.cnig.es) in interoperable formats (e.g. WFS, GML, shapefile). These ensure spatial consistency and integration with other core datasets.

For environmental data (hazards, risks, floods, etc.), multiple actors are involved: sectoral ministries, state agencies, and autonomous communities. Access is via datos.gob.es or specialised platforms, with openness and frequency of publication varying significantly. Energy/water consumption data are mainly held by private operators or regional agencies; bulk publication at the building or dwelling level is rare, often limited to municipal or regional statistical aggregates (with restrictive licences and GDPR protection). Nominative or detailed access requires specific authorisations.

The register of Energy Performance Certificates (EPC/Eficiencia Energética) is managed by the Ministerio para la Transición Ecológica y el Reto Demográfico and organised via a central geoportal (the Geoportal de Certificados de Eficiencia Energética de Edificios). The architecture is hybrid: each autonomous community collects, certifies, and updates EPCs in its territory, then regularly uploads the data to the central platform, which aims to unify and standardise national-level consultation. Public access enables searching for and verifying a certificate online by address. Aggregated datasets on energy efficiency are offered on datos.gob.es or regional sites; however, bulk download or highly detailed extraction requires specific licences or authorisations.

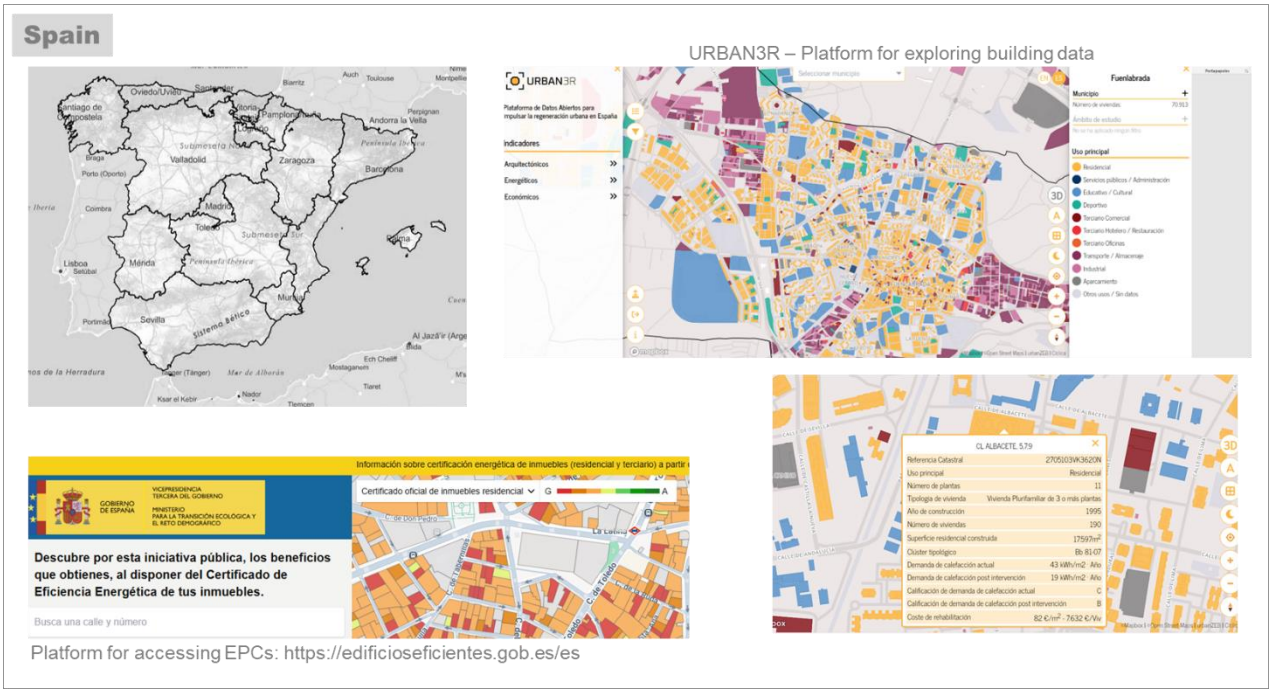


Figure 4. Non-exhaustive overview of building data in Spain

5.4.4.2 Data quality and interoperability

The quality of data is based on the centralisation of major national reference systems (cadastre, EPC, addresses, administrative units) and a homogeneous structure. The cadastre, overseen by the Ministerio de Hacienda, ensures both geometric and attribute uniformity thanks to updates synchronised with administrative changes.

Interoperability is supported by the use of technical standards (CSV, shapefile, WFS, GeoJSON) and unified protocols (APIs, dedicated portals). This enables parcel-building cross-referencing, address-building linkages, and integration with administrative boundaries. However, the absence of a stable national identifier associated with all layers restricts automated linkage, particularly for secondary themes (e.g. risks, consumption, environment).

Nonetheless, this national homogeneity can mask differences in data quality and update frequency at the local level: there may be significant variation in geometric accuracy, attribute density, or data freshness between urban, rural, or island areas and depending on the engagement of local authorities or autonomous communities in validation processes. Energy performance certificates, for instance—though centralised—depend on data flows from each autonomous community and may show delays or variations in the richness of open data available.

For secondary thematic layers (consumption, risks, environment), interoperability remains less consistent. The lack of a unique national building identifier across all themes sometimes hinders the complete automation of parcel-building-consumption linkages and the structuring of metadata does not always match the harmonised level of the cadastre or the EPC register.

In summary, Spain is developing technical interoperability for its key layers (cadastre, EPC, addresses, territorial units), enabled by semi-open formats, standardised structures, and national catalogues. However, attribute consistency, update frequency and granularity, and the interoperability of secondary layers vary across regions and still require ongoing efforts for truly comprehensive integration.

5.4.4.3 Governance, openness, and legal framework

Governance is shared: the State oversees the cadastre, land taxation, and the main energy data flows, under a national legislative framework (notably Ley 19/2013 and the GDPR). IGN and CNIG manage the addressing and administrative reference datasets; the EPC sector follows a mixed model,

with each region having its own approach to data collection, publication, and openness.

Data openness is partial: certain layers—addresses, administrative units, EPC aggregates—are accessible via open data or public licence on the main portals (sedecatastro.gob.es, datos.gob.es, centrodedescargas.cnig.es). In contrast, the cadastre itself is not open: access to its detailed layers requires strict electronic identification, authorisation or licence, and automated downloads are tightly controlled or very limited. Autonomous communities have their own regulatory authority, especially for the granular publication of EPCs or local indicators that feed into building and geospatial data.

National portals centralise documentation, access conditions, and request traceability, thereby ensuring legal security and transparency for users.

5.4.4.4 Usage potential and digital maturity

The potential use of Spanish building and land databases to establish a centralised BDNB depends heavily on the digital maturity of existing systems, their openness, and the large-scale availability of datasets at national level. Technically, the main Spanish reference datasets—cadastre, addresses, EPC, administrative units—are well-structured, use standard formats, and cover nearly the entire territory. National platforms disseminate this information in a controlled way, mostly as geographic data streams (shapefile, WFS, GeoJSON), accompanied by structured metadata and technical documentation. This infrastructure would theoretically enable the aggregation and cross-referencing of datasets necessary for a BDNB.

However, feasibility remains constrained by two factors:

- Limited openness of the cadastre (requirement for identification, licensing);
- Strict control over nominative information (tax, energy), and uneven granularity in some local or thematic datasets.

In conclusion, although the infrastructure is favourable, creating an interoperable and large-scale BDNB would require changes in the legal framework, harmonisation of data openness between the State and autonomous communities, and support strategies for administering sensitive data and establishing specific, clear licences to facilitate data access.

5.4.4.5 Challenges

Several major challenges arise:

- Opening up the cadastre and inter-regional pooling: Access to the cadastre remains the main bottleneck. Restricted access, the requirement for licences, or identification procedures hinder any large-scale use, automated cross-referencing, or standardised integration.
- Governance fragmentation: The heterogeneity of openness policies and practices between the central State and the autonomous communities hampers the national harmonisation of building data.
- Data protection and risk management: The need to preserve confidentiality, avoid re-identification, and control the misuse of sensitive layers demands robust anonymisation or data aggregation measures before any dissemination or sharing.
- Interoperability and quality: The absence of a unique building identifier complicates automation of secondary layer cross-referencing (risks, consumption). Local disparities persist in terms of data depth, update frequency, and harmonisation.
- Skills development and support: For a BDNB to become a real policy, innovation, or research lever, continuous support, documentation, and training for decision-makers, operational staff, and users need to complement technical development.

5.4.5 Italy

5.4.5.1 Building data infrastructures and existing data sources

Italy's building data architecture relies on several specialised national portals. Address data are produced and aggregated by the Archivio Nazionale dei Numeri Civici delle Strade Urbane (ANNCSU Open Data , geodati.gov.it), published as open data with national coverage and monthly updates. Each municipality or region can export CSV files of addresses and streets, ensuring reference consistency via detailed documentation and official specifications.

