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*Cost-effective building stock decarbonization and seismic resilience:
Incorporating EPBD implementation in renovation plans and passports.*

D.2.1 Sustainable renovation-supporting building archetypes

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Executive Summary

This deliverable presents a harmonised methodological framework for defining sustainable renovation-supporting building archetypes in five pilot countries: Greece, Italy, Belgium, Austria, and Slovenia. The work responds to the growing need for integrated approaches that simultaneously consider energy efficiency, seismic resilience, and environmental performance—particularly in light of the Energy Performance of Buildings Directive (EPBD), the Renovation Wave strategy, and broader climate and sustainability targets under the European Green Deal.

The document outlines a two-phase approach to data collection, harmonisation, and archetype definition.

In the first phase, a structured and modular database was developed for each country, using a three-level classification: Sector (e.g., Residential or Service), Subsector (e.g., Single-Family Houses, Apartment Blocks, Trade), and Building Age Class (reflecting national construction and regulatory milestones). These categories formed the foundation for defining coherent Building Categories. Data collected include general characteristics (stock size, occupancy rates), geometry (surface area, volume, height), energy consumption (useful and final energy for heating, cooling, DHW), thermal transmittance, construction materials, and technical systems.

The second phase involved aggregating Building Categories into a limited but representative set of 30 archetypes per country, each enriched with additional descriptors such as climatic zone distribution, seismic hazard level, energy performance class, and typical technical systems (e.g., HVAC, DHW, renewables). This structured synthesis allows for both vertical (per country) and horizontal (cross-country) comparisons, enhancing consistency and interoperability in subsequent modelling activities.

To address challenges related to missing or uncertain data—common in building stock characterisation—the project adopted a dual approach. When data variability within the same category was substantial, variants were either reported separately or accompanied by shared factors. When data were lacking altogether, the minimum values prescribed by national regulations or expert-informed estimates were used. This ensures the framework remains usable, consistent, and ready for refinement as more data becomes available.

Regulatory frameworks on energy performance and seismic safety were analysed in detail for each pilot country to ensure that all archetypes reflect the actual

requirements and evolution of national standards. In parallel, national datasets and construction practices were studied to ensure that the resulting typologies are both realistic and representative of current renovation challenges.

Ultimately, this deliverable provides not just a descriptive tool but a decision-support structure for identifying renovation priorities, assessing environmental impacts (including Global Warming Potential – GWP), and simulating decarbonisation scenarios.

It ensures compatibility with national building codes, statistical conventions, and energy certification systems while remaining flexible enough to accommodate future regulatory updates and technological changes.

In summary, the developed archetype framework offers a unified language for describing and comparing buildings across countries and construction contexts. It enhances the capacity to simulate and assess renovation scenarios by integrating energy, environmental, and seismic indicators into a coherent structure. Supporting evidence-based strategies, it strengthens long-term planning and investment decisions in the building sector.

Most importantly, it provides a solid and adaptable foundation to accelerate renovation actions that are aligned with the goals of climate neutrality and resilience. Through more targeted and integrated planning, this work contributes directly to the transformation of Europe's building stock into a safer, more sustainable, and future-ready asset.

1. Introduction

The characterization of the national building stock through representative archetypes is now a widely recognized practice in the fields of energy efficiency, structural safety, and environmental impact assessment.

Archetypes are simplified models capable of representing the main geometric, physical, and functional characteristics of real buildings. Thanks to these models, it is possible to assess performance at the building stock level without the need to model each individual structure.

Their use is fundamental for strategic planning, setting intervention priorities, and aligning regulatory frameworks.

An archetype can be seen as a generic representation of buildings, allowing fragmented data to be organized into a structured dataset. This is particularly useful across Europe, where the heterogeneity of the building stock among different countries makes it difficult to compare performance or implement common policies. In this context, archetypes are valuable tools for estimating renovation rates, simulating energy savings, assessing environmental impacts, and analysing seismic vulnerability. Their importance is further emphasized by the objectives of various European policies, such as the Energy Performance of Buildings Directive (EPBD), the Renovation Wave, and the Green Deal. A key review by Shen et al. [1] classifies the main approaches to archetype-based energy modelling, distinguishing between normative, data-driven, and hybrid methods. As the authors highlight, the choice of method always depends on the purpose, data availability, and level of detail required. In general, these approaches have been used for scenario analysis and multi-objective assessments in various national contexts.

Today, however, beyond energy efficiency, archetypes are also used to evaluate environmental impacts, structural risks, and to support urban resilience planning, becoming central tools for policies related to the built environment. One of the earliest large-scale examples found in the literature is the work by Mortimer et al. [2], who developed a comprehensive database on energy use in the UK's non-residential building stock. This study introduced a classification system based on building use and construction period, establishing a reference model for many subsequent analyses and policy frameworks. On the other hand, advances in spatial data collection technologies have opened new opportunities, as highlighted by Parezanović et al. [3]. The authors demonstrated how technologies such as LiDAR and GIS can accurately map the

urban building stock, quantifying materials and geometries. This type of modelling also supports circular economy strategies, where knowing the quantity and type of materials within a territory is essential. Moreover, integration with BIM, digital twin models, and remote sensing can further enhance the digital representation and effectiveness of archetypes.

In parallel, Pei et al. [4] proposed a parametric learning model for archetype generation, trained on a dataset of 52 buildings in Singapore. The model is based on similarity metrics, such as Euclidean distance. Starting from EPC and geometric data, the model generates archetypes adaptable to different urban contexts, even when data are limited or inconsistent.

Palladino [5] analysed the energy performance gap (EPG) of residential buildings in Italy by simulating different archetypes across several climate zones. The study emphasized the role of occupant behaviour, construction quality, and maintenance, highlighting the importance of including behavioural variables in archetype models.

One of the main data sources for archetype development is the Energy Performance Certificate (EPC). The following are several scientific applications of EPC-based archetypes, used for different purposes.

Hörner et al. [6] combined EPC data with cadastral records and homeowner surveys to classify the non-residential building stock in Germany. Marinova et al. [7] integrated EPC data with material databases to assess material intensity and stock evolution.

Kinay et al. [8] applied EPC-derived archetypes to estimate renovation potential in Finland and Turkey, demonstrating the usefulness of EPCs even in contexts where certification systems are not fully standardized.

Meanwhile, the introduction of clustering and machine learning methods has further enriched the development and quality of archetypes.

In this regard, Zhou et al. [9] employed unsupervised learning techniques, such as k-means and k-prototypes, to identify hidden structures in building data. These methods allow the combination of both numerical and categorical variables into a single model and support continuous updating of archetypes. Some supervised models have also been tested to predict renovation needs or usage profiles. A crucial aspect, however, is the empirical validation of archetypes against real-world data.

Magalhães et al. [10] examined the gap between theoretical and actual performance in the Portuguese building stock, while Sarabia-Escrivá et al. [11]

assessed the effectiveness of EPCs in Spain, highlighting shortcomings in labelling procedures.

Raushan et al. [12] improved the reliability of EPC data in Ireland through a qualitative filtering process.

Sasso et al. [13] proposed a bottom-up model for office buildings, validated through real consumption data.

In conclusion, one of the main challenges in generating archetypes from national EPCs lies in the varying assumptions and methodologies, as well as the lack of crucial data such as user behaviour, ventilation strategies, or seismic vulnerability. While machine learning techniques show promise, their performance remains highly dependent on data quality and is still under development. The aim of this deliverable is to establish a harmonized, multi-criteria framework for categorizing the building stock in the project's pilot countries: Greece, Italy, Austria, Slovenia, and Belgium.

Thirty archetypes will be identified for each country, incorporating both energy and seismic criteria, in line with the EPBD Directive. All major energy services will be considered (heating, cooling, ventilation, domestic hot water, and lighting), and the necessary input for assessing the Global Warming Potential (GWP) will be provided.

Particular attention will be given to compatibility with national and regional building codes, energy regulations, and statistical classifications. The approach will combine well-established methods with innovative solutions to overcome known challenges, such as data fragmentation. The ultimate goal is to build a solid and coherent methodological foundation that integrates energy, seismic, and environmental aspects into decision-making and long-term planning. This work will support the development of more transparent and equitable renovation strategies, strengthen alignment with climate and resilience targets, and improve the understanding of synergies between technical solutions and policy instruments.

2. Analysis of Existing Data Sources and Regulations

The preliminary analysis of existing data sources and the current regulatory framework is a key step in the development of a robust, consistent, and harmonized building stock model across the pilot countries. This phase focused on identifying and critically assessing the availability, quality, and relevance of data needed to define building archetypes based on energy, seismic, and environmental criteria.

The objective was twofold: on the one hand, to verify the extent to which available datasets support the calculation of performance indicators in line with the Energy Performance of Buildings Directive (EPBD), including those related to life-cycle assessment and Global Warming Potential (GWP); on the other hand, to frame the national regulations concerning energy efficiency, seismic safety, and renovation strategies, ensuring that the resulting archetypes align with both local and European targets.

The outcomes of this analysis provide the foundation for the methodological structuring of building archetypes and the identification of compatible, integrated renovation solutions. This step also supports cross-country comparability and consistency. Detailed insights into the examined databases and national regulations are presented in the following sections.

2.1. Overview of Existing Databases

The definition of representative building archetypes at national and regional level requires a solid, structured, and coherent information base aligned with European objectives in the fields of energy efficiency, seismic safety, and environmental sustainability. In this context, the analysis of existing databases focused on official European sources, datasets from research projects, and technical databases relevant to the description of the building stock.

The main reference platform is the **Building Stock Observatory (BSO)** [14] of the European Commission, which serves as an aggregation point for many of these sources.

It is a platform developed in 2016 by the Directorate-General for Energy of the European Commission, with the aim of collecting, harmonising, and making accessible data on the building stock across Member States. Its purpose is to support the implementation of the EPBD Directive and broader European policies related to the decarbonisation of the building sector. The database includes

information on building typologies, age of buildings, energy performance, renovation rates, final energy consumption, and the diffusion of technical systems and technologies. The BSO is not an original data source itself, but rather a platform that collects and organises information from multiple European sources, which are briefly described below.

Among the main data sources integrated into the BSO are **European statistical databases**, such as **Eurostat** [15], which provides, for example, data on residential energy consumption expressed in TJ/year, disaggregated by energy carrier and end-use system, covering the period from 2015 to 2021.

The **European Environment Agency (EEA)** [16] also contributes valuable datasets, offering environmental indicators and emission figures related to the residential and tertiary building sectors. In particular, it is possible to retrieve data on both direct emissions produced by the combustion of fossil fuels within buildings and indirect emissions associated with the production of electricity or thermal energy used to meet buildings' energy demands. These values are reported in MtCO₂eq/year and cover annual trends from 1990 to 2021.

Regarding the number of dwellings in each Member State, the BSO draws on statistics from national institutes. Notable examples include **ISTAT** for Italy [17], **ELSTAT** for Greece [18], **STAT** for Slovenia [19], **STATBEL** for Belgium [20], and **Statistics Austria** for Austria [21].

Furthermore, the BSO database also integrates the results of several recent European projects aimed at enriching the data infrastructure required for modelling the building stock from an energy, environmental, and seismic perspective. Among these, the **MODERATE** project (Modelling and Observing Data for Energy Research And Technology Evaluation) [22] plays an important role in data structuring and harmonization. The project has developed a semantic and technological infrastructure to facilitate the collection, interoperability, and secure sharing of energy-related data in the European building sector. Rather than being a direct source of building archetypes, MODERATE provides a digital ecosystem that enables access to disaggregated data from heterogeneous sources (public, regional, or private) enhancing their traceability, quality, and consistency. Its contribution to the BSO lies in strengthening the underlying data architecture, allowing the integration of high-resolution, dynamic data aligned with common standards.

The BSO also includes the **AmBIENCE** project (Active Managed Buildings with Energy Performance Contracting) [23], which provides a European database of the building stock designed to support innovative approaches to active energy

performance contracting. However, it is important to clarify that the data provided by AmBIENCE, although formally included in the BSO, largely originate from pre-existing sources, in particular the **TABULA** project. AmBIENCE relied on TABULA's typological data to develop representative archetypes of the European building stock, organizing them into simplified grey-box models suitable for energy simulation and flexibility assessments.

Consequently, the most direct and methodologically significant reference for the definition of building archetypes remains the **TABULA** project, along with its follow-up, **EPISCOPE** [24]. TABULA was one of the first European initiatives to introduce a standardized classification system for residential buildings, structured by country, building type, construction period, and energy configuration. It produced detailed typological sheets including geometries, envelope characteristics (opaque and transparent), HVAC systems, and theoretical energy demands. EPISCOPE later expanded this framework by introducing monitoring tools and validation methodologies for the real energy performance of buildings, as well as developing national-level evolutionary scenarios for the building stock.

The value of **TABULA/EPISCOPE** in the context of the present work is twofold: on one hand, it provides a consolidated set of national archetypes that have already been widely adopted in scientific literature and European projects; on the other hand, it offers a coherent and transparent data foundation for the construction of new integrated archetypes covering energy, seismic, and environmental dimensions tailored to the pilot countries, in line with the methodological framework of the project.

Collectively, these data sources offer a quantitative foundation essential for describing the building stock at the national level, facilitating cross country comparisons and supporting the development of harmonized building archetypes aligned with the actual housing context in each country.

Finally, an additional recent data source is linked to the study “Analysis of life-cycle greenhouse gas emissions of EU buildings and construction” for DG GROW, further referred to as **DG GROW study**.

2.2. Overview of National Regulations

Although databases and statistical sources represent a fundamental element for the analysis of the building stock, they alone are not sufficient to provide a complete and realistic picture of the built environment. Databases, particularly those harmonised at the European level, may contain incomplete or some invalid

information, or be influenced by simplifying assumptions and heterogeneous data collection methodologies adopted in different countries. For this reason, in order to fully understand the characteristics, transformations, and potential of the building stock, it is essential to also analyse the national regulatory frameworks, which serve as the concrete and binding reference for the design, renovation, and assessment of buildings.

National regulations define the minimum requirements for energy performance, classification criteria, calculation and certification procedures, as well as obligations and incentive mechanisms for improvement interventions. In addition, they include technical provisions concerning structural safety, environmental sustainability, the efficiency of technical systems, and seismic protection.

It is important to emphasise that, despite the existence of European directives guiding overall objectives, the normative contents and application procedures vary significantly from one Member State to another. Each country transposes these directives according to its own timelines, tools, and priorities, thus defining a national regulatory framework that reflects specific technical needs, environmental conditions, and institutional structures.

This heterogeneity makes it necessary to carry out a separate analysis of the regulations in each pilot country, in order to clearly identify the strategic goals, technical constraints, and operational challenges that shape the configuration and evolution of the local building stock. Regulatory analysis is in fact essential to understand how the legal context has influenced and continues to influence the construction characteristics, the technologies adopted, and the spread of renovation practices.

2.2.1. National Regulations – Greece

In Greece, the evolution of the regulatory framework for the building sector has followed two main and complementary trajectories: on the one hand, the regulation of the energy performance of buildings, which has developed mainly since the 1980s; and on the other, the regulation of seismic safety, which has a longer history due to the high seismicity of the national territory. Both regulatory domains have profoundly influenced the characteristics of the existing building stock and are essential for understanding the initial conditions and the potential for renovation interventions in the Greek context.

Regarding energy regulations, until 1979 there were no binding requirements concerning thermal insulation or energy efficiency in Greek buildings. Design practices were based primarily on structural and functional considerations, with

no specific guidance on the thermal performance of the building envelope. The first regulation addressing these aspects was introduced in 1979 with the **Thermal Insulation Regulation for Buildings**, which established maximum allowable thermal transmittance (U-value) thresholds for walls, roofs, floors, and windows. However, these values were applied uniformly across the country without any climatic differentiation, and the enforcement of this regulation remained limited—especially in the private residential sector—due to a lack of monitoring and control mechanisms.

A major advancement occurred with the adoption of Law 3661/2008, which transposed Directive 2002/91/EC on the energy performance of buildings into national law. In accordance with this law, the **Regulation on the Energy Performance of Buildings (KENAK)** was adopted in 2010 and remains the cornerstone of Greece's building energy code. KENAK introduced a performance-based approach, including national calculation methods for estimating energy demand, mandatory energy classification of buildings, minimum efficiency requirements for the envelope and building systems, and obligations for the use of renewable energy sources. Importantly, it established four climatic zones: A, B, C, and D, as shown in Figure 1, each with differentiated U-value requirements for building elements.

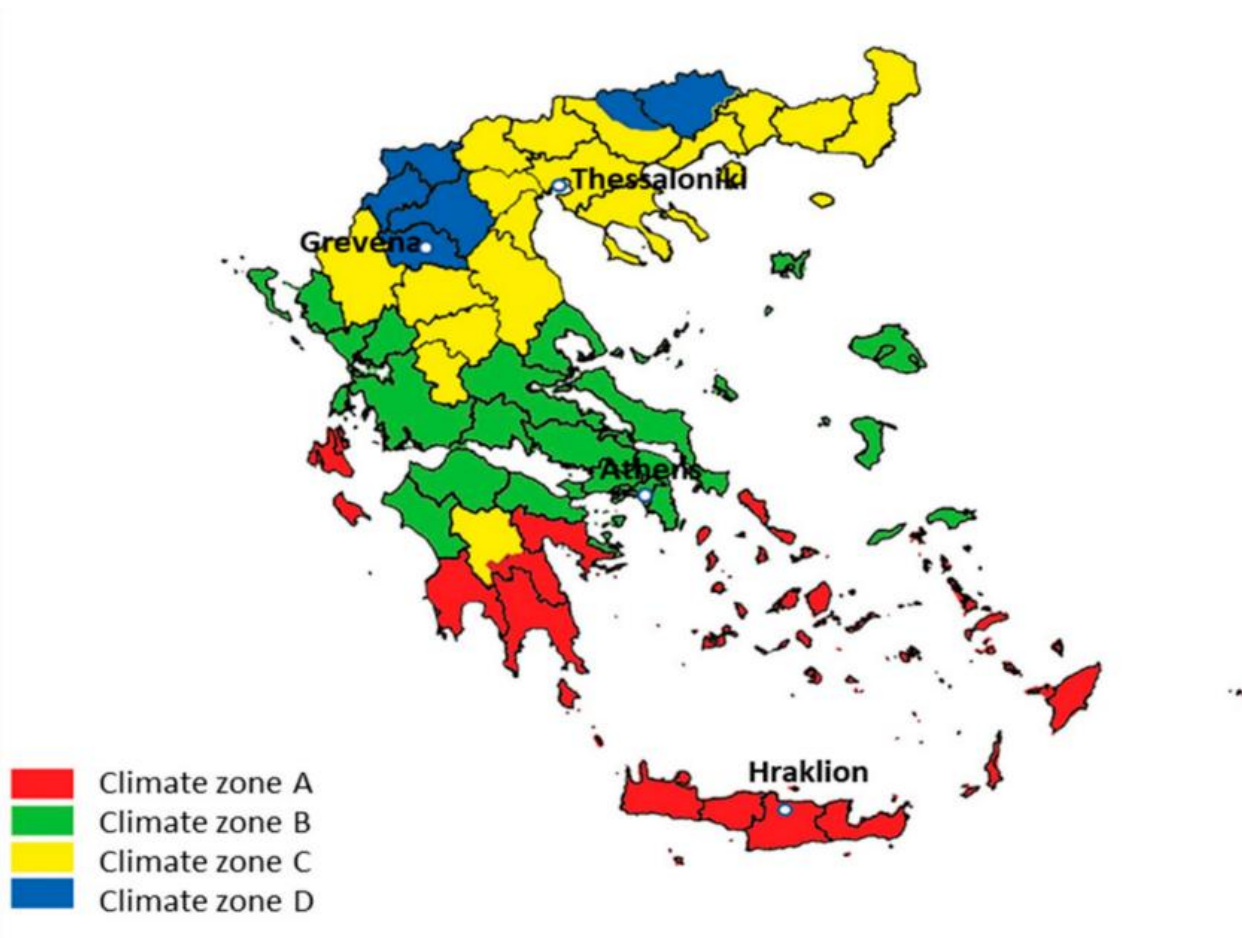


Figure 1: Climatic Zone of Greece. Ref [25]

KENAK is supported by the **Technical Guidelines TOTE 20701/2010** [26], which provide detailed instructions for energy performance assessments and define maximum U-values for each building component. In 2017, KENAK was updated [27], resulting in stricter requirements. For instance, the maximum U-values for external walls were reduced from $0.60 \text{ W/m}^2\text{K}$ to $0.55 \text{ W/m}^2\text{K}$, in the climatic zone A. Similarly, the allowable U-values for windows were reduced to $2.2 \text{ W/m}^2\text{K}$, from $2.6 \text{ W/m}^2\text{K}$ in colder areas. Furthermore, since 2019, the construction of nearly Zero Energy Buildings (nZEBs) has become mandatory for all new public buildings, with the requirement extended to all new constructions from 2021.

Furthermore, the evolution of seismic regulations in Greece begins since the mid-19th century and is directly linked to the country's seismic activity which is very intense and continuous. It is a fact that all the constructions that were established during the period from 1850 to 1959, were without specific seismic regulations, relying mainly on traditional materials such as stones and wood and in the following years fired bricks.

After the appearance of the devastating earthquakes in Kefalonia and Zakynthos in 1953, the first Greek Seismic Code (EAK) was drafted in 1959, which was revised in 1984 with additional regulations that were put into exclusive application in 1985. During the same period, the **first Reinforced Concrete Code** was drafted in 1954, replaced in 1991 by the New Greek Code for the constructions of **Reinforced Concrete (1068/B` 31.12.1991)**, and subsequently in 2000 by the **Greek Reinforced Concrete Code (ΕΚΩΣ-2000)**. At the same time, in 2000, the **European Union Eurocodes** were gradually introduced, with the main ones being EN 1998 (**Eurocode 8**) for seismic design and EN 1992 (**Eurocode 2**) for reinforced concrete.

Regarding the seismicity of Greece, it is important to initially mention the seismic zones that comprise it. Greece is divided into three seismic zones (Zone I, II and III) according to the expected maximum ground acceleration. More specifically, Zone I corresponds to the highest seismicity with PGA (Peak Ground Acceleration) of 0.36 g, Zone II to 0.24 g and Zone III to 0.16 g.

This categorization stems from Greece's position in the boundary zone of the Eastern Mediterranean between African and Eurasian tectonic plates. The specific role of this parameter is shown in the design of buildings according to PGA which constitutes the basis of modern seismic design, where seismic force is calculated from $F = a \times W$, with a being the seismic acceleration coefficient, depending on the seismic zone and W the weight of the structure.

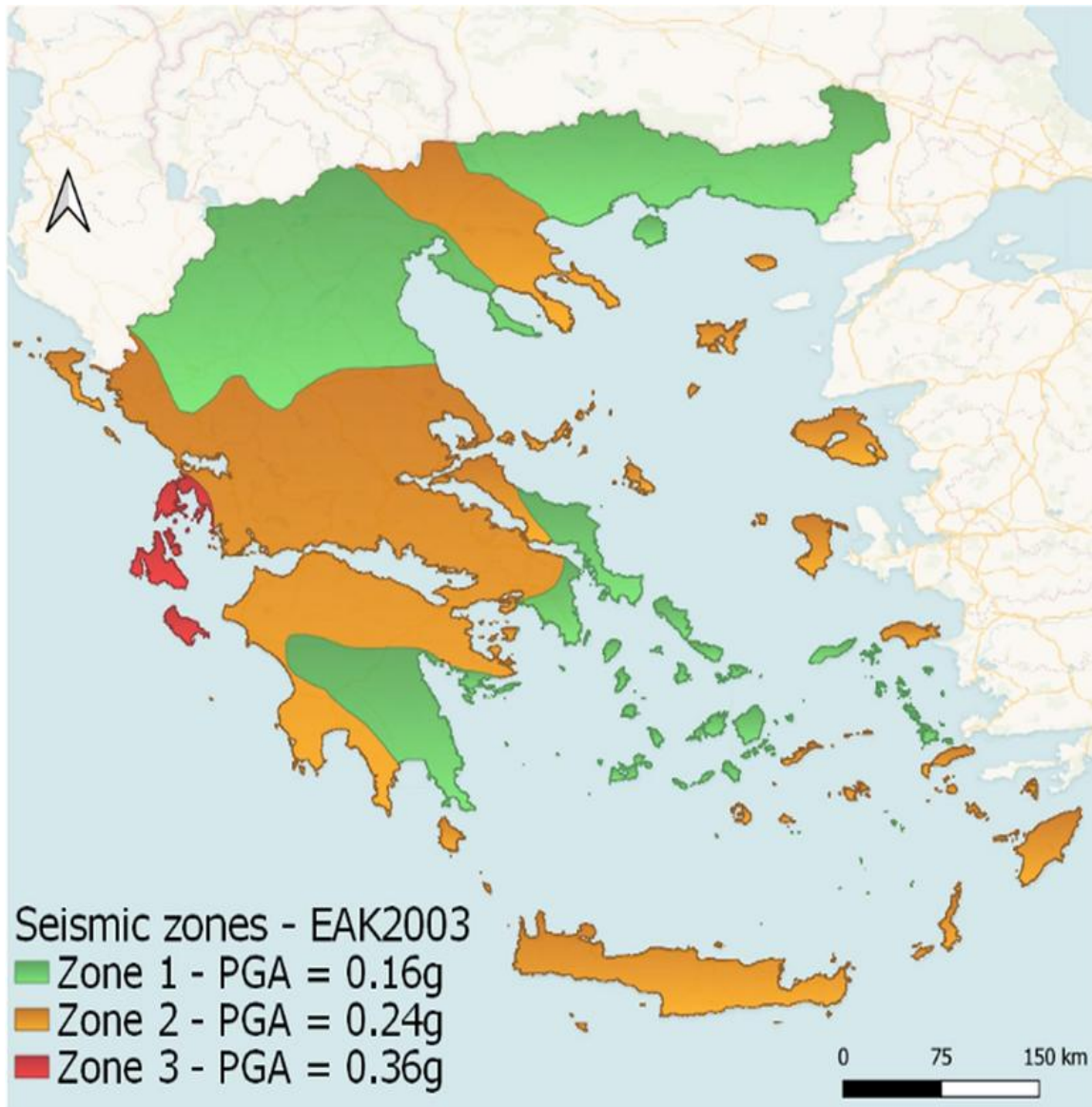


Figure 2: Current seismic hazard zonation for Greece. Ref.[28]

Concerning the evolution of construction materials, it includes the transition from the traditional stone masonry of the 19th century to reinforced concrete after 1920, with the introduction of steel frames after 1960, and the development of other materials such as prestressed concrete and composite materials from 1980s–1990s. The latest Eurocodes foresee further tightening of requirements, with emphasis on climate change adaptation and construction sustainability. In general, current regulations emphasize not only structural safety but also serviceability, durability and environmental considerations, reflecting the strict requirements for earthquake-resistant constructions in Europe’s most seismically active region.