The cadastre, managed by the Agenzia delle Entrate, allows online consultation of geometric, physical, and administrative information about parcels and buildings—except in the autonomous provinces of Trento and Bolzano—via the official portal Agenzia Entrate – Visura catastale online. This service provides core cadastral data: parcel or building identification, surface area, intended use, and cadastral value. Consultation is free for one's own properties or for third-party assets, provided authentication (SPID, CIE, or CNS). However, the cadastre does not coincide with land ownership data. Directly nominative information (the identity and qualification of title holders, real property rights held, transaction history) is considered land/asset data and is protected. Access to these details requires a specific procedure and is not available via open data. Only authenticated owners or qualified professionals can access extracts containing these elements; large-scale or structured extraction (e.g. XML) for professional reuse is reserved for professionals with a contract and a subscription to the dedicated Sister, platform. In most cases, files provided to the public are issued in PDF format. Only contracted professional users may obtain data in structured formats like XML via the Sister platform, in accordance with rules on data protection and regulated use of property extracts.

Administrative units (municipalities, provinces, regions) are referenced and made freely available by the Istituto Nazionale di Statistica (ISTAT) through the INSPIRE portal. These datasets are distributed in standard interoperable formats (shapefile, GML, WMS for GIS) and support the cross-referencing of cadastral, building, and statistical layers. Their regular updating ensures the reliability of spatial analyses and administrative chains.

Management of Energy Performance Certificates (EPCs), called PAE (APE: Attestato di Prestazione Energetica), is primarily regional, with a recent centralisation effort led by the national SIAPE – ENEA (Sistema Informativo sugli Attestati di Prestazione Energetica) platform. Each region or autonomous province registers, issues, and updates its own APE certificates through dedicated portals, regularly transmitting data to SIAPE, the national infrastructure managed by the Dipartimento Unità per l'Efficienza Energetica (ENEA). The SIAPE platform aims to unify access, consultation, and exploitation of APE data nationwide. To find or verify a certificate, users can use the SIAPE portal, provided they have the necessary accreditations; requests can be made accordingly. Nevertheless, access to raw data remains limited, and the availability of aggregated or disaggregated data is tightly controlled, requiring specific authorisations, particularly to guarantee confidentiality. The platform also supports digitalisation and automation of procedures, fostering quality control, anti-fraud efforts, and improved statistical relevance, while progressively meeting European standards of interoperability and transparency.

entralisation of geospatial data offerings and catalogues is managed by the RNDT/Geodati.gov.it and dati.gov.it portals, in line with the INSPIRE directive. These platforms, through their metadata, APIs, and catalogues, provide access to most major datasets: addresses, parcels, buildings, administrative divisions, etc.—all in open and interoperable formats, with regular updates.

Finally, land fiscal data are subject to restricted access: only requests made to the Agenzia delle Entrate, accompanied by specific agreements or licences, allow access to detailed data on property taxation or certain sensitive cadastral components.

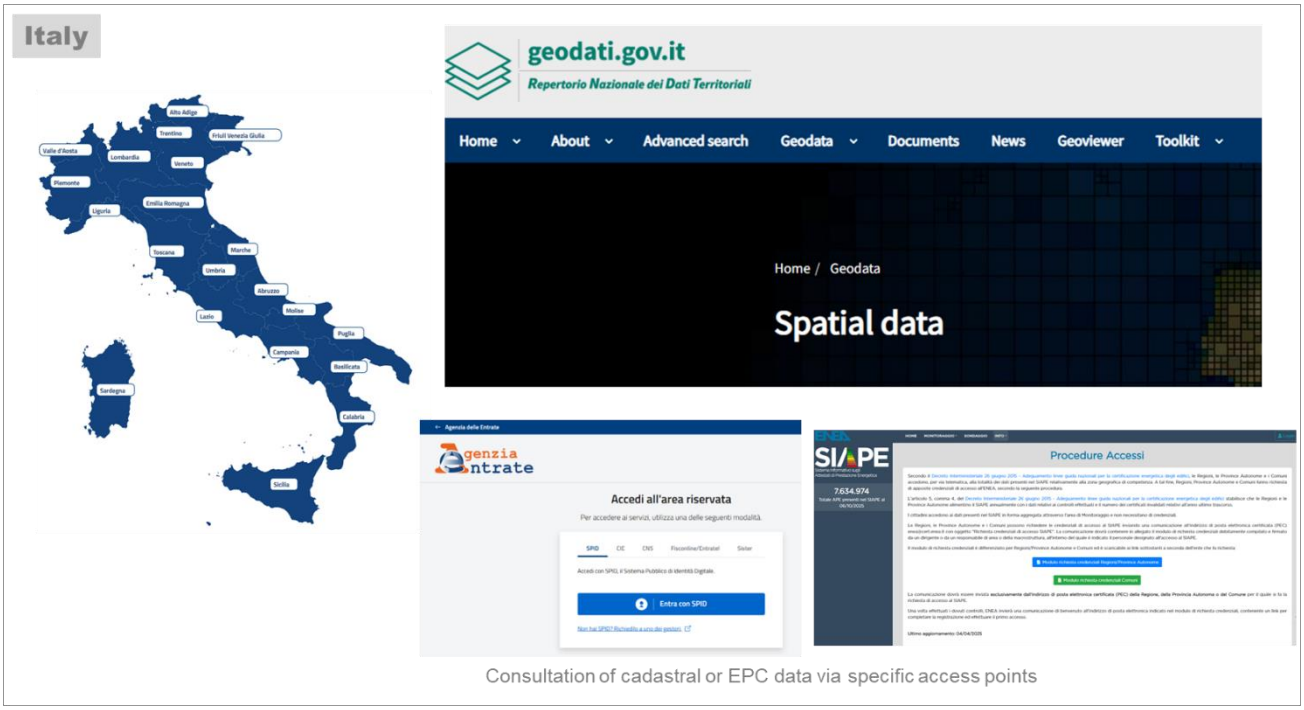


Figure 5. Non-exhaustive overview of building data in Italy

5.4.5.2 Data quality and interoperability

The quality of Italy's key datasets is primarily based on the centralisation and regular maintenance of national reference sources. Address data benefit from standardised specifications, consistency checks, and granularity down to the individual address, providing monthly updates and a quality level aligned with European standards. The cadastre integrates all structural or administrative changes to the property stock, ensuring operational reliability both at plot and building level.

Technical interoperability is ensured by the consistent use of standard interoperable formats (CSV, shapefile, GML, WMS, WFS, REST API). Administrative boundaries provided by ISTAT allow detailed spatial layering, with each unit coded for easy cross-referencing with other datasets and the creation of complex analytical chains. This technical infrastructure guarantees a high degree of compatibility among public, regional, and national actors.

However, some bottlenecks remain, especially regarding cross-referenced identifiers. The unification of reference datasets—particularly between addresses, parcels, buildings, and EPCs—is not systematic, limiting full interoperability and the automation of thematic integration. The diversity of regional databases, the update frequency of SIAPE by regions, and heterogeneous local practices complicate harmonisation.

On the whole, Italy thus offers both technical robustness and a dynamic of continuous improvement in publication, documentation (see geodati.gov.it), and interoperable openness of main data flows. These structuring efforts ensure widespread data reuse in a mature digital ecosystem, even if certain challenges remain regarding identification, granularity, and synchronisation.

5.4.5.3 Governance, openness, and legal framework

Italian governance is based on a distributed but coordinated structure: ANNCSU administers the address data; the Agenzia delle Entrate manages the cadastre and supervises land record extractions; ISTAT ensures the consistency of administrative boundaries; and ENEA coordinates the EPC/SIAPE system with the regions. Italy has transposed the INSPIRE directive into legislation, but its application remains somewhat uneven due to strong institutional decentralisation.

Openness characterises non-nominative layers: addresses, administrative units, and aggregated EPCs are accessible on national portals (ANNCSU, Geodati.gov.it, dati.gov.it). Each portal publishes

specifications and technical details, promoting transparency, traceability, and comprehensive documentation. Conversely, access to land/asset layers is strictly regulated: it requires robust identification, specific professional status, and where appropriate, a licence or agreement (notably for Sister and nominative or structured cadastral formats).

On the energy side, SIAPE's centralisation is gradual and still being improved: while aggregated consultation is facilitated, bulk extraction remains restricted to local authorities or public entities and is subject to administrative procedures and validation. The entire legal framework is shaped by the need to guarantee personal data protection (GDPR, Codice della Privacy), legal security in land transactions, and integrity in the use of data flows.

5.4.5.4 Usage potential and digital maturity

Italy has solid foundations for considering the construction of a structured and comprehensive national building database. The core reference datasets—addresses (ANNCSU), parcels and buildings (Agenzia delle Entrate), administrative boundaries (ISTAT/INSPIRE), and energy performance certificates (SIAPE/ENEA)—are organised at the national level, updated regularly, and offered in open formats to promote interoperability. This standardisation, together with national catalogues, ensures access to harmonised data layers that are essential for any large-scale aggregation or cross-referencing project.