In conclusion, Figure 3 illustrates the temporal evolution of the main regulations affecting the building sector in Greece, highlighting key milestones in both energy

performance and structural safety from 1850 to the present. Seismic aspects are shown in grey, while energy-related aspects are highlighted in red.

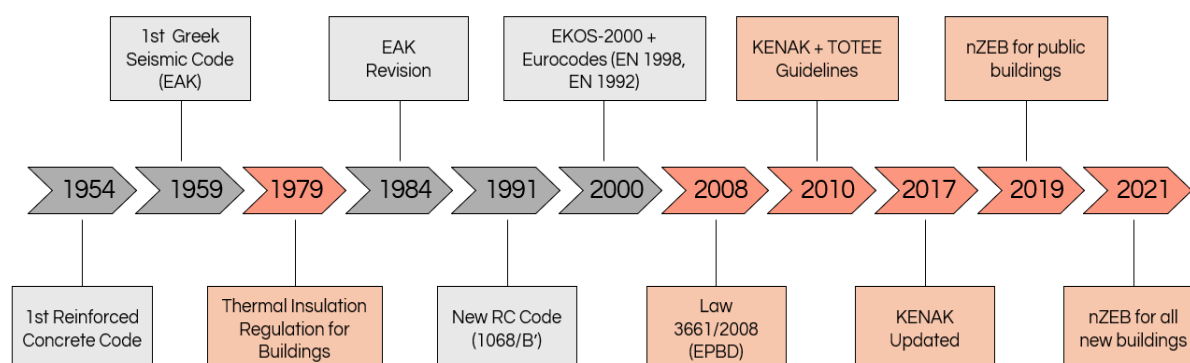


Figure 3: Greek Normative Timeline.

2.2.2. National Regulations – Italy

In Italy, the regulatory framework on building energy performance has progressively evolved since the 1970s, following a structured path aligned with European directives. The first comprehensive legislative reference dates back to **Law No. 373/1976**, which introduced maximum thermal transmittance limits for newly constructed buildings, with the aim of reducing energy consumption following the oil crisis. Subsequently, **Law No. 10/1991** consolidated and expanded the regulatory framework, aiming to reduce energy consumption and improve environmental compatibility, by introducing the requirement for a technical report and more stringent design criteria. Following this law, its implementing decree was issued—**Presidential Decree No. 412/1993**—which introduced key elements such as the classification of the national territory based on degree days and the classification of buildings based on their intended use. In particular, the territorial division into six climate zones (from A to F) is defined precisely based on the number of degree days, as shown in the Figure 4.

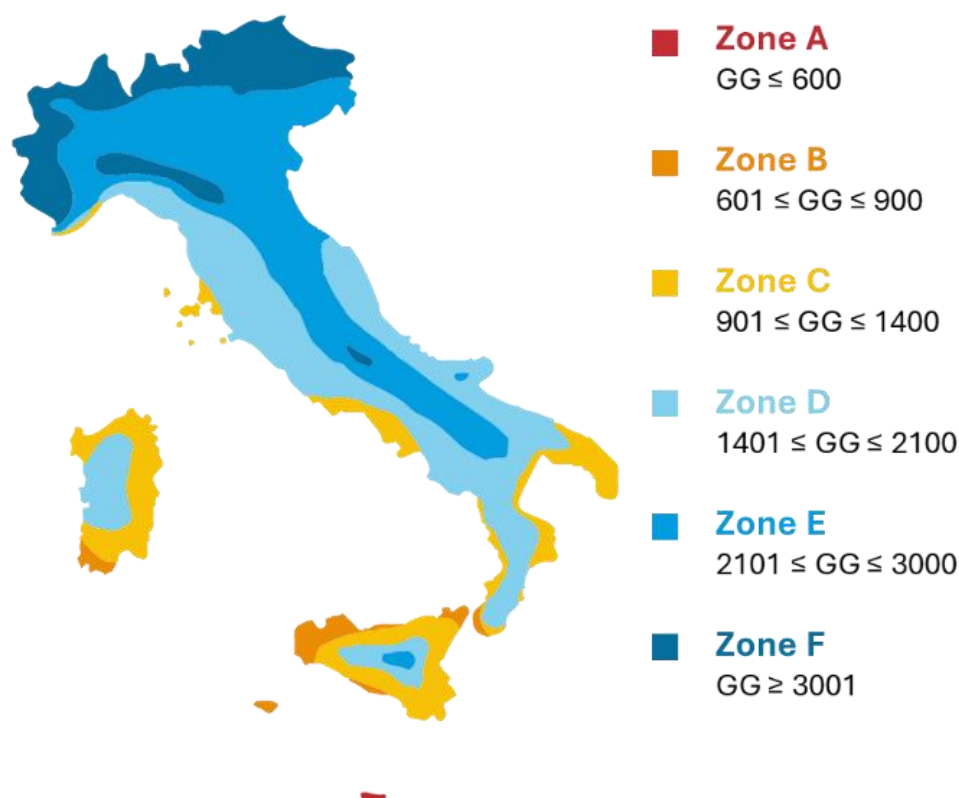


Figure 4: Climatic Zone of Italy.

A decisive turning point was the adoption of **Directive 2002/91/EC** through **Legislative Decree 192/2005** and subsequent amendments. This introduced a dynamic, performance-based approach to assessing the energy efficiency of buildings. This framework relies on measurable parameters and system efficiency criteria, introducing indicators such as the winter heating energy performance index (E_{Pi}) and the Energy Qualification Certificate (in Italian AQE). The Certificate includes calculated primary energy needs, the energy class of the building or unit, and reference threshold values. The current regulatory framework is mainly defined by the **Ministerial Decree of 26 June 2015** [29], which introduced three key implementation measures: Minimum Requirements; Guidelines for Energy Certification; and Reference Schemes for Calculation Software.

The Decree established the concept of a reference building as a regulatory benchmark based on building use, climate zone and year of construction. It also adopted a performance-based method using normalized indicators such as EP_{gl,nren} (non-renewable global primary energy). The decree also set maximum thermal transmittance (U) values for building envelope components, differentiated by climate zone (e.g. for roof structures, values range from 0.38 W/m²K in zones A–B to 0.23 W/m²K in zone F), as well as minimum efficiencies for

HVAC systems and increasing requirements for renewable energy integration, in line with **Legislative Decree 28/2011**. Since 2021 (for the adoption of **Directive 2010/31/EC**), all new buildings, both public and private, must comply with the Nearly Zero Energy Building (nZEB) standard, ensuring high energy performance that is largely covered by renewable sources. This contributes to the decarbonization of the national building stock. Completing this framework, the new **Directive (EU) 2024/1275** ("Green Homes Directive") establishes binding targets for reducing energy consumption and renovating existing buildings. It aims to ensure that residential buildings achieve at least energy class E by 2030 and class D by 2033, while also promoting deep renovations, electrification, the integration of renewables, and renovation passports. This regulatory evolution will shape future retrofit strategies and inform the development of the building archetypes used in this study, ensuring they align with European decarbonization goals. Figure 5 shows the evolution of Italian national regulations, which are fully integrated with European regulations.

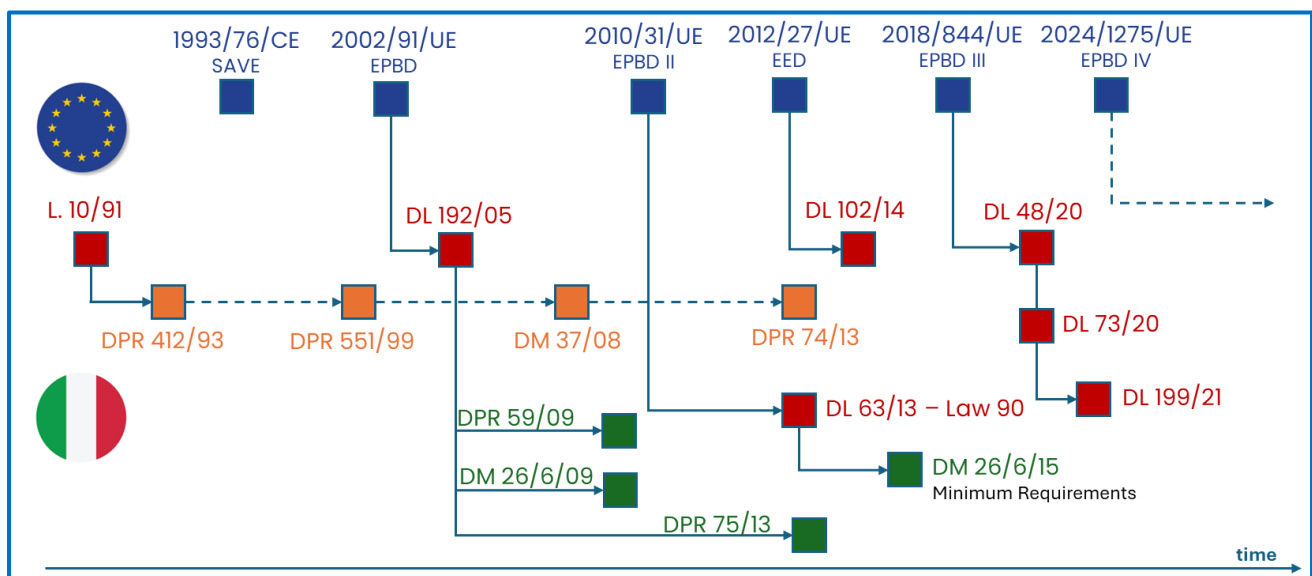


Figure 5: Evolution of Italian national regulations.

The **Italian seismic regulatory** framework has historical origins dating back to the early 20th century, first introduced with the **Regio Decreto** issued after the catastrophic earthquake that struck Messina and Reggio Calabria on 28 December 1908. In the decades that followed, seismic classification of the territory was applied in a reactive manner, with the list of seismic municipalities updated only after each major event.

A turning point came with the **Legge 5 Novembre 1971, n. 1086**, which introduced regulation for reinforced concrete and steel structures, ending nearly four

decades of limited seismic oversight. This laid the groundwork for the **Legge 2 Febbraio 1974, n. 64**, which established the first coherent national criteria for seismic structural design, enabled updates to technical standards and zoning based on scientific progress, and delegated to the Ministry of Public Works the authority to issue the relevant *Norme Tecniche* (Technical Standards for Construction).

These legislative milestones were followed by a **series of Ministerial Decrees**, starting in **1975**, and subsequently updated in **1982** and **1996**, that progressively refined seismic design requirements across the country. These decrees progressively integrated and refined the structural design requirements for constructions located in seismic zones.

A major reform came with the **Ordinanza del Presidente del Consiglio dei Ministri (OPCM) n. 3274 del 20 marzo 2003**, issued following the Molise earthquake of 2002. This ordinance marked a turning point by declaring the entire national territory as seismically classified and subdividing it into four zones of decreasing seismic hazard. For the first time, seismic zoning was based on probabilistic criteria. The ordinance also introduced transitional technical standards applying to a broad range of structures, including buildings, bridges, and geotechnical works.

In 2005, a new set of construction standards was approved by the **DM 14 settembre 2005**, establishing **Norme Tecniche per le Costruzioni (NTC)** inspired by performance-based design principles and aligned with **Eurocode 8**. This framework was further reinforced by the **DM 14 gennaio 2008** (commonly referred to as **NTC 2008**), which formally incorporated probabilistic seismic hazard models through hazard maps developed by the *Istituto Nazionale di Geofisica e Vulcanologia* (INGV).

The most recent update is represented by the **DM 17 gennaio 2018 (NTC 2018)**, which constitutes the current normative reference. This version introduces further advancements in calculation methodologies, geotechnical parameters, and seismic safety verifications.

It provides more detailed guidance for dynamic analyses, the assessment of existing structures, and the design of strategic infrastructure. Notably, the NTC 2018 emphasizes local seismic hazard (microzonation), recognizing variations in seismic response between geologically diverse areas—even within a single municipality.

As a result, the current regulatory framework is founded on a scientifically driven, performance-based approach. It equips designers with tools that take into

account site-specific seismic responses, definitively moving beyond the older, zoning system defined at the municipal level.

For the seismic characterization of the national building archetypes, reference was made to the official seismic zoning provided by the **Italian Civil Protection Department**, the national authority responsible for the forecasting, prevention, and management of natural and anthropic risks, including earthquakes.

Italy is classified into four seismic zones (from 1 to 4), based on the expected peak ground acceleration (a_g) with a 10% probability of exceedance in 50 years (Figure 6). The corresponding acceleration ranges are as follows:

- **Zone 1:** $0.25 < a_g \leq 0.35 \text{ g}$
- **Zone 2:** $0.15 < a_g \leq 0.25 \text{ g}$
- **Zone 3:** $0.05 < a_g \leq 0.15 \text{ g}$
- **Zone 4:** $a_g \leq 0.05 \text{ g}$

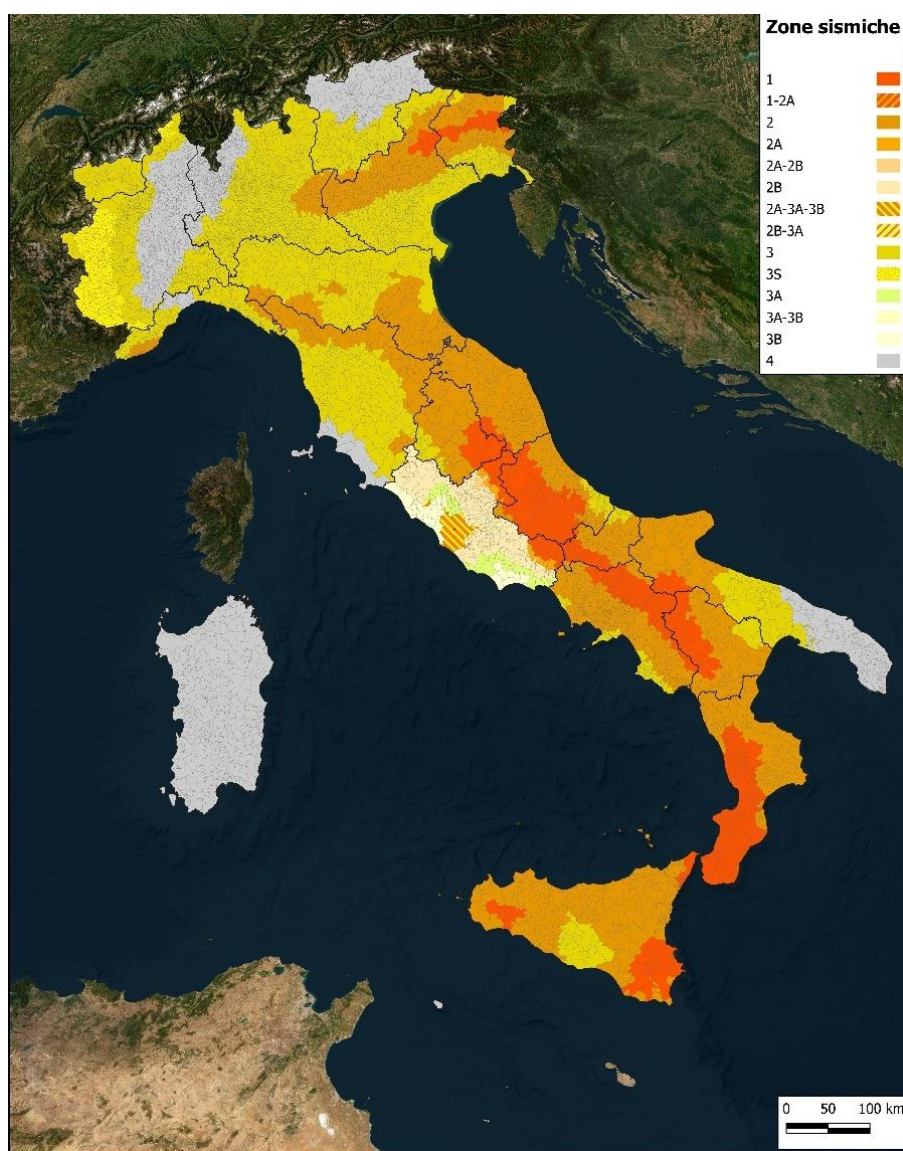


Figure 6: Seismic hazard zonation for Italy.

Among these, **Zone 3** is the most representative at the national scale, as it covers a substantial portion of the Italian territory. Consequently, a **moderate level of seismic hazard**, corresponding to Zone 3, was considered as the reference condition for all building archetypes in the Italian case study. This assumption provides a reasonable compromise between representativeness and comparability across different building configurations.

2.2.3. National Regulations – Belgium

Since the institutional reformatations in 1980, the authority on energy regulation was transferred from the federal state to the regions. The former federal “**Incentives for rational energy use**” [30] were replaced by the regional initiatives to establish a premium for adaptation and improvement of dwellings [31]. The latter increased the requirements on the energy use in buildings by introducing a reduction pathway for the K-value, a characteristic describing the global heat transfer of a building. According to the European Directive 2002/91/EC, the Flemish Government introduced **minimal requirements on the energy performance of buildings in 2006**. From then onwards, requirements gradually became stricter. The current legislation is based on the **Energiedecreet** dating from 2009 and the **Energiebesluit** dating from 2010. To date, the EPBD requirements [32] are different for residential and non-residential buildings, and for new buildings and refurbished buildings. An overview of the current requirements is presented in Table 1 and Table 2 [33].

Table 1: Overview of current requirements for residential buildings in Flemish EPBD regulation.

	New buildings	Deep renovation	Renovation
Thermal insulation	Max. S 28 Max. U values for building envelope	Max. U values for building envelope	Max. U values for building envelope
Energy score	Max. E 30	Max. E 60	No requirement
Indoor climate	Minimal ventilation requirements and prevent risk on overheating	Minimal ventilation requirements	Minimal ventilation requirements
Renewable energy	Min. 15 kWh/m ² .a solar energy	Min. 20 kWh/m ² .a solar energy	No requirement
Installations	Low temperature heating (max. 45°C)	Min. efficiency 130% for heating system	Min. requirements for installations

	New buildings	Deep renovation	Renovation
	Min. efficiency 130% for heating system		

Table 2: Overview of current requirements for non-residential buildings in Flemish EPBD regulation.

	New buildings	Deep renovation	Renovation
Thermal insulation	Max. U values for building envelope	Max. U values for building envelope	Max. U values for building envelope
Energy score	Max. E value depending on function	Max. E value depending on function	No requirement
Indoor climate	Minimal ventilation requirements	Minimal ventilation requirements	Minimal ventilation requirements
Renewable energy	Min. 20 kWh/m ² .a solar energy	Min. 20 kWh/m ² .a solar energy	No requirement
Installations	Low temperature heating (max. 45°C) Min. efficiency 130% for heating system	Min. efficiency 130% for heating system	Min. requirements for installations

The **Energiebesluit** and **Energiedecreet**, moreover include the obligation to draw up an EPC when a residential building is sold (since 2008) or rented (since 2009). From 2024 onwards, an EPC certificate was mandatory for all public buildings, while since 2025 this is mandatory for all large (> 1000 m²) non-residential buildings. The small non-residential buildings (< 100 m²) shall have an EPC by 2026. The EPC certificate for residential buildings presents the EPC score, which is related to a theoretical energy use for heating per square meter per year, as presented in Figure 7.

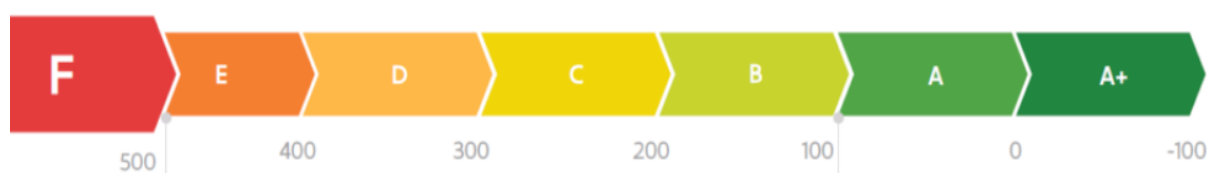


Figure 7: EPC score for residential and non-residential buildings.

The EPC certificate for non-residential buildings is based on two parameters: the EPC score which is based on the EPC score for residential buildings and the EPC label, as presented in Figure 8, which is based on the ratio of the measured amount of renewable energy compared to the total energy use.

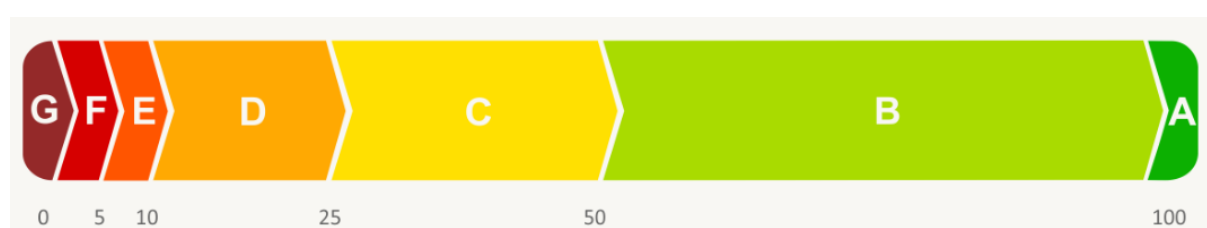


Figure 8: EPC label for non-residential buildings.

In 2019, the Flemish Government approved the **Flemish Climate Strategy 2050**. One of the key points of this strategy in the reduction of energy use and GHG emissions linked to the building stock. The goal for residential buildings is a reduction of 75% in GHG emissions compared to 2005, for non-residential buildings the goal is carbon neutrality. To realise the goal for residential buildings, the focus is on the renovation of the building envelope combined with an energy efficient heating system. Incentives such as the “renovation loan” and “renovation premiums” are put in place to support (deep) renovation.

From 2023 onwards, there is an obligation to renovate a dwelling in the next five years after the dwelling is sold.

In the strategy for non-residential buildings, public office buildings play an exemplary role as they shall be carbon neutral by 2045, while the target for other non-residential buildings is 2050.

2.2.4. National Regulations – Austria

Austria’s national energy codes are defined by the directives of the **Österreichisches Institut für Bautechnik (OIB)**, with **OIB Richtlinie 6 (OIB RL 6)** from 2023 serving as the central regulation concerning energy efficiency and

thermal insulation in buildings. This regulation forms a critical part of Austria's compliance with the European Union's Energy Performance of Buildings Directive (EPBD), ensuring that new buildings and major renovations meet strict standards for energy performance and environmental sustainability.

OIB RL 6 establishes requirements for the overall energy efficiency of buildings, which are measured using the **Energieausweis**, or energy performance certificate. This certificate quantifies parameters such as the final and primary energy demand, offering a comprehensive view of the building's operational energy use. The directive also outlines minimum thermal insulation standards, prescribing specific U-values (thermal transmittance rates) for components like walls, roofs, floors, and windows. These values vary depending on whether the building is new, undergoing a major renovation, or being extended.

In addition, OIB RL 6 promotes the integration of renewable energy technologies. While the extent of mandatory use may depend on the federal state or the nature of the building project, the regulation encourages systems such as solar thermal collectors, photovoltaic panels, biomass heating, and heat pumps. Heating, cooling, and ventilation systems are also subject to efficiency requirements under this directive, and in some regions, the use of oil-based heating systems has been restricted or phased out entirely.

One of the key goals of OIB RL 6 is the realization of Nearly Zero-Energy Buildings (nZEB), a European objective that mandates highly energy-efficient construction, particularly for public buildings and all new construction projects post-2020. These standards require very low energy demand and a significant share of that demand to be met through renewable sources.

Importantly, the energy requirements under OIB RL 6 are regionally adjusted based on Austria's climate zoning. The country is divided into different climatic zones, Zone A, B, and C, each with tailored performance criteria reflecting local temperature and weather patterns.

While OIB RL 6 governs energy performance and insulation, seismic safety in Austria is regulated separately. Earthquake resistance is addressed through the Eurocode 8 standards, implemented nationally as **ÖNORM EN 1998-1**. This standard governs the structural design of buildings to resist seismic forces, incorporating factors such as local seismic hazard, soil classification, the importance of the structure, and required ductility.

Austria uses national annexes to adapt the **Eurocode 8** standards to its specific seismic conditions. These annexes provide peak ground acceleration values and

define seismic zones within Austria. Although much of Austria is considered to have low to moderate seismic risk, areas such as southern Styria, parts of Carinthia, and eastern Tyrol are classified as higher-risk zones and are subject to stricter design requirements.

Seismic regulations are typically enforced during the planning and permitting stages, particularly for public buildings, infrastructure, and multi-story residential structures.

2.2.5. National Regulations – Slovenia

Slovenia's approach to energy efficiency and decarbonisation is structured around a set of comprehensive policy documents that reflect both national priorities and commitments under European Union climate and energy legislation. Central among these are the **National Energy and Climate Plan (NECP)**, the **Long-Term Strategy for the Renovation of Buildings**, and the **Regulation on the Efficient Use of Energy in Buildings (PURES)**. Together, these documents form the backbone of Slovenia's strategy to reduce greenhouse gas emissions, improve the energy performance of its building stock, and support a just and cost-effective energy transition. While the NECP sets overarching targets and pathways up to 2030, the long-term renovation strategy provides a roadmap for deep building renovation through 2050.

PURES, on the other hand, operationalises these objectives through technical requirements and performance standards for new construction and major renovations. This integrated policy framework aims to improve energy security, reduce energy poverty, and promote sustainable development across all sectors of the economy.