From a technical point of view, the Italian infrastructure already enables the linking of critical datasets: matching between address, cadastral parcel, building, and EPC is theoretically feasible, even if sometimes limited by identifier disparities or heterogeneous regional practices. The ongoing updating of the SIAPE database by the regions, the existence of integrating catalogues (geodati.gov.it, dati.gov.it), and comprehensive documentation provide a competitive digital foundation for establishing a BDNB.

However, the effective centralisation of building information—a sine qua non for a BDNB—comes up against the tradition of local management: much detailed information about buildings (construction characteristics, history, uses) remains dispersed across regional or municipal databases, not always synchronised or standardised. The absence of a unique national building identifier poses a challenge for automated linkage between layers and restricts the ability to directly integrate all themes (especially for merging with EPCs or consumption data).

Finally, the technical maturity of the ecosystem is real: the use of catalogues and the broad openness of certain core datasets demonstrate Italy's capacity to progress rapidly in national structuring—provided that governance is coordinated and there is clear political will for harmonisation.

5.4.5.5 Challenges

The main challenge is institutional and structural: Italy's strong decentralisation leads to fragmented practices, update schedules, and dissemination frameworks. The management of building information, often at regional or municipal level, results in incompatibilities in formats, coding, and descriptive depth, which complicates upward integration into a comprehensive national database.

Legal protection of sensitive or nominative data (cadastral, land, historical, owner, EPC data) limits both access and wider sharing: almost all detailed content related to property or building tax remains protected and not open. The creation of an interoperable BDNB would thus require robust mechanisms for anonymisation and aggregation, as well as a solid contractual framework.

Another barrier is the heterogeneity of identifiers and registration systems. The lack of a unique building identifier recognised across all national and local registers prevents the automatic creation of links between addresses, parcels, EPCs, and other essential descriptive layers for the BDNB. Standardisation, the creation of a national building ID, and the harmonisation of data reporting and updating practices are therefore priorities.

Finally, the success of such a database requires strong national leadership capable of coordinating regional diversity and guaranteeing continuity, quality, and security of data flows, while supporting the alignment of professional tools with national and European standards.

5.4.6 Luxembourg

5.4.6.1 Building data infrastructures and existing data sources

Luxembourg has a unified and well-structured national ecosystem for the management, storage, and dissemination of building and land data. The Administration du Cadastre et de la Topographie (ACT) plays the central role in producing, maintaining, and publishing major geographic reference datasets: addresses, cadastral parcels, building footprints, and 2D/3D building models.

National address data are accessible as open data via the portal data.public.lu, available in geojson, shapefile, and csv formats. They are granular to the address level, cover the entire territory, and include a georeferencing system compliant with European standards.

The digitised cadastral map, distributed by the ACT (plan-cadastral-numerise-pcn), provides comprehensive and homogeneous coverage of parcels and buildings throughout the national territory. Each land entity—parcel or building—is described by its geometry, cadastral reference, surface area, and administrative affiliation (municipality, section, sector). These data are structured according to interoperable standards (geojson, shapefile). The layers thus provide a foundation for land governance, urban planning, environmental analysis, and spatial planning, supported by thorough documentation that facilitates reuse for all public and private sector professions.

Ownership information—nominative owner data and land taxation—remains protected: the ACT restricts itself to the dissemination of only the geographic components, while tax and asset issues fall under the Administration de l'Enregistrement, with restricted access for authorised actors for specific administrative uses. This access policy is designed to protect the confidentiality of personal data while ensuring the free availability of geometric and administrative reference datasets. Added to this is the publication in open data of a national 3D building database (base nationale des bâtiments 3D), enabling more detailed urban modelling and supporting the development of BIM applications and innovation in Luxembourg's building management sector. Supporting the building and cadastral layers, the data offering is rounded out with national and municipal administrative boundaries, in collaboration with STATEC (administrative boundary dataset), available as open data in geojson and shapefile formats. Additionally, population census statistics are accessible, allowing for statistical correlations between buildings, population, and land use.

Management of energy performance certificates is organised around a centralised national database, although raw data access is more restricted than in some other European countries. The Ministry of the Economy, via the meco.gouvernement.lu portal, provides general information on building energy efficiency and EPC-related procedures. However, direct public access to individual certificates or the downloading of unaggregated data is not possible via this portal. The data are primarily used for statistical purposes, with aggregated and anonymised reports available on request. Access to more detailed information, particularly for research projects or specific needs, is subject to formal requests and the granting of licences.

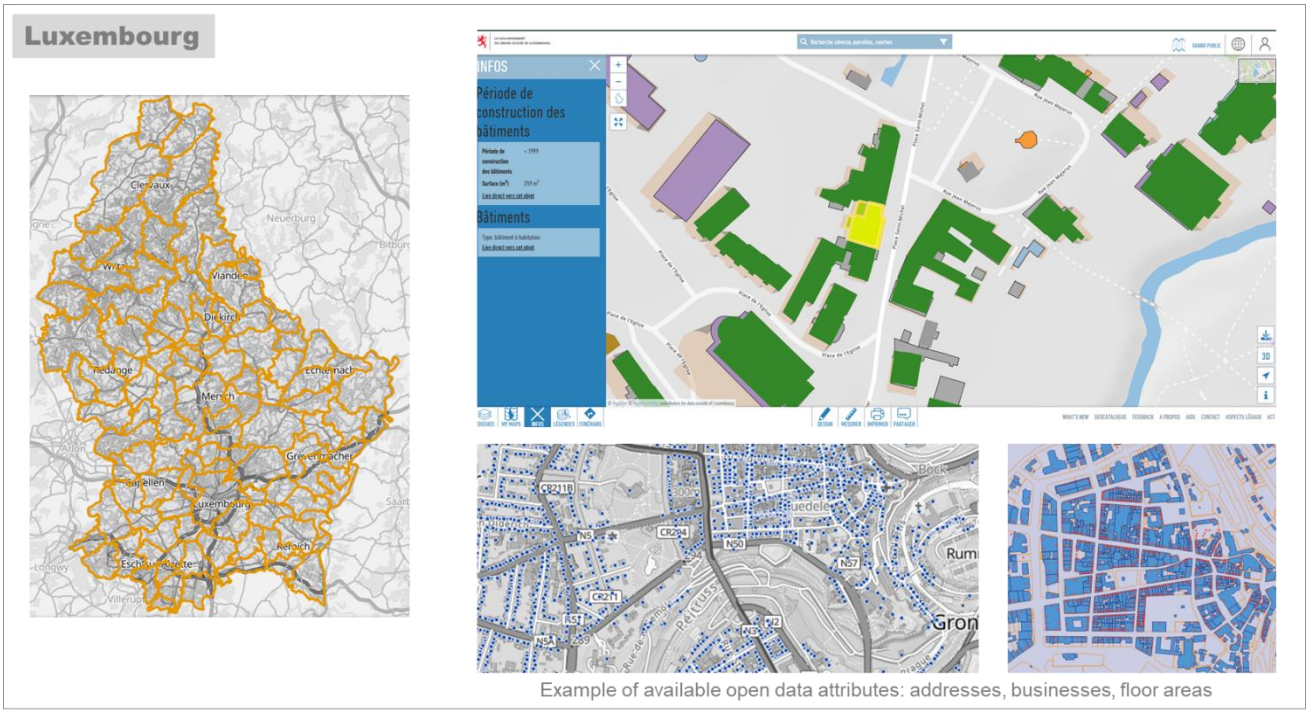


Figure 6. Non-exhaustive overview of building data in Luxembourg

5.4.6.2 Data quality and interoperability

The quality of Luxembourg's building and land data is founded on strong national centralisation, regular updating, and widespread use of standard interoperable formats. The Administration du Cadastre et de la Topographie (ACT) ensures a homogeneous structure for key datasets: each parcel and each building, along with its associated address, is assigned a unified code.

Files are systematically offered in geojson, shapefile, or csv formats, guaranteeing compatibility with all GIS and facilitating integration into professional processes, 3D modelling, and urban planning. Detailed documentation for each dataset describes technical specifications, data models, assembly rules, and attribute schemas, supporting high-quality reuse for scientific, public, or private purposes.

The country has also taken a significant step with the open publication of a national 3D building database, covering the entire territory, harmonising 2D building footprints and 3D geometries. This alignment allows seamless linking between addresses, buildings, parcels, and administrative units, and encourages the development of advanced uses (energy analysis, sunlight calculations, urban heat island simulations).

Thanks to centralised and standardised processes, update frequency and synchronisation are guaranteed: each update to the cadastral map is quickly reflected in the building and address layers. However, interoperability with certain supplementary datasets (energy consumption, EPCs, taxation) remains limited: these are not directly linked in public open data portals due to regulatory and data protection constraints, requiring distinct administrative procedures for cross-access.

Governance of building and land data in Luxembourg is based on institutional centralisation led by the Administration du Cadastre et de la Topographie (ACT). This organisation ensures consistency in the management, publication, and updating of core datasets (addresses, parcels, buildings) at the national level. The ACT is responsible for producing, naming, and ensuring compliance with European standards—such as INSPIRE—coordinating all cycles from data collection to public dissemination.

5.4.6.3 Governance, openness, and legal framework

The Luxembourgish open data framework is characterised by the wide availability of descriptive geographic layers: almost all core datasets (parcels, building footprints, addresses, 3D models, administrative boundaries) are accessible as open data via the national platform data.public.lu or the

ACT portal, without usage restrictions for research, planning, or innovation purposes. The links between the cadastre, addresses, and administrative boundaries are guaranteed by the quality of the institutional chain and the public release of the datasets.

Conversely, the legal protection of sensitive data is ensured by strict regulation in the areas of taxation and land ownership. Access to nominative, patrimonial, transactional, or tax information remains reserved for the Administration de l'Enregistrement, and is subject to privacy legislation and authorised administrative use. This separation ensures, on the one hand, broad dissemination and openness of geometries, and on the other, the security and confidentiality of elements relating to property rights, values, or asset situations. Data on the energy performance of dwellings are also not available to the general public; thus, steps still need to be taken to make these accessible. Luxembourg thus offers a balanced and decidedly modern model, combining national governance, widespread openness, and legal protection of sensitive records.

5.4.6.4 Challenges

Malgré Despite growing centralisation and the opening up of major building datasets in Luxembourg, several challenges remain to achieve fully integrated, comprehensive, and innovation-oriented management.

The first challenge concerns the limits of the interoperable chain: land, building, and address layers are highly standardised and accessible, but sensitive data such as land ownership, taxation, and energy performance (EPC) are not directly interoperable with the other open data reference datasets. This separation, required by privacy legislation and administrative transparency, creates a barrier between the potential desired uses (building scoring, tax simulation, energy performance analysis) and the data that are actually accessible.

The second challenge lies in the integration of additional thematic data flows. EPC data, essential for energy monitoring, are not released as open data and are not structured alongside the other key layers. Likewise, the granularity, timing, and provision of fiscal information are subject to complex access procedures or are reserved for administrative uses. This limitation slows the development of advanced services based on the cross-referencing of multisource data (energy management, urban planning).

The third challenge relates to the continuity and enrichment of the data. Although Luxembourg has made significant progress in open dissemination, the ability to dynamically integrate new layers—for example, social, environmental, or forward-looking indicators—will depend on coordination between administrations, alignment of sectoral priorities, and the flexibility of national portals to respond to emerging needs for interoperability and data linkage.

Finally, the sustainability of digital governance will remain a long-term issue: adapting to European regulatory developments (INSPIRE, GDPR, requirements for digital twins, etc.), ensuring continuous updating, and promoting inter-administrative pooling and skills development among all stakeholders—private, public, and academic—are strategic priorities to be addressed.

5.4.7 Pays-Bas

5.4.7.1 Building data infrastructures and existing data sources

The Netherlands benefits from one of the most advanced national ecosystems in Europe for building and land data, characterised by remarkable centralisation and technical quality. The pivotal institutional body is the Kadaster (Kadaster Nederland), which manages almost all core geospatial registers: cadastral parcels, buildings, and addresses, in synergy with other national databases such as BAG (Basisregistratie Adressen en Gebouwen).

The Addresses and Buildings Registry (BAG) brings together, at the national level, the identifiers, geometries, administrative and historical attributes of each building and address, according to a unified data model. This database, updated daily, is accessible via the PDOK et data.overheid.nl. portals. The granularity reaches the individual building and address level, with a unique national coding (BAG ID).

The Dutch cadastral map (Kadastrale Kaart) provides exhaustive mapping of parcels, property rights, and links to ownership and taxation, in standard formats (GML, GeoJSON, SHP). Geometry data are freely accessible; detailed access to ownership or tax information remains restricted or paid, in accordance with Dutch regulations. The Netherlands also offers urban 3D model datasets (3D BAG, 3D NL) for certain cities or regions.

Management of EPCs is also provided through a centralised national database, accessible via the EP-Online. platform. This portal is the reference for all real estate stakeholders, enabling them to consult building labels and performance indicators. The system ensures data reliability through rigorous verification and regular updates. Public access to individual information fosters market transparency. However, for in-depth analysis or application development requiring large datasets, specific access via API keys is required. This graduated approach strikes a balance between public transparency, confidentiality, and the management of big data, while stimulating innovation in the sector.

In addition, administrative boundaries (gemeente, provincie, wijk), environmental layers (flooding, risks, climate), and population statistics are published on national portals (CBS, data.overheid.nl), as open data and in interoperable formats, allowing dynamic cross-referencing with all main data flows.

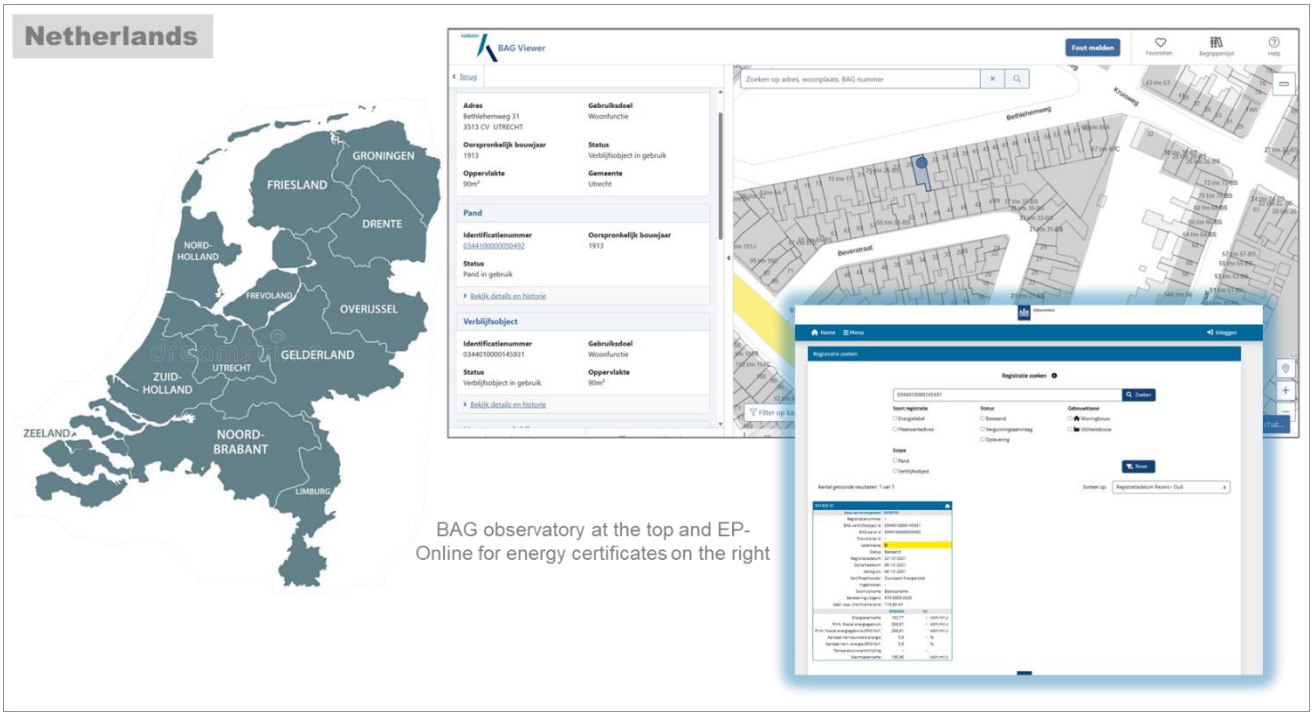


Figure 7. Non-exhaustive overview of building data in the Netherlands

5.4.7.2 Data quality and interoperability

The Netherlands stands out for its high data quality and interoperability, the result of national standardisation and a strong institutional commitment to compatibility at all scales. The main databases—BAG (addresses and buildings), Kadaster (parcels), Kadastrale Kaart (cadastral mapping), along with 3D datasets and administrative units—follow unified data models, are thoroughly documented, and are distributed in interoperable formats (GML, GeoJSON, SHP, CSV, WFS, REST API).

Granularity usually reaches the individual object: each building, address, or parcel receives a unique national identifier (BAG ID for buildings/addresses, Kadastraal Nummer for parcels), which allows robust and automatic linking between layers and the creation of complex analysis or visualisation chains. Data feeds are updated daily or weekly, and any new or modified data is propagated throughout the entire system within a few days—ensuring remarkable freshness at the European level.

Interoperability is further strengthened by the policy of federated open data portals like PDOK and data.overheid.nl, which organise access to metadata, ensure the harvesting of raw datasets, and maintain identifier and format stability.

The technical documentation is comprehensive, and includes integration guides, XML schemas, open APIs, and community FAQ spaces—supporting both expert reuse and innovation. Some limits do exist for sensitive layers: for example, individual property, detailed tax data, or certain performance metrics remain subject to differentiated access control protocols, but the core infrastructure is among the most open and robust in Europe.