According to the European Energy Performance of Buildings Directive (EPBD), EU member states must ensure that all new buildings are constructed as nearly zero-energy buildings (nZEB) by the end of 2020, and public buildings by the end of 2018. In addition, they must member states to promote the renovation of existing buildings in the direction of increasing their energy efficiency.

In Slovenia, on June 5, 2022, new legislation was adopted in the field of efficient use of energy in buildings, which replaces the previous rulebook from 2010. It is the Rulebook on efficient use of energy in buildings (PURES-3), which sets minimum requirements for the energy efficiency of new and existing buildings and their technical systems, and for the **Technical Construction Guideline TSG-1-004:2022 Efficient use of energy in buildings (TSG-1-004:2022)**, which defines in more detail the methodology for calculating the required heat for heating, cooling and

ventilation, necessary electricity for lighting and operation of technical systems, as well as primary energy and CO₂ emissions for the entire building.

Technical guideline TSG-1-004:2022 was prepared on the basis of the European standards of the EN ISO 52000 series, which were adopted in 2017 and represent a common framework for assessing the energy efficiency of buildings at the EU level. The guideline consists of four parts:

- Part 1: General Provisions
- Part 2: Methodology for calculating the required heat for heating, cooling and ventilation
- Part 3: Methodology for calculating the necessary electrical energy for lighting and the operation of technical systems
- Part 4: Methodology for calculating primary energy and CO₂ emissions for the whole building

Some of the main innovations and features of TSG-1-004:2022 are:

- Introducing the concept of a near-zero-energy building (sNES), which is defined as a building with very high energy efficiency, whose near-zero or very low amount of energy required is largely covered by energy from renewable sources, including renewable energy produced on site alone or nearby.
- Introduction of new indicators for evaluating the energy efficiency of buildings, which comply with European standards. These indicators are: required energy for heating, cooling, ventilation and lighting (EPHND), required electrical energy for the operation of technical systems (EEL), primary energy (EP) and CO₂ emissions (ECO₂). These indicators are calculated for the entire building on an annual basis and are expressed in kWh/m²a or kgCO₂/m²a. In addition, the indicator of the use of renewable energy sources (ROVE) is also used, which is expressed as a percentage and means the share of energy from renewable sources in the total energy required for the operation of the building.
- The introduction of new minimum requirements for the energy efficiency of buildings, which depend on the type of building, purpose, location and age. The minimum requirements relate to the required energy for heating, cooling and ventilation as well as to primary energy and CO₂ emissions for the entire building. The minimum requirements are set to ensure the achievement of the goal of almost zero-energy buildings by 2020 or 2018 for

public buildings. The minimum requirements will gradually become more stringent as technology and the market progress.

- Introduction of new methodologies for calculating the required energy for heating, cooling, ventilation and lighting, as well as the required electrical energy for the operation of technical systems. The methodologies are based on a balanced approach between the thermal properties of the building envelope, the efficiency of technical systems and the influence of internal and external factors on the heat balance in the building. The methodologies also take into account the different climate zones in Slovenia and the possibility of using passive strategies to reduce heating and cooling needs, such as solar gain, shading, night ventilation, etc.
- Introduction of a new methodology for calculating primary energy and CO₂ emissions for the entire building. The methodology is based on the use of primary energy conversion coefficients and CO₂ emissions for different energy sources, which are determined at the national level. The conversion coefficients take into account the average efficiency of energy production, transmission and distribution and the average structure of energy supply in Slovenia. The methodology also makes it possible to take into account the production of energy from renewable sources on-site or nearby and to deduct it from the total energy required for the operation of the building.

Technical guideline TSG-1-004:2022 represents an important step in the transition to sustainable building construction in Slovenia. The guideline introduces new standards, indicators and methodologies for assessing the energy efficiency of buildings and sets the minimum requirements for achieving the goal of almost zero-energy buildings by 2020 and 2018 for public buildings. The guideline is intended for all stakeholders involved in the process of planning, construction and renovation of buildings, such as investors, designers, contractors, supervisors, managers and users. The guideline is also the basis for issuing energy certificates for buildings and for determining the amount of financial incentives for energy renovation of buildings.

The use of technical guideline TSG-1-004:2022 will contribute to the reduction of energy consumption and CO₂ emissions in the building sector and to the increase of the use of energy from renewable sources. With this, Slovenia will follow European and national goals in the field of climate change and energy policy and improve the quality of living and functioning in buildings.

The long-term strategy for the energy renovation of buildings until 2050 is regulated in **Article 9 of the Act on the Efficient Use of Energy**, where the

government, on the proposal of the Ministry of Infrastructure, adopts the Long-term strategy for the renovation of the national fund of existing public and private residential and non-residential buildings into a highly energy-efficient and decarbonized building fund until in 2050.

The long-term strategy for the energy renovation of buildings until 2050 (DSEPS 2050) defines and upgrades the existing ones and adds new measures that will achieve the goals in the field of buildings, which are defined in the Comprehensive National Energy and Climate Plan of the Republic of Slovenia (NEPN). The strategy contains indicative goals for the year 2050 and intermediate goals for the years 2030 and 2040. In terms of content, it addresses the vision, framework, goals, indicators, review of the building stock by different sectors (residential, non-residential, public), obstacles and opportunities for the renovation of public buildings, cost effective approaches to the renovation of public buildings, policies and measures, and financing the implementation of measures.

Renovation of buildings is a long-term task, which will gradually cover the entire building stock in the coming years, and at the same time has a great impact on the quality of the internal environment. More than 75% of today's buildings are expected to still be in use by 2050. Larger investments in the renovation of individual buildings can be expected in the event of new findings regarding the inadequacy of building resistance in connection with endangering human lives, in the event of possible damage, such as the result of material aging or accidents (earthquake, flood, landslides, etc.), and under the conditions of a normal scenario, approx. only every 30 years (e.g. change of ownership, change of purpose, obsolescence and wear and tear).

The vision defined by DSEPS 2050 is to significantly improve energy efficiency and reduce greenhouse gas emissions by increasing the use of renewable energy sources (RES) in buildings. Approaching net zero emissions in the building sector by 2050 will be achieved by maintaining a high level of energy renovations of buildings and a targeted method of heating using RES technologies and a centralized heating system with RES. Renovations and new constructions will be encouraged with the achievement of almost zero emissions during the lifetime, while other aspects of the renovation will also need to be taken into account (e.g. earthquake and fire safety, aspects of the quality of the indoor environment). This will significantly reduce emissions of other harmful substances into the air. The goal of the strategy is also for Slovenia to become recognizable in the field of sustainable construction and renovation of buildings. DSEPS 2050 sets out a timetable with measures and nationally determined indicators to measure

progress, namely to achieve the long-term goal of reducing greenhouse gas emissions in the European Union by 80–95 percent by 2050 compared to 1990. By implementing these measures, it will be ensured highly energy-efficient and decarbonized national building fund.

The Comprehensive National Energy and Climate Plan (NEPN) is a guide and one of Slovenia's key steps towards a climate-neutral Slovenia and the European Union (EU) by 2050. With it, Slovenia will set energy and climate goals as well as policies and measures to achieve these goals. until 2030 and with a view to 2040. The fulfillment of the NEPN goals is supported by a comprehensive environmental impact assessment (EIA), which is part of the formal process of preparing the NEPN. In addition to the assessment of environmental impacts, the CPVO also enables the broad involvement of stakeholders (ministries and organizations, non-governmental organizations, sectors, interested individuals) and the definition of the appropriate path for Slovenia to achieve its goals. The CPVO process continues, and through the public disclosure and definition of the content of the NEPN proposal and the environmental report, there will also be room for additional considerations.

NEPN is the most ambitious in improving energy and material efficiency in all sectors and consequently reducing the use of energy and other natural resources, which is also the first and key measure on the way to a climate-neutral society. This also has a significant impact on other areas (decarbonisation, energy security, internal energy market and research and innovation). Slovenia's goal is to improve energy efficiency by 35% compared to the base year of 2007. Fulfilling the NEPN leads us to reduce dependence on fossil fuels and increase reuse. With NEPN, we also support sustainable solutions in transport (public sustainable transport), in buildings (heating and cooling, comprehensive renovation) and in industry (ongoing to ensure competitiveness). Today, traffic in Slovenia contributes more than 50% of emissions (outside the EU emissions trading system).

Following the 1895 Ljubljana earthquake, a set of building rules for earthquake-resistant construction was established in 1896. These regulations became a necessary consideration under the Building Code for the design and construction of masonry buildings [34]. A milestone with regard to seismic design was in Slovenia set by the 1963 Ordinance [35], which significantly increased the horizontal design loads. The code was in Slovenia adopted shortly before the catastrophic earthquake in Skopje, Macedonia, and was also the basis for the 1964 Regulation adopted then for Yugoslavia [36]. After the stronger earthquakes in

Kozjansko, Friuli and Montenegro, updated Regulations “Pravilnik o Tehničnih Normativih Za Graditev Objektov Visoke Gradnje Na Seizmičnih Območjih s Spremembami in Dopolnitvami” [37] were adopted in 1981. The more recent knowledge on seismic design was more fully and comprehensively incorporated into the **European code provision EC8** [38], which has been in Slovenia in use from 2006 and mandatory since 2008.

Seismic hazard maps, developed alongside various design codes, have been updated over the years to define seismic loads for different locations in building design. The MSK-64 intensity map was introduced in 1987 [39], where seismic 475-year return period intensities for various regions in Slovenia ranged from VI to IX. With the adoption of Eurocodes, seismic hazard began to be expressed in terms of peak ground accelerations (PGA). The current design codes specify seismic loads based on the latest seismic hazard map [40], which defines PGA values for a 475-year return period, ranging from 0.10 g to 0.325 g across Slovenia. Use of this updated seismic hazard map (Figure 9) became mandatory at the beginning of 2024. This represents an increase in hazard compared to the previous seismic hazard map [41], which was in mandatory use from 2008 and defined for Slovenia PGA values between 0.10 g and 0.25 g.

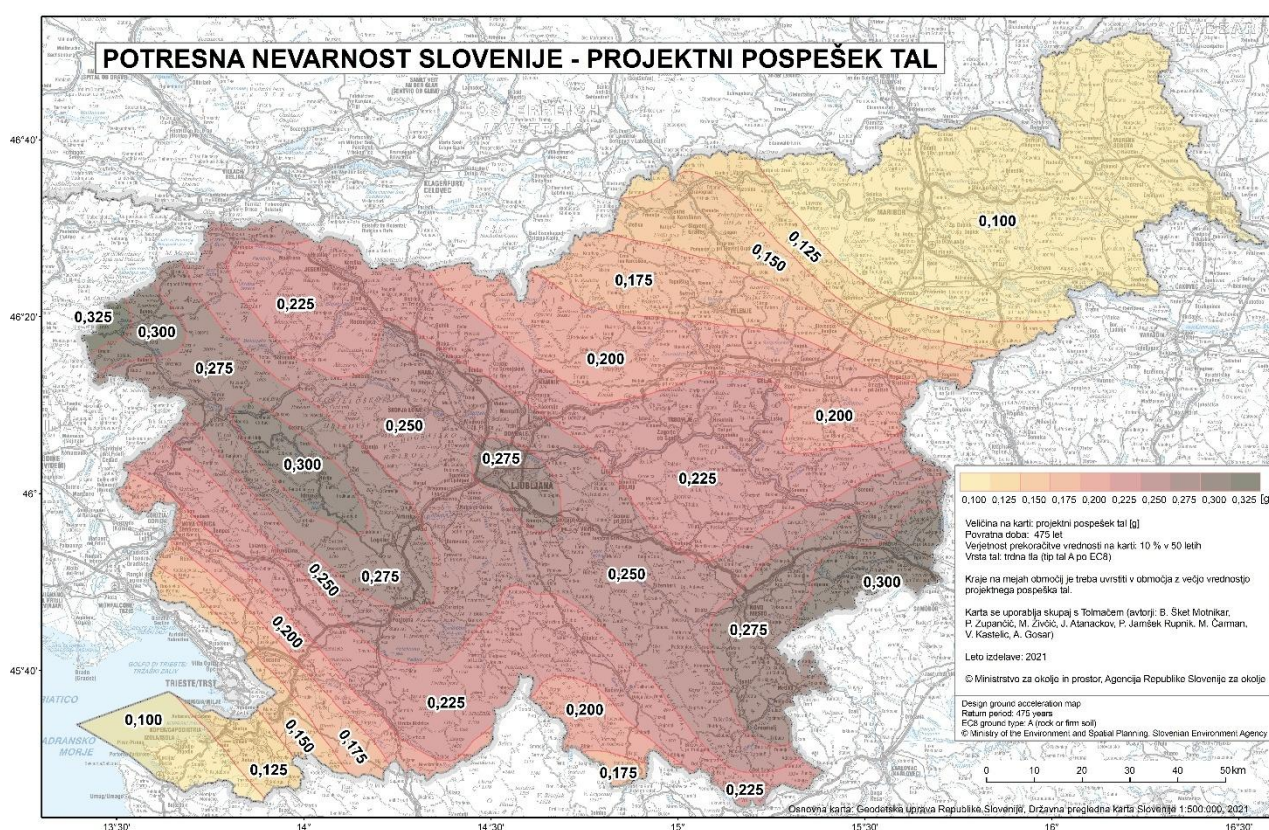


Figure 9: Updated seismic hazard map for Slovenia; 475-year return period design ground accelerations. Ref: [40]

For the seismic risk assessment of the existing building stock, an intensity-based seismic hazard map using the EMS-98 scale [42] was also updated in 2011 [43]. According to this map (Figure 10), different regions of Slovenia fall into EMS intensity zones VI, VII, or VIII for 475-year return period earthquakes.

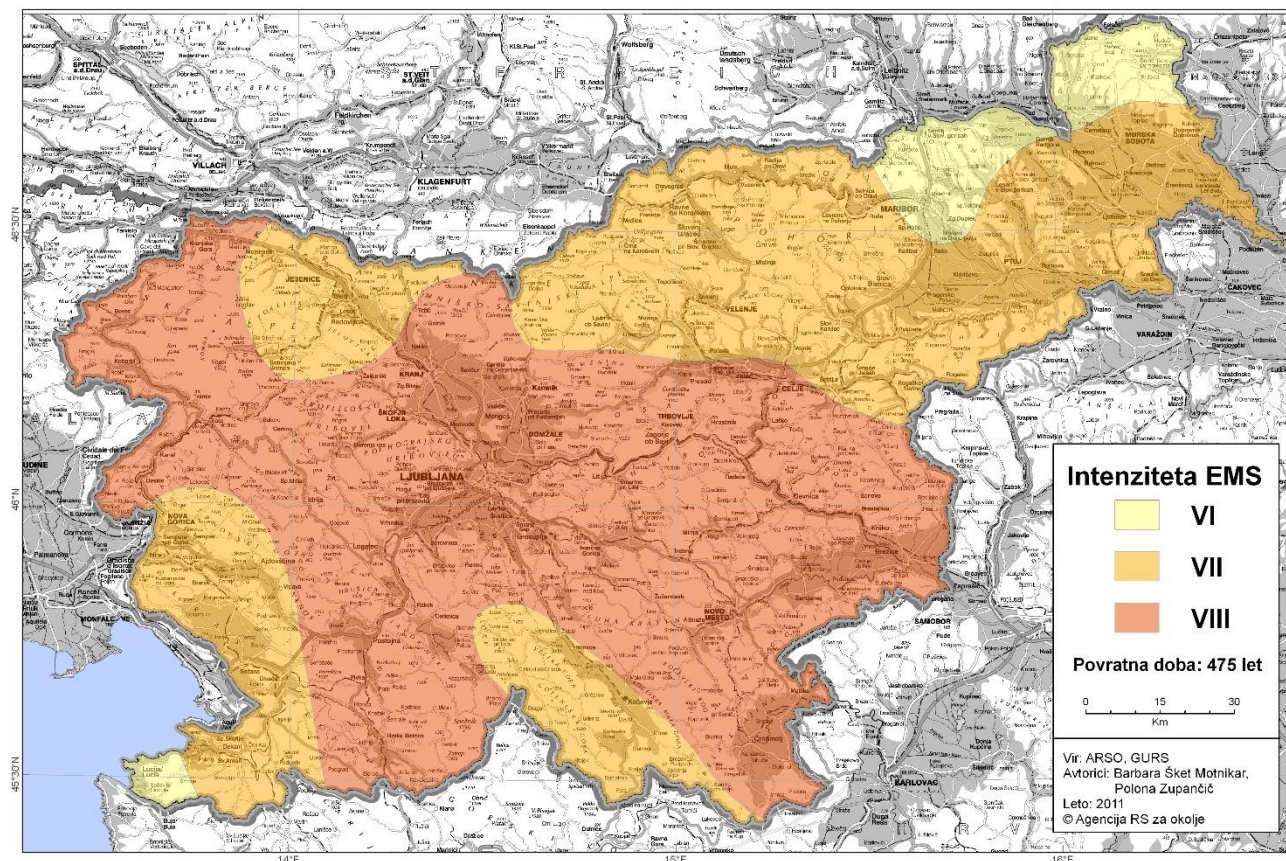


Figure 10: Seismic hazard map for 475-year return period earthquake EMS intensities. Ref [43]

The evolution of the main regulations affecting the building sector in Slovenia for both energy performance and structural (seismic) safety from its first known start in 1896 to the present are presented in Figure 11.

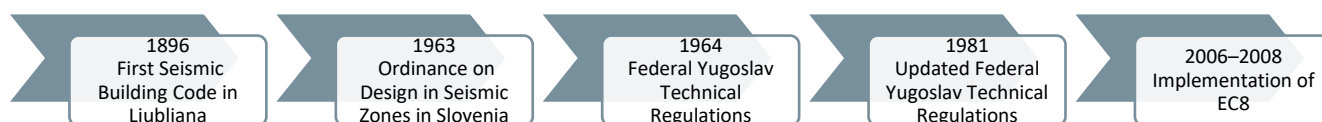


Figure 11: Timeline of the adopted normative regulations in Slovenia.

3. Methodological Framework and Template Development

This chapter presents the methodological framework adopted for the definition and development of building archetypes across the pilot countries. The process was structured in two main phases, aimed at collecting, organizing, and harmonizing data relevant to the energy and seismic characterization of the existing building stock. A dedicated template was designed to ensure consistency in data representation, while allowing flexibility to account for national specificities and construction typologies. The following sections illustrate the approach used and the main outcomes of the process.

3.1. Data Collection and Template Structure

The first phase of the methodological framework consisted in the creation of a structured and harmonized database to support the energy and seismic characterization of the building stock across the participating countries. This process aimed to ensure that the diverse national datasets could be systematically compared and aggregated, while respecting country specific construction practices and available information.

To achieve this, a consistent classification system was adopted, based on a three-level structure that reflects the main characteristics influencing building performance. The classification criteria, harmonized across all countries involved in the project, are as follows:

- **Sector:** This level distinguishes between broad categories such as residential and non-residential buildings, which differ significantly in terms of use patterns, occupancy profiles, and system configurations.
- **Subsector:** Within each sector, a finer differentiation was introduced according to the specific building function. For example, in the residential sector, categories include single family houses and apartment blocks, while the service sector covers offices, trade buildings, hotels and restaurants etc.
- **Building Age Class:** This dimension groups buildings based on their construction period. The selected time intervals reflect significant regulatory or technological changes that may have affected construction methods, materials, and energy or seismic performance. These classes allow the identification of trends over time and support the temporal mapping of building characteristics.

The combination of these three classification levels led to the definition of a series of distinct **Building Categories**, each representing a homogeneous group of buildings in terms of use, typology, and historical construction context. These categories serve as the basis for the subsequent analysis and modelling steps.

Each Building Category is uniquely identified by an alphanumeric label in the format:

[Subsector Code]–[Building Age Class]

For example, the category SFH-1850-1919 refers to Single Family Houses constructed between 1850 and 1919.

This classification system provides a structured and transparent way to organize and reference the various segments of the building stock. It allows for a modular approach in the collection and analysis of data and facilitates the definition of representative configurations for simulation and scenario development. While the set of subsectors considered is consistent across all countries involved in the project, the definition of the Building Age Classes may vary from one country to another. These differences reflect the availability of national datasets, as well as key regulatory milestones and construction trends that shaped the evolution of each country's building stock. As a result, each country defines its own set of Building Categories with respect to construction periods, ensuring contextual relevance and accuracy.

The full classification scheme is presented in Figure 12, which shows the specific age class subdivision adopted for Greece as an example.

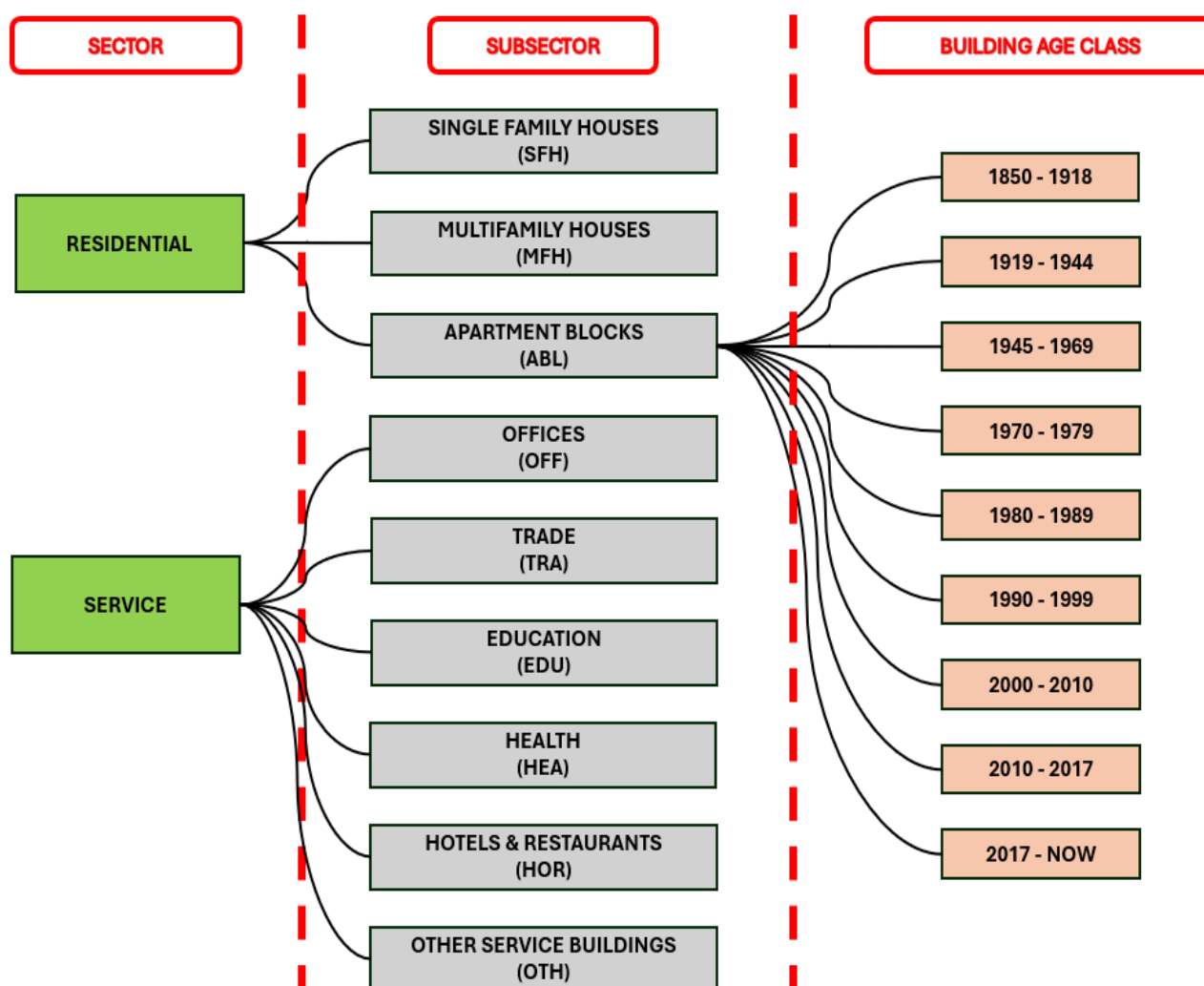


Figure 12: Classification scheme for Building Categories (e.g., as applied for Greece)

Building Categories are then further detailed according to five main data groups: General Data, Geometry, Energy Consumptions, Thermal Transmittance, and Element Characterization, which together ensure a comprehensive and harmonized description of each case. These groups, shown in Figure 13, encompass the key information required to describe each category in terms of distribution, form, performance, and construction features, while maintaining consistency across different national datasets.

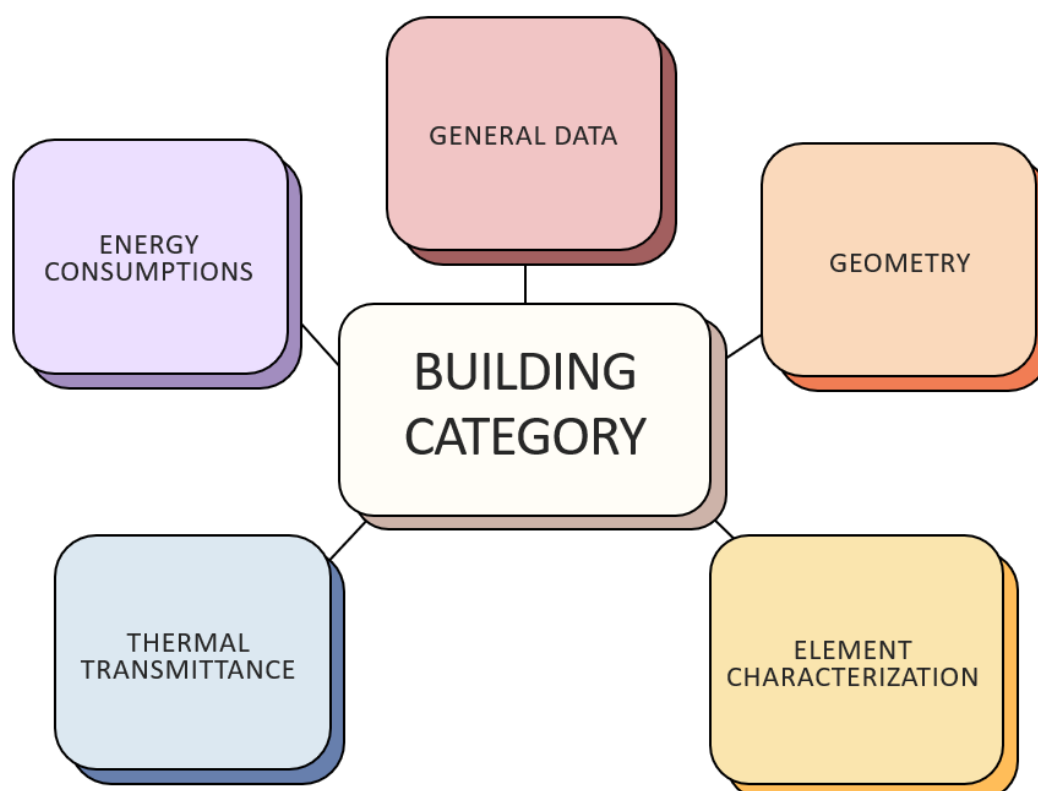


Figure 13: Structure of the five data groups describing each Building Category.