5.4.7.3 Governance, openness, and legal framework

Building and land data governance in the Netherlands is built on strong institutional foundations, marked by coordination, clear assignment of responsibilities, and an increasing culture of openness. Kadaster acts as the lead entity, overseeing management of the cadastral register, integration of national databases (BAG for buildings and addresses, Kadastrale Kaart for parcels), and the production and dissemination of data streams according to quality standards set by Dutch and European legislation.

This governance is supported by a national open data policy. The main reference datasets—particularly the BAG, cadastral mapping, and increasingly, 3D urban models and administrative boundaries—are published as open data via national portals (such as PDOK and data.overheid.nl). This transparency is governed by the “reutilization of government and public sector information” law.

Access rights are clearly tiered: the geographic, descriptive, and administrative components (geometry, type of buildings, location, addresses) are always open and free to use, while sensitive layers—especially access to nominative ownership information or certain tax data—remain protected, chargeable, or accessible only to authorised professionals or in a justified administrative context. These controls are defined by European and Dutch regulations, striking a balance between legal security and administrative efficiency.

Finally, a regulatory framework ensures sustainable governance: documentation, version traceability, and historical integrity are systematically maintained and audited, with public feedback processes and regular audits involving the scientific community, local authorities, and private actors. This model fosters innovation, operational security, and the development of a shared digital strategy, while maintaining a very high level of trust and responsibility for national building and land data.

5.4.7.4 Challenges

The Netherlands possesses one of the most advanced potentials for building and land data usage, supported by a high level of digital maturity and an ambitious integration policy. The national structure of the BAG and Kadaster databases, their reliability and near real-time updates, as well as unique identifier management systems, enable the rapid construction of national platforms or databases such as a “BDNB”, without the need for massive harmonisation campaigns.

The richness of the Dutch ecosystem encourages the development of advanced use cases: the identifier chain between addresses, buildings, and parcels enables cross-analyses at the unit level. Robust APIs, comprehensive documentation, and open data portals guarantee industrial, scientific, and public reuse on a very large scale—ranging from urban mobility to energy planning, risk assessment, and environmental management.

Access restrictions primarily concern nominative or fiscal layers (ownership, value information, transactions), which remain subject to professional authorisation processes or secure protocols. Ongoing investment in distributed infrastructures, continual alignment with European standards (INSPIRE), a policy of transparency and inclusion for academic and industrial ecosystems, and the ability to transfer regional innovations to the national system all position the Netherlands as a model to replicate for the management, enhancement, and circulation of building and land data in the digital age.

5.5 Summary for the panel

To assess the transferability of the BDNB approach at the European level, a comparative analysis was carried out on a panel of seven countries (Denmark, the Netherlands, Belgium, Luxembourg, Spain, Germany, and Italy), examining a range of structural parameters. The focus was on the feasibility of constructing a robust data foundation—including core layers such as the cadastre, addresses, land data, and EPCs—based on the availability, accessibility, completeness, and quality of the data, as well as governance dynamics and institutional openness to open data. These dimensions are crucial: only an active open data policy, backed by a clear governance framework, allows not only for the initial construction of the databases but also for their ongoing maintenance and continuous updating by all relevant stakeholders.

The analysis highlighted a deep heterogeneity in national situations. Denmark and the Netherlands stand out as the territories offering the most favourable ground for rolling out a BDNB-type initiative: mature data infrastructures, advanced open data orientation, centralised and dynamic governance, and a strong culture of data sharing. Belgium, Spain, Luxembourg, Germany, and Italy, in contrast, present more complex environments, where institutional fragmentation, disparities in framework design, access restrictions, and lower maturity in practices make the generalisation of the BDNB approach more complex and gradual. This overview reveals a direct correlation between the degree of institutional structuring, open data maturity, and the feasibility of building a strong and sustainable national reference system. The chart below provides a qualitative score for each country in the panel according to feasibility criteria.

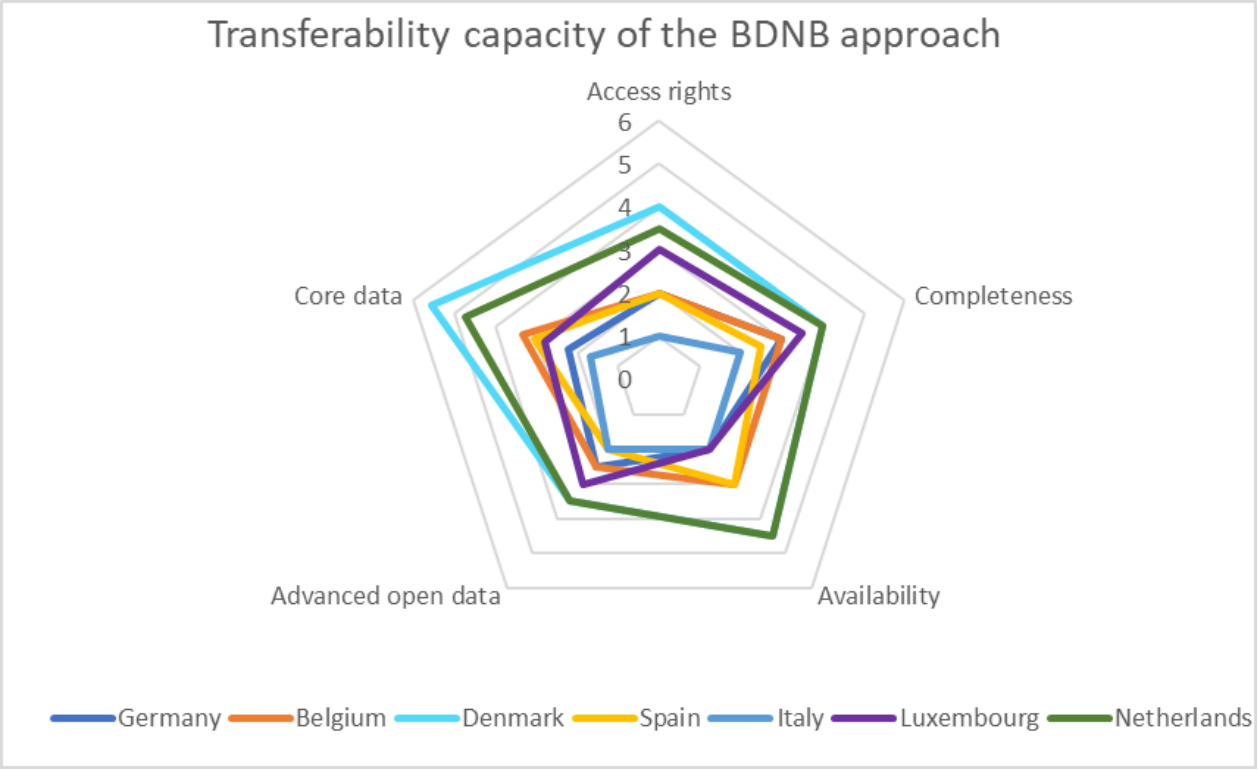
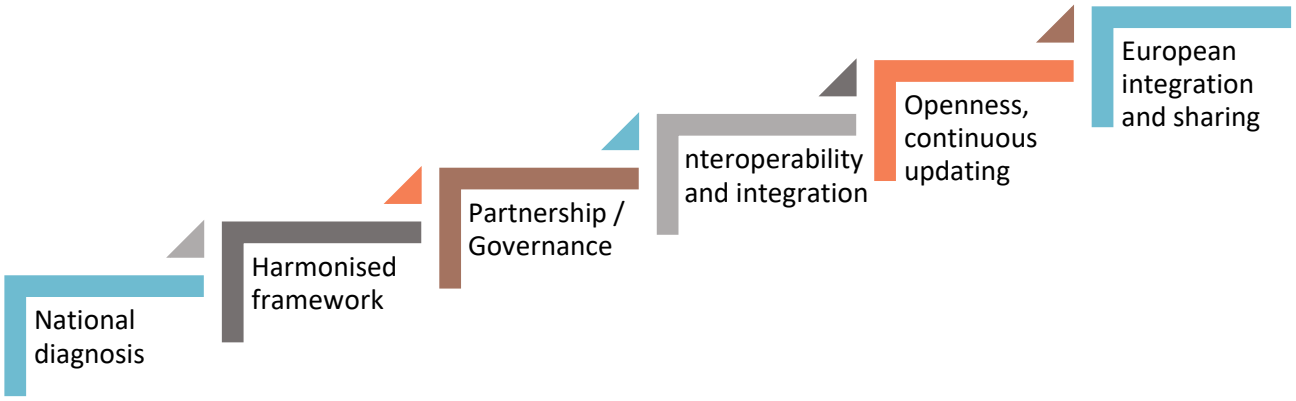


Figure 8. Transferability capacity of the BDNB approach

6 Methodological principles proposal

The main objective of this section is to propose an operational framework aimed at encouraging the creation of national building databases similar to the BDNB, interoperable and adapted to the diversity of national institutional contexts. The goal is to define methodological principles that ensure, from the outset, robustness in diagnosis, rigour in data structuring, as well as openness and shared governance, while guaranteeing interoperability and sustainability within a federalised European space. These principles should support the establishment of a common foundation, while remaining adaptable, for building data serving the energy transition, urban planning, and innovation, whether the data are public or private.