All the variables defined within these five groups were systematically collected and compiled into two structured Excel files, which together form the output of this first phase. The file **“ArchetypeStockData.xlsx”** contains the core dataset, where each row corresponds to a Building Category and each column represents one of the harmonised descriptors previously introduced and further detailed in the following sections. Complementarily, the file **“ElementModelling.xlsx”** focuses on the physical characterisation of the building envelope components, detailing the structure, insulation, and finishing layers of each element. These two data repositories form the operational basis for the second phase of the methodology, which involves the aggregation and modelling of representative archetypes.

For each pilot country, a pair of country specific files was created, with filenames preceded by the corresponding country code (e.g., GR_ArchetypeStockData.xlsx and GR_ElementModelling.xlsx for Greece).

3.1.1. General Data, Geometry and Energy Consumptions

As a first step in the characterization process, the General Data group provides the foundational quantitative information necessary to understand the extent and relevance of each Building Category within the national stock. This group is not

limited to simple counts but rather includes a wide array of statistical and contextual variables that collectively support the definition of consistent modelling assumptions and aggregated analyses.

The data are structured into three interrelated subgroups. The first focuses on stock information, capturing the number of buildings and dwellings or housing units associated with the category. These figures are essential to quantify how representative each category is in the overall building stock. Additionally, the “ratio of typology in stock” allows for relative comparisons across categories and enables weighting procedures for extrapolations at regional or national scale.

The second subgroup addresses area distribution, detailing surface-related metrics that help define the physical scope of the category. The total constructed area, together with the portions that are heated and cooled, provides insight into the potential energy demand associated with the typology. The inclusion of useful floor area refines this understanding by focusing on occupiable space, which is often a better indicator of actual use. Moreover, the surface area per person introduces a demographic dimension, linking built space to user density and supporting socio-technical analyses.

A third subgroup concerns occupancy status, distinguishing between occupied, vacant, and secondary-use spaces. This distinction is particularly relevant when estimating energy consumption profiles and identifying opportunities for energy renovation. For instance, categories with a high share of vacant or seasonally used buildings may exhibit lower consumption values but could also represent strategic targets for refurbishment policies due to their underutilized potential.

All the variables included in this group are associated with standardized units of measurement, ensuring comparability and transparency. The structure and content of the General Data group are summarized in Figure 14, which visually outlines its internal articulation and relationship to the broader dataset.

GENERAL DATA	Stock Information	Number of buildings	[n]
		Number of dwellings/units	[n]
		Ratio of typology in stock	[n]
	Area Distribution	Constructed area	[m ²]
		Heated area	[Mm ²]
		Cooled area	[Mm ²]
		Surface area per person	[m ² /per capita]
		Useful floor area	[m ²]
	Occupancy Status	Occupied	[m ²]
		Vacant	[m ²]
		Secondary dwellings/units and others	[m ²]

Figure 14: Structure of the General Data group.

Within this methodology structure, the Geometry group provides a detailed description of the physical characteristics of the reference buildings associated with each Building Category. These geometric parameters are fundamental for the construction of representative building models and play a key role in both energy and seismic assessments.

As shown in Figure 15, the Geometry group is structured into three main subgroups. The first, dedicated to building shape and envelope dimensions, includes quantitative descriptors such as gross floor and ground floor area, gross volume, and the surface areas of external components (walls, roofs, windows). Additional ratios such as the shape factor and the window-to-wall ratio help capture the compactness and morphological efficiency of the building envelope, with direct implications for thermal losses and solar gains.

The second subgroup focuses on the vertical configuration, which includes the number of storeys above and below ground, the interplane height, and the total building height. These parameters are particularly important as they affect both the thermal behaviour of the building, especially in relation to stratification and façade exposure, and its structural response in case of seismic events.

The vertical distribution of mass and height directly influences dynamic characteristics such as stiffness, centre of mass, and potential modes of vibration, all of which are relevant for seismic vulnerability assessment.

The third subgroup refers to boundary and space conditions, including the number of external surfaces that are in direct contact with other structures and the number of users associated with the building. These aspects contribute to the definition of boundary conditions in energy simulations and provide insights into occupancy intensity, internal heat gains, and possible interaction effects between adjacent buildings in dense urban contexts.

In summary, the Geometry group ensures a harmonized, multidimensional description of the building form, supporting cross sectoral analyses that integrate architectural, energy, and structural perspectives. Its standardised structure allows for the generation of coherent reference models and facilitates comparability across countries and typologies.

GEOMETRY	Building Shape and Envelope Dimensions	Gross volume	[m ³]
		Gross floor area	[m ²]
		Ground floor area	[m ²]
		Wall area	[m ²]
		Window area	[m ²]
		Roof area	[m ²]
		Envelope area (Facades + Roof)	[m ²]
		Shape factor	[-]
		Ratio of window area/external wall area	[-]
	Vertical Configuration	Number of storeys above ground	[n]
		Number of storeys below ground	[n]
		Interplane height	[m]
		Building height	[m]
	Boundary and Space Conditions	Number of faces touching other buildings	[n]
		Number of users	[n]

Figure 15: Structure of the Geometry group.

The third group, Energy Consumptions, complements the geometric and general descriptors by introducing information on the energy needs and consumption levels associated with each Building Category. These values are essential for characterizing the energy performance of buildings under typical conditions of use, and they form the basis for future analyses related to decarbonisation potential, retrofit prioritisation, and policy evaluation.

The dataset distinguishes between useful energy demand which refers to the energy theoretically required to satisfy comfort conditions inside the building and final energy consumption, which accounts for system inefficiencies, distribution losses, and user behaviour. This dual perspective provides a more complete understanding of how energy is both needed and actually consumed within the stock.

The variables collected in this group cover the three main end uses: space heating, space cooling, and domestic hot water (DHW). For each of these services, values are provided both in terms of useful energy and final energy.

Additionally, some aggregate indicators are included, such as the total useful energy demand (for heating and DHW, or cooling) and the total final energy consumption for the same uses.

While the Energy Consumptions group does not include detailed information on technical systems, covered in a later section, it does provide an essential baseline for estimating performance gaps and identifying areas where improvements in efficiency or envelope design may lead to significant energy savings. All values are expressed in standardized energy units (e.g., kWh/year or kWh/m²·year). The structure and content of the Energy Consumptions group are summarised in Figure 16, which provides a clear overview of the collected variables and their classification.

ENERGY	Useful Energy Demand	Space Heating	[kWh/m ² year]
		Domestic Hot Water (DHW)	[kWh/m ² year]
		Space Cooling	[kWh/m ² year]
		Total (Space Heating + DHW)	[TWh/year]
		Total (Space Cooling)	[TWh/year]
	Final Energy Consumptions	Space Heating	[kWh/m ² year]
		Domestic Hot Water (DHW)	[kWh/m ² year]
		Space Cooling	[kWh/m ² year]
		Total (Space Heating + DHW)	[TWh/year]
		Total (Space Cooling)	[TWh/year]

Figure 16: Structure of the Energy Consumptions group.

3.1.2. Thermal Transmittance and Element Characterization

To ensure a robust and harmonized representation of the building envelope, this data group provides both indicative thermal transmittance values and a detailed material characterization of each construction element. These descriptions are essential for energy simulation, as well as for Life Cycle Assessment (LCA) and Global Warming Potential (GWP) calculations.

For all opaque components such as external walls, roofs, storey floors, and ground floors, the element definition is structured into three main layers: structural core, thermal insulation, and finishing layers. This classification reflects real world construction logic and allows each element to be modelled with the depth needed for operational and environmental performance assessments.

The structural core describes the load-bearing part of the component, including the type of material used, the method of construction, and the typical thickness. This layer influences not only thermal inertia but also the embodied impact of materials.

The thermal insulation layer is characterized by its material, thickness, and position within the assembly. Whether placed internally, externally, or within the core, its properties significantly affect heat transfer, and its description is essential for evaluating thermal performance and potential retrofit actions.

The finishing layers, both internal and external, complete the stratigraphy by representing surface treatments and interfaces with the surrounding environment. They are particularly relevant in LCA and GWP studies, where even thin coatings can contribute to the overall environmental impact.

Windows and doors are treated separately, with detailed attributes describing frame type, glazing configuration, surface treatments, and associated thermal performance. Although structurally distinct, these elements are equally critical in shaping both energy behaviour and environmental impact.

The full articulation of variables used for Element Characterization and Thermal Transmittance data groups are visually summarized in Figure 9.

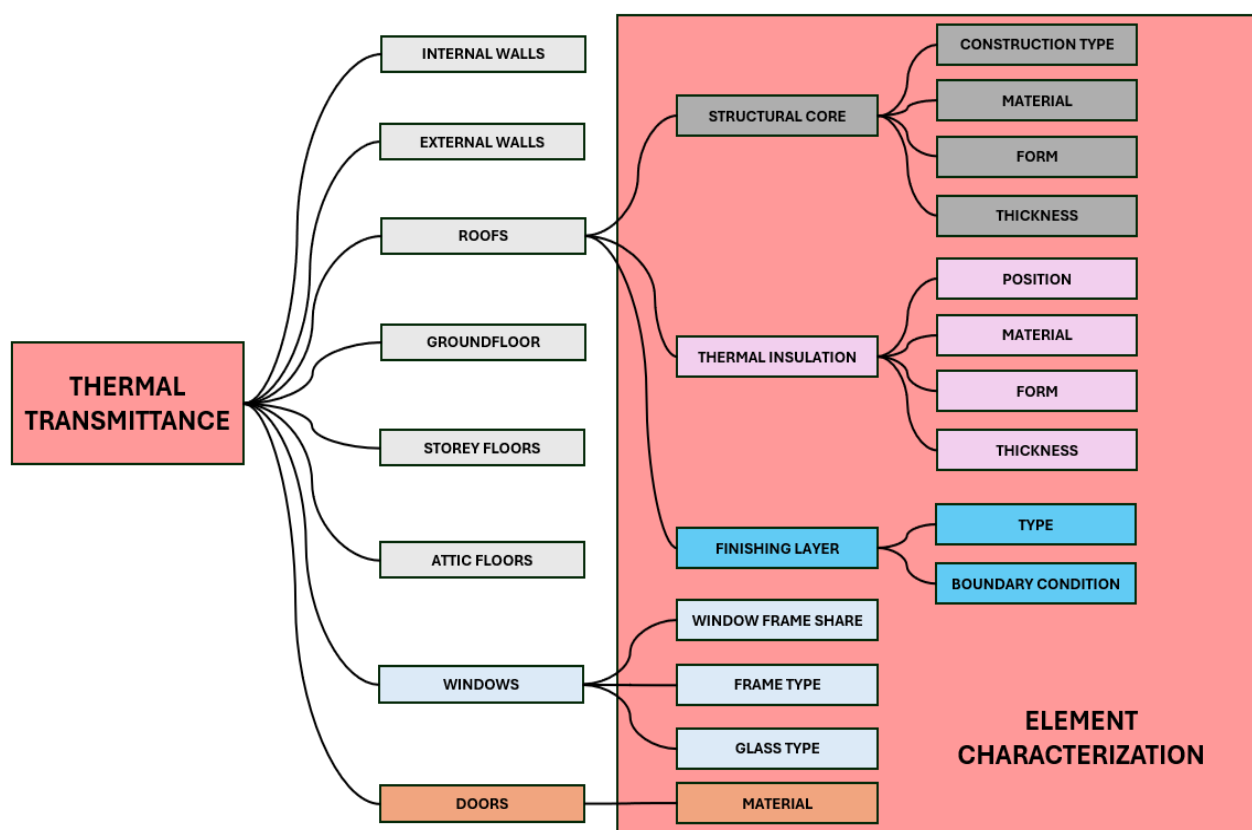


Figure 17: Methodological scheme adopted for the Element Characterization and Thermal Transmittance data groups.

3.2. Definition of the Archetypes

Following the extensive data collection and structuring carried out in the first phase, the second part of the methodology focuses on consolidating this information into a representative but reduced set of building configurations. The main objective is to simplify the overall dataset by identifying a limited number of archetypes that reflect the most recurrent combinations of building use, construction period, and envelope characteristics across the analysed stock.