6.1 Initial Diagnosis & Scoping

The launch of a national BDNB-type initiative begins with an in-depth diagnosis of the data ecosystem in the territory concerned. This involves carefully mapping all available core and supplementary layers: building footprints, geolocated addresses, cadastral parcels, energy performance certificates, fiscal layers, or risk exposure data. This inventory must include national, regional or local datasets, whether they come from official sources, scientific platforms, open data, or contributive communities. It is essential to assess actual geographic coverage, dataset granularity, update frequency, documentation quality, and format consistency.

A regulatory analysis completes this overview: each identified dataset must be evaluated according to its access, licensing, reuse and legal compliance constraints (GDPR, fiscal or patrimonial specifics). This step guarantees not only the security of future uses and partnerships, but also the ability to define the necessary boundaries of openness, anonymisation, or contractual adaptation for confident exploitation. At the same time, it frames operational guidelines by clearly outlining the margins for manoeuvre and risks linked to territorialisation or the fragility of certain systems.

Finally, the diagnosis must imperatively reveal all gaps and structural obstacles within the data landscape: lack of openness, insufficient granularity (e.g. too aggregated for fine-scale modelling), unharmonised regional segmentation, lack of public technical documentation, or significant discrepancies in update frequency (some areas updated monthly, others every 3 years, or even not at all). These elements are decisive levers for defining strategic priorities: not only accelerating and guaranteeing data openness, but also systematically raising granularity to the individual building level, harmonising and standardising exchange formats, synchronising updates at the relevant temporal scale for each use, and promoting—both nationally and at the European level—a shared culture emphasising versioning, technical documentation, and traceability. Where standards exist, they must be strictly applied; where not, collective effort should go towards their co-construction, engaging all stakeholders to align themselves with evolving, open, and sustainable frameworks in order to ensure robustness, interoperability, and replicability at every stage of the building data value chain.

6.2 Structuring a harmonised data schema

The unification of building-related data relies on the implementation of a harmonised data schema, structured around core entities and themes. The model of the French National Building Database (BDNB) can unquestionably be considered a reference, as it formalises organisation around key entities: building, parcel, unit, address — as well as their natural linkage with other modules or supplementary layers such as EPCs and performance indicators. It is worth noting that this model also provides an administrative reference framework, regularly updated with each new version, to ensure that the territorial divisions remain consistent with ongoing changes. This organisation guarantees the completeness of functional and spatial links, facilitates precise data traceability at the physical unit level, and ensures the scalability needed to progressively integrate new modules or sectors.

The integration and sustainability of a harmonised data schema depend essentially on the adoption and rigorous application of recognised standards, both nationally and at the European level. To ensure upward interoperability with major European platforms or sectoral observatories, it is crucial that data structuring be based on common, compatible models, formats, and vocabularies. The example of the French BDNB shows that creating unique identifiers (via the RNB) and installing a stable attribute reference ensures semantic consistency as well as automatic linking with other external reference systems. Widespread adoption of open standards, well-documented formats, and robust procedures for metadata and version management are guarantees of easy reuse, portability, and ongoing alignment of datasets over time. For each territory and stakeholder, this requires a strong methodological commitment: proactive vigilance, constant alignment, and regular adaptation in response to the evolution of European and international standardisation. Ultimately, convergence around shared standards remains the sine qua non condition to maximise the collective value of building data, ensure its scientific robustness, and increase its operational impact at all levels.

A third methodological principle is to establish a minimum common attribute reference across all partner territories. This foundation should include essential structural variables: geometry/footprint, year of construction, main use, surface area, energy characteristics (EPC type), as well as any attribute allowing for interterritorial comparability and also linking to local-to-European territorial strategies and ambitions. This reference should, from the outset, be designed as both scalable and modular, in order to gradually accommodate additional attributes from sectoral or local initiatives, thereby increasing the relevance, precision, and cross-disciplinary usefulness of the data. This modularity determines the model's capacity to adapt to future needs and ensures the sustainable, transparent, and shared consolidation of knowledge about the building stock. This is essential at both national and European levels for supporting public policy, research, and innovation.

6.3 Partnership and governance

The success of a unified building data project requires the early and coordinated involvement of all relevant public stakeholders. It is particularly essential to bring together cadastral services, national or regional energy agencies, national statistical institutes, as well as local authorities and operators responsible for urban and land policies. This broad governance ensures not only access to reference sources, legitimacy, and completeness of the collected datasets, but also firmly anchors the database's structuring in the operational and regulatory requirements of the institutional ecosystem.

The management, updating, and dissemination of the database must be entrusted to an operator with a clear mandate as a "trusted third party," based on proven expertise, methodological transparency, and effective partnership facilitation. The French model provides an illustration of this: CSTB (Centre Scientifique et Technique du Bâtiment) acts as the main operator of the BDNB, responsible for collection, cross-referencing, enrichment, documentation, and dissemination through the bdnb.io portal. This mission is carried out in close collaboration with major technical partners like CEREMA or IGN, as well as through active participation in national discussions on standardisation, governance, and the development of reference systems such as the RNB. This framework guarantees quality, traceability, secure access, and openness to both the professional and scientific ecosystem.

Finally, the process must rely on a network of scientific and technical partners—true engines of innovation and adaptation. University laboratories, applied research centres, maker collectives, and digital developer communities contribute to prototyping, continuous scientific validation of methods, and experimentation with new uses for the database. Their involvement drives methodological improvement, fosters the emergence of innovative services, and anchors the collective appropriation dynamic necessary for the success and sustainability of the data infrastructure at every scale. It is also essential to set up mechanisms for consultation and regular feedback from end users; their practical insights facilitate the continual improvement of the reference system's relevance, usability, and robustness, ensuring that the data infrastructure remains aligned with the evolving needs of the public, private, and academic sectors.

6.4 Interoperability

Ensuring the interoperability of a building database involves establishing mechanisms for linking, feeding, and cross-validating between key reference datasets and official sources—such as the cadastre, land records, or EPCs. This approach is not optional: it helps improve data granularity, ensures continuous updating at the building or dwelling level, and fills existing gaps (for example, the lack of vintage data in certain regions or undetected discrepancies in usage). More importantly, it guarantees independent and cumulative traceability, which strengthens confidence and legitimacy for both end users and regulators.

The success of interoperability relies on an ambitious data processing architecture. It is essential to systematically align geometric data, normalise attributes (matching dictionaries, logical linking between internal and external IDs, harmonising professional codes and labels), and perform semantic, geometric, or heuristic matching (duplicate detection, reliability scoring, completeness of areas). The BDNB model demonstrates this chain through its algorithmic cross-referencing processes, the use of expert algorithms, and the continuous creation of traceable workflows. This methodological foundation must also compensate for asynchronous updates and address regional variability, both of which remain major challenges in France and Europe.

Finally, technical and scientific transparency requires the publication and documentation of all code, matching scripts, methods, and models on open collaborative platforms like GitLab or GitHub, ideally following FAIR (Findable, Accessible, Interoperable, Reusable) standards. This approach ensures auditability, facilitates the reproducibility of processing chains at national and European level, and encourages collective intelligence as well as the pooling of resources. This is the model currently supported by major European reference systems and used on platforms like bdnb.io, which, as far as possible, guarantee transparency regarding scripts, error reports, and processing chains. In short, the success and sustainability of interoperability projects depend on technical rigour, the ability to document, and the integration of openness into data governance.

6.5 Guaranteeing the Lifecycle, openness, and updating

Within methodological management, it is essential to establish, as much as possible, an open licensing policy—such as Open Data Commons or Creative Commons Attribution—in order to maximise reuse, transparency, and portability, in accordance with European regulations. This legal openness must be matched by the provision of sustained and technical access to the data: supplying documented APIs and options for downloading files in standard formats, accompanied by clear and accessible documentation. This dual foundation (legal and technical) ensures that every actor—whether public, private, researcher, or citizen—can effectively make use of all or part of the reference dataset, while respecting security and traceability obligations.

To ensure the relevance and freshness of reference datasets, it is essential to set up robust mechanisms for the automatic retrieval of new data, based on automated inbound flows and regular synchronisation with source bases such as the cadastre, EPC, and renovation records, among others. This monitoring requires the implementation of active surveillance systems: update alerts, completeness indicators, and change management systems (logs, version tokens). This strategy aims

to anticipate deviations, promptly detect discrepancies, and ensure the temporal consistency of datasets used for multi-scale or longitudinal analyses.

Finally, regular updating requires the systematic and publicly accessible documentation of the database schema, including: formalisation of attributes, semantic descriptions, history of changes, and clear indication of update cycles. Such methodological transparency encourages reproducibility, skill development within the user community, and the ongoing ability to connect these databases with European references. The convergence of these requirements constitutes the guarantee of reliable, sustainable, and truly open management of building data, serving public policy and collective intelligence.

6.6 Sustainability, communication & European integration

The sustainability of a national building database first and foremost requires strong consolidation at the local level, based on the commitment of national stakeholders and sound methodological choices. It is imperative to establish transparent governance among administrations, local authorities, institutions, and private actors within the country to ensure continuity, traceability, and regular updating of information flows. This foundation relies on the systematic adoption of open licences, publication of data through APIs or downloadable formats, and the implementation of automated pipelines for acquiring new data. Technical documentation, regular updates to the database schema, and the public sharing of methodology are key elements for building trust, encouraging internal innovation, and guaranteeing the long-term success of the project.

Local success then becomes the pillar for an ambitious European integration strategy. Active participation in European projects and institutional visibility on major continental platforms (data.europa.eu, INSPIRE, national portals) are essential levers for promoting the approach and positioning the national database as a benchmark, thus facilitating the convergence of standards and the sharing of expertise. Opening the source code and publishing detailed processing mechanisms (data models, APIs, workflows) further foster this dynamic by enabling the replication of the experience in other countries, while creating an interoperable community of users, developers, and decision-makers across Europe.

This progressive approach, moving from local consolidation to European federation, transforms the national database into a true “catalyst of shared resources,” ready to integrate with major continental systems, shape policy roadmaps, and ensure the collective resilience of the building sector. It allows each country to retain control of its data flows while actively contributing to the establishment of a shared foundation—serving the energy transition, urban planning, and methodological excellence across the European Union.

7 Discussion et conclusion

7.1 Diversity and national inequalities in data Structuring

European analysis highlights major disparities in the structuring of building data, revealing a true mosaic of national models. Pioneer countries such as France have developed comprehensive and regularly updated databases, along with increasingly open interfaces and ongoing discussions aimed at establishing a common language and standards, thus facilitating the cross-linking of data at the national level. These systems offer simplified access for all stakeholders—local authorities, researchers, the private sector—fostering cooperation and transparency.

Nevertheless, many other states—such as Germany, Italy, and Spain—continue to face persistent institutional and technical fragmentation: separate databases by region, topic, or administrative level; access restrictions; patchy documentation. This fragmentation results in significant inequalities regarding update frequency and the possibility of producing multi-source analyses or homogeneous indicators. The absence of a unique reference key and the diversity of attribute schemas complicate standardisation, traceability, and ultimately the establishment of a truly common national foundation.

This maturity gap is also reflected in the effort invested in qualification, documentation, and openness. While in Nordic countries, attribute harmonisation, the production of guides, and progress in open data accessibility are proceeding rapidly, many Member States still struggle to define the boundaries, quality, and evolution of their public data. Fundamental elements of the common language—such as what constitutes a building—continue to be defined in different ways, making directly comparable indicators impossible to produce.

Finally, despite the growing importance of European standards and infrastructures like INSPIRE, the reality of interoperability remains far from optimal. The continued existence of isolated legacy databases, the deficit of homogeneous metadata, or uneven standards implementation impede the creation of a single, coherent market for building data. The slow pace of regulatory convergence, the persistence of local exceptions, and insufficient resources dedicated to governance or integration all hinder the development of a federated, open, and shared ecosystem.

In conclusion, the structuring of building data in Europe is situated between leading poles and zones of both institutional and technical vulnerability. Harmonising practices, creating a common language, and ensuring uniform qualification of reference systems will require concerted efforts, sustained investment, and strong political will in order to turn the vision of an interoperable European data space into a tangible reality.

7.2 Structural and methodological gaps in building data

Despite significant progress in data at the European scale, the analysis reveals persistent, major structural gaps in the coverage, quality, and functionality of building data. These shortcomings are particularly acute in the core layers. Often, such deficits are partially masked by workarounds—purchasing licences, restricted access for institutions—which create an illusion of completeness while vast “white areas” remain, both in temporal coverage (update frequency, historical depth) and in spatial and semantic granularity (lack of parcel-level information, absence of attribute standardisation, difficulties linking datasets from multiple operators). These factors affect the granularity, historical depth, or quality of linking between diverse datasets, limiting the creation of comprehensive and operational reference frameworks for, for example, urban management, energy renovation, or risk prevention.

The scale and persistence of these gaps depend fundamentally on the political, institutional, and technical parameters specific to each state. The legislative framework for open data, the presence of active government strategies, digital maturity, and public investment in data collection or maintenance are key criteria. Countries that have developed a genuine culture of openness and collaborative governance generally possess more complete, up-to-date, and better-standardised datasets, while elsewhere, the absence of unified schemas or sufficient resources hampers access, integration, and

portability.

Other barriers relate to the sensitivity, cost, and timeliness of data. Access can be hampered by legal constraints (confidentiality, fiscal secrecy, personal data), models that limit the circulation of reference data (restrictive licences, lack of data sharing), and often prohibitive acquisition, maintenance, or interfacing costs. Timeliness is also crucial: obsolete data or information delivered outside the decision window may lose all strategic relevance, while prompt updating can have a major impact on the success of public policy or renovation projects.

Another key factor is vertical and horizontal collaboration among public, private, and citizen actors. The absence of data sharing or common platforms, fragmentation of data collection drivers, and a lack of institutional interoperability exacerbate the dispersion, duplication, or loss of strategic information, especially at regional or municipal scales. National datasets can offer an overview, but often lack granularity; conversely, local datasets, though more precise, struggle to be federated or valorised nationally or at the European level due to the absence of common standards and architecture.

Ultimately, publishing a dataset—even as open data—does not automatically ensure its impact in practice. An “ambition gap” remains: the trend to consider accessible—even incomplete or poorly qualified—data as sufficient leads to neglect of continuous improvement, updating, and cross-enrichment. Genuine added value requires interrogating the timeliness of gaps, the cost and effort needed to reach optimal exhaustiveness and granularity, and the data’s capacity to generate operational value: decarbonisation, territorial equity, risk anticipation, or urban innovation.

Overcoming these challenges will require coordinated methodological, institutional, and technical investment, along with a culture of continuous improvement at both national and European scales. Structural actions are needed, such as: the creation of a shared European data dictionary, development of federated solutions for data management and traceability, and progressive harmonisation of standards among institutional, public, and private actors. Operational valorisation of building data therefore demands enhanced methodological governance, coordinated investments, and a common culture of continuous improvement—an essential condition for meeting the ambitions of climate action in the building sector.

7.3 Cross-cutting challenges in standardisation and governance of building data

Following the coverage and quality gaps identified in previous sections, the analysis brings to light a set of cross-cutting challenges that hinder the creation of truly interoperable and sustainable reference frameworks at the European scale. The review of available building data across the studied panel of European countries highlights persistent fragmentation in formats, models, and levels of detail, which acts as a structural barrier to the establishment of truly interoperable and long-lasting systems. This heterogeneity arises from the diversity of business processes, the rapid evolution of sectoral needs, and the persistence of legacy practices unique to each territory. Such segmentation significantly reduces the potential to cross-link data from multiple stakeholders, slows the integration of new datasets—whether open or under licence—and complicates the production of reliable, common indicators for public action, research, and innovation.

Beyond purely technical challenges, data governance appears as a decisive factor in the evolution of the sector. The lack of structural coordination among stakeholders, weak incentives for adopting shared standards, and the difficulty in sustaining user and producer communities all slow down the spread of good practices and the development of mature reference frameworks. To address this, it is essential to promote targeted support, produce tailored guidelines, and implement pooling mechanisms to reduce entry costs and foster sectoral convergence. Moreover, exploring models of decentralised governance is relevant: rather than systematically centralising datasets, federated solutions could preserve each stakeholder's data sovereignty while facilitating interoperability, secure access, and reuse according to common protocols. Maintaining, ensuring the quality, and updating standards represent long-term commitments and substantial investments that few actors can manage alone, hence the need for robust and sustainable collective structuring.

Integrating decentralisation into data governance emerges as a key lever for stimulating innovation and the participation of sector actors. This involves resource pooling, creating tailored methodological guides, and running dialogue platforms open to the entire value chain. A collective commitment to the maintenance, quality, and evolution of standards—within a federated and shared framework—ensures the ongoing growth and operational relevance of reference systems.

Finally, rapidly adapting to emerging technologies—such as connected objects, environmental monitoring devices, or new climate indicators—challenges the robustness of current frameworks and calls for dynamic, flexible, and inclusive governance. Only by judiciously balancing innovation, consultation, support, and anticipation of new needs can the sustainability, resilience, and strategic value of building data systems at the European level be ensured.

7.4 Towards a European federation of national building databases: convergence, interoperability, and open data challenges

The structuring of a federated ecosystem of National Building Databases (BDNB), linked, for example, to a European aggregator like EUBUCCO, lays the foundation for a major transformation in the governance of building data in Europe. Built on open standards (INSPIRE, etc.), this architecture would support state sovereignty over the production and reliability of national datasets, while ensuring the technical alignment needed for upward integration from local and national data to continental platforms. This structural framework makes it possible to combine exhaustiveness, freshness, and local responsibility with European-level comparability, visibility, and analytical agility.

Interoperability with EUBUCCO would be based on harmonised data models, shared protocols, and detailed metadata, making automation and rapid cross-border data integration possible. EUBUCCO would then serve as an aggregator, indexer, and comparator, optimising traceability, standardisation, and the availability of data flows for all European policies, universities, and the private sector. This system streamlines the sharing and practical valorisation of innovations, while laying the foundations for a common European building data framework.

However, this entire system faces major methodological challenges. Update frequency, the level of dataset completeness, and attribute harmonisation remain highly variable between countries, leading to inconsistencies in the quality and freshness of integrated data. Differences in governance models, the existence of proprietary formats, and the persistence of institutional and legal barriers impede automated consolidation and systematic compliance with INSPIRE standards. Fragmentation and “integrity gaps” in some territories require greater coordination, transparency, sharing of best practices, and incentives for regular updates.

Ultimately, the success of such a federation will depend on the convergence of technical innovation (APIs, open-source tools, versioning protocols), methodological standardisation (metadata catalogues, public documentation, unique identifiers), collective governance, and regulatory incentives. Only this combination will enable the shift from a heterogeneous mosaic to an integrated and dynamic landscape, serving science, urban and climate resilience, and an ambitious European policy for open building data in a time of transition.

8 Operational and strategic recommendations for developing approaches similar to the BDNB in Europe

To sustainably anchor the BDNB approach within an effective national and European architecture, it is imperative to combine operational ambition and strategic vision at every stage of the data value chain. The following recommendations offer a foundation of concrete and structuring actions, decisive for guaranteeing the robustness, visibility, and integration of national initiatives within the European open building data ecosystem.

8.1 Operational recommendations

8.1.1 Structure a “minimum data foundation”

Structuring a “minimum data foundation” of open data first requires the transparent publication of the key layers of the built environment: addresses, cadastres, parcels, energy performance certificates (EPC), and fiscal data. This approach determines the robustness, scalability, and accessibility of the data system for all stakeholders—public actors, researchers, businesses, and civil society. However, when certain layers cannot be fully opened due to legal, contractual, or administrative requirements (such as personal data protection, fiscal secrecy, or commercial clauses), it becomes strategic to adopt specific licensing policies. These should precisely define differentiated access conditions, scope of use, methods for anonymisation or pseudonymisation, and any restrictions on redistribution or commercial exploitation. In this context, it makes sense to publish any fully open dataset, while systematically documenting, for each restricted dataset, the applicable legal constraints, the nature of rights holders, and any procedures for access upon justified request, in accordance with a specific agreement or permit. This includes a detailed description of technical flows (e.g., partial joins, masked attribute sets) and traceability of changes in dissemination regime. All of this foundation must be standardised according to proven European formats, supported by strong methodological guides, and supplemented by exhaustive metadata documentation: production chain, update frequency, provenance, access methods, and timestamping of changes to licences or data status. By anticipating, from the design stage, the possibility of changes in legal or regulatory frameworks, this strategy aims to strengthen traceability, readiness for future openness, cohesion of the data foundation, and its integration, ultimately, into federated national and European infrastructures.

8.1.2 Facilitate access and use

To facilitate data access and use, it is essential to ensure availability through high-performance APIs and well-indexed national portals, while maintaining the possibility of automated synchronisation at the European level. This dissemination model allows a wide range of users—local authorities, developers, consultancies, and research actors—to easily integrate data into their own tools and workflows, support multi-scale analyses, and interconnect national datasets with the main federating platforms on the continent.

The effectiveness of this system relies on two complementary imperatives: on the one hand, regular updates of the data, at least annually, coupled with detailed traceability of all changes (additions, corrections, deletions, status changes); on the other hand, favouring the highest possible granularity—at least at building or parcel level, ideally down to individual dwelling level—to enable detailed analyses, optimised targeting of public policies, and the creation of innovative, high value-added services for all users across Europe.

8.1.3 Interoperability and quality

Interoperability and data quality requires systematic cross-validation between different open sources to strengthen reliability, identify discrepancies or gaps, and improve the overall consistency of the reference system. This collaborative verification approach leverages the diversity of available datasets (cadastre, EPC, land data, OSM, etc.) to achieve a consolidated view of the building stock and to

detect anomalies or duplicates in advance.

The establishment of a rigorous quality assurance process is essential at every stage: it must include protocols for documentary control, tracking corrections, and continuous assessment of completeness and granularity. To ensure collective ownership of the quality process, it is recommended to offer each actor a set of self-assessment tools—such as compliance checklists, interactive dashboards, or best practice guides—facilitating internal audits, alignment with established standards, and the gradual increase in maturity of data producers. This transparent, shared quality foundation is a powerful lever for integration into the federated European building data space.

8.2 Strategic recommendations

8.2.1 Governance and partnership

The strategic anchoring of an open building data base requires the establishment of a dedicated governance structure capable of steering, arbitrating, and guaranteeing the institutional and operational coherence of the system. Governance may rely on an inter-municipal alliance, partnership with a public institute or a national open data operator, or be built at the European level to maximise resource pooling and influence standardisation. This structure should act as a trusted third party, organise stakeholder coordination, ensure sustainability, and methodological openness of datasets.

At the same time, it is strategic to establish "open building data labs" at national or local level: these collaborative spaces are tasked with stimulating innovation, carrying out active technical and regulatory monitoring, and encouraging the experimentation and dissemination of best practices among producers, users, and decision-makers. These labs bring together public players, researchers, developers, and also civil society representatives, around workshops, competitions or pilot projects, to strengthen collective adaptability, document feedback, and speed up the maturity of the open building data ecosystem.

8.2.2 Political and incentive support

To enhance data quality and accelerate digital transformation in the sector, certain public aids—whether European or national—should be conditional on true openness and methodological excellence of published datasets. This incentive acts as a powerful alignment engine, encouraging stakeholders to structure their datasets according to best practices and shared standards, while ensuring gradual maturity improvement of information assets across the continent.

In the same spirit, promoting a "European building data code" is strategic for sustainably harmonising requirements for publication, documentation, and sharing between Member States. This unified regulatory foundation would facilitate comparability, portability, and the progressive integration of national datasets within a shared European space. It would provide clear guidelines for producers and users, speed up cross-border integration, and ensure solidarity and coherence in public investments supporting open building data at the EU level. Political and incentive support is essential for the widespread adoption of best practices in open building data. It is recommended that access to certain European or national grants be subject to strict criteria on methodological quality and genuine openness of datasets; this would catalyse efforts in structuring, regular publication, and maturity improvement of national and local references.

Extending this, promoting a "European building data code" would be a decisive milestone for harmonising publication, documentation, sharing, and validation requirements among Member States. This code would not only provide a solid common framework for the comparability and portability of datasets across Europe, but also offer increased legal security, clear guidelines for producers, and reinforce European solidarity in the modernisation and interoperability of strategic sector data.

8.2.3 Strengthen support and communication

Strengthening support and communication in building data management means providing a comprehensive range of tools adapted to different access regimes, whether open data, licensed, or restricted. It's essential to train and support data providers—not only in open data publication, but also in the use of specific licensing models, anonymisation procedures, or request-based agreements. Practical guides, training sessions, and template licences (e.g., for scientific use, professional use by local authorities or private partners) should be provided to secure and facilitate these processes.

In addition, the promotion and visibility of the process should cover all access regimes. Active communication on the uses and benefits of data—open or licensed—via showcase portals, data reuse competitions, or impact studies, helps expand the user community and highlight the range of usage options. Making the entire approach visible at the European level—with open source code publication (e.g. GitHub), joint scientific publications, and detailed documentation of licence models—encourages transparency, reproducibility, and prepares for transnational interoperability of best practices in building asset management.

8.2.4 Sustainability and innovation

The sustainability and innovation in building data management require ongoing compatibility with emerging European standards (INSPIRE, High Value Datasets, etc.), which is essential for guaranteeing the integration, interoperability, and openness of datasets over time. This regulatory anticipation should be linked to a progressive enrichment of datasets: it's not enough to structure a base on geometry or administrative data; gradually, high-value attributes such as materials, consumption, usage, or risk exposure should be added to meet the growing diversity of public and private needs.

It is also essential to go beyond data publication alone by focusing on the creation and use of models, simulators, and key indicators derived from these data. The development of analysis algorithms, automated diagnostics, or monitoring tools (e.g. for energy renovation, environmental monitoring, risk resilience) gives meaning, operational value, and effective visibility to published datasets. Finally, these initiatives should be closely coordinated with major climate and adaptation policies—national renovation plans, adaptation/mitigation strategies, support systems—to ensure convergence between data governance, relevant indicator production, and the effective management of transformations at both European and local levels.

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10 Annexes

See Excel tables:

- EU countries comparisons
- Panel data core availability