This step is formalised in a dedicated Excel file titled **"GRV8_Archetypes.xlsx"**, which summarises the selection and synthesis of the 30 main archetypes considered in the project. Each archetype was derived from aggregation of Building Categories that share similar technical properties, especially in cases where variations between them are minor or negligible. The selection was based on a consistent and transparent methodology, using as reference the data framework developed in the first phase.

Figure 18 illustrates how the number of Building Categories was progressively reduced to reach a total of 30 representative Archetypes. As an example, the generation of one such archetype, labelled *SFH-1850-1989*, is shown in detail. This

archetype combines several Building Categories that fall within the specified construction period. As previously explained, the grouping and data merging are based on an evaluation of technical variations, which allows the selection of one reference Building Category from which the data defined in Phase 1 are retained. In the example, *SFH-1980-1989* is chosen as the reference and highlighted in red.

The process then continues with the definition of the next archetype, which does not necessarily need to include the immediately following category (e.g., *SFH-1990-1999*), especially if its data are deemed negligible or not sufficiently representative of the national building stock under consideration.

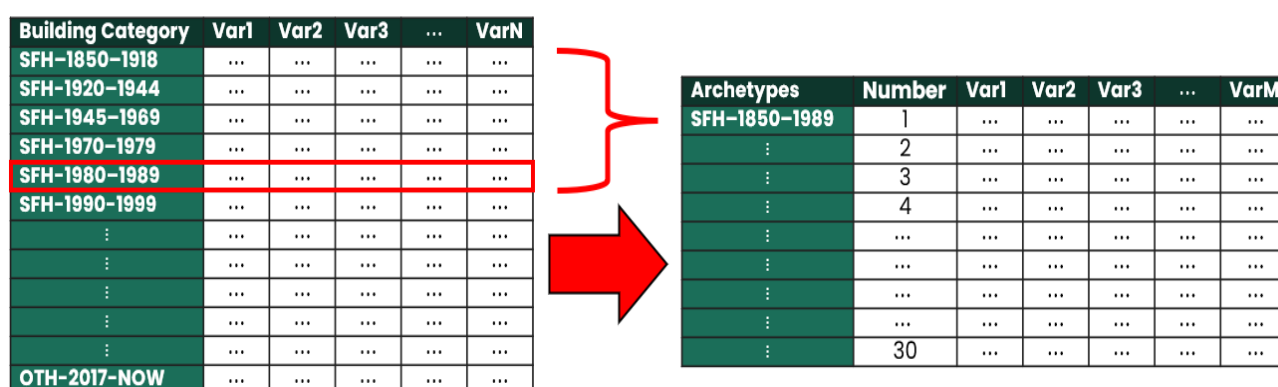


Figure 18: Example of aggregation process from multiple Building Categories to a representative Archetype.

To enable broader assessments and integrated evaluations, additional parameters were introduced for each archetype. As clearly illustrated in Figure 18, the number of variables associated with each configuration increases as a result of this step, evolving from an initial set of N descriptors per Building Category to a more comprehensive dataset of M variables per archetype.

In the Excel file dedicated to the archetype (**GRV8_Archetypes.xlsx**), a specific sheet named **Seismic and Climatic Zones** was developed to collect essential spatial and structural information for each archetype. This sheet includes a dedicated block of five columns specifically addressing seismic characterization. These columns are designed to capture key aspects that influence a building's expected performance in the event of an earthquake:

- **Seismic Hazard** refers to the intensity of potential ground shaking at the building location, typically based on national hazard maps or probabilistic models. It provides the baseline risk level to which a structure is exposed.

- **General Structural Type** identifies the primary load-bearing system of the building (e.g., masonry, reinforced concrete, timber), which heavily influences seismic behaviour.
- **Specific Structural System** offers a more refined classification of the structural layout (e.g., frame system, shear walls, mixed systems).
- **Specific Structural Type** refers to the standardized code typically used to identify the structural typology in seismic classification systems. This code encapsulates specific attributes such as the material used, the structural arrangement, and the construction period or practice, and is essential for associating vulnerability models and damage functions.
- **Seismic Vulnerability** is a synthetic index or classification expressing the expected fragility of a given structural type under seismic action, usually derived from empirical studies or national guidelines.

These parameters are meant to be populated with the most representative values for each archetype, based on expert judgment, official databases, or scientific references. A shared reference adopted within the project is the EFEHR interactive mapping platform [44], which provides harmonised seismic hazard and risk data across Europe. However, considering national differences in legislation and hazard mapping practices, individual countries are allowed to follow their own classification schemes or introduce justified modifications to better reflect local standards and conditions.

In addition to seismic characterization, this sheet integrates the geographical distribution of each archetype across national climate zones. Since these zones are defined differently in each country according to local building regulations, the number and nature of zones vary across the dataset. For each archetype, a set of columns, one for each climate zone, captures the estimated share of the building stock located in that zone. For example, an archetype may be predominantly found in a cold region, influencing its average thermal demand profile, while another may span across warmer areas with greater cooling needs.

This spatial disaggregation allows for climate-weighted evaluation of performance indicators, supporting more accurate modelling of energy behaviour and renovation priorities across regional contexts.

Furthermore, each archetype was disaggregated by energy performance class, allowing for more detailed modelling of energy demand. For each class, updated values of thermal transmittance were associated with the envelope components, and energy consumption estimates were adapted accordingly.

To manage this information, a dedicated worksheet titled **Energy Performance Class** was created within the archetype file. This sheet contains one column for each energy class, whose number and classification may vary depending on national definitions, and provides, for every archetype, the percentage distribution across the different classes. This information is crucial to identify which archetypes are more likely to undergo future energy retrofits and to prioritise policy interventions accordingly.

In addition, a further worksheet named **EPC value + U-values** was developed to provide a detailed quantification of thermal transmittance and energy use by energy class. This sheet is organised separately for the residential and service sectors and includes, for each energy class, reference U-values for all building envelope components such as walls, roofs, windows, and floors, as well as the corresponding energy use in kWh/m² year. These values support the estimation of performance gaps and enable scenario simulations aimed at evaluating potential savings through envelope upgrades or system replacements.

As a final element, technical systems were characterised for each archetype and energy class, considering the possible presence of multiple configurations serving the same end use. This detailed characterisation supports energy simulation and decarbonisation modelling by capturing the diversity of technologies and their performance. The scope includes heating, cooling, and domestic hot water systems, mechanical ventilation, and renewable energy sources such as photovoltaic panels and solar thermal collectors.

Moreover, solar shading devices were considered as an additional layer of energy-relevant features. Although not strictly classified as active systems, they play an important role in reducing solar gains and improving indoor thermal comfort, particularly in climates with high cooling needs.

This information is structured within a dedicated sheet named **Technical Systems**, where each row corresponds to a specific combination of archetype and energy class. For each case, up to three different HVAC system groups can be defined, each associated with a corresponding share parameter. This reflects the relative prevalence of each system type within the archetype.

Each system group is detailed through macro-variable clusters, as illustrated in Figure 19, and is classified as follows:

- **Heating (H):** Described through type, technology, dimensions, fuel used, efficiency, emission system, useful energy demand (UED), and final energy consumption (FEC).

- **Domestic Hot Water (DHW):** Includes technology, dimensions, fuel used, efficiency, whether combined with heating, UED, and FEC.
- **Cooling (C):** Characterised by technology, dimensions, fuel used, efficiency, emission system, UED, and FEC.
- **Mechanical Ventilation (MV):** Defined by system type, demand control, heat recovery, efficiency, UED, and FEC.
- **Solar Shading (SS):** Includes installation type (internal, external, or both) and system type.
- **Renewables:**
 - **Photovoltaic (PV):** Defined by installed power, installed surface area, module type, and annual energy production.
 - **Solar Collectors (SC):** Includes collector type, collector area, storage capacity, and annual energy production.

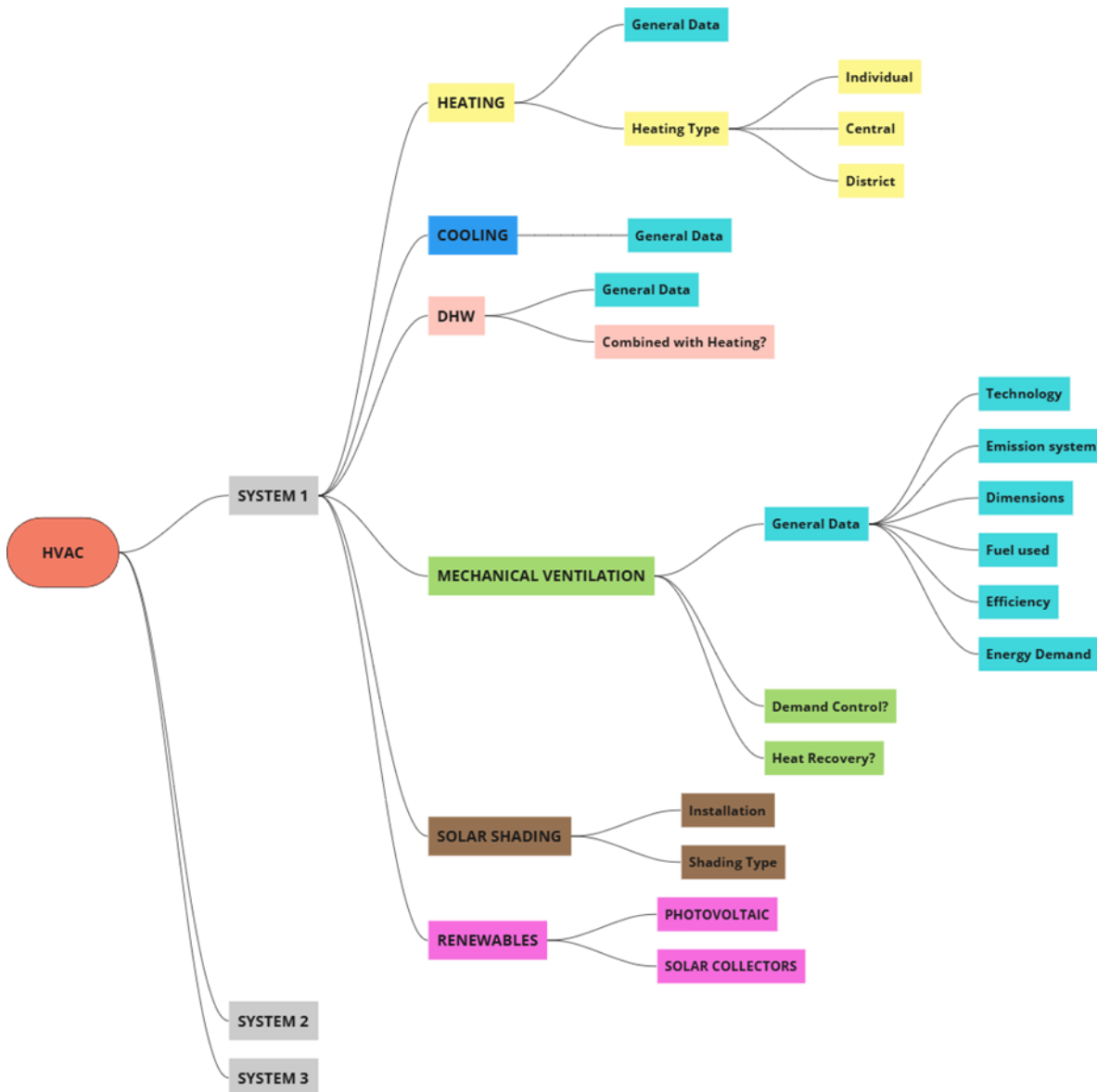


Figure 19: Structure of Technical Systems classification by subsystem and key variables.

In addition, lighting systems were included as part of the broader sustainability assessment. For each archetype and energy class, data were collected on lamp type, UED, and FEC. These variables, together with indicators such as primary energy use and CO₂ emissions, also contribute to the evaluation of the Global Warming Potential (GWP) associated with each configuration.

3.3. Management of Missing or Uncertain Data

Given the complexity and extent of the information required, the presence of partial, uncertain, or missing data represents one of the main challenges in the development of a harmonised building stock database. The methodology

adopted to manage these limitations aimed to ensure maximum consistency, transparency, and flexibility, while allowing for future updates and refinements.

A critical issue arises from the intrinsic variability that can exist within the same Building Category. For instance, buildings classified under the same use and age group may differ significantly in terms of construction materials or structural systems, such as stone, brick, or reinforced concrete, or in the presence and quality of insulation layers. This variability introduces what can be defined as a “variant” which add a layer of complexity to the data modelling process.

To account for these differences, two main strategies were implemented during phase I.

Where feasible, distinct configurations were included by duplicating rows within the dataset to reflect alternative variants. When this was not practical, additional columns were introduced with share factors to indicate the relative distribution of each variant within the same Building Category. This approach mirrors the methodology used for the definition of HVAC systems, where up to three different system configurations can coexist for the same archetype, each associated with a percentage share.

Thermal transmittance values (U-values) represent a fundamental parameter for energy analysis. In situations where existing datasets already contained discretised values aligned with the structure of the template developed in this project, those values were directly adopted. However, in cases where such detailed data were not available, a conservative approach was applied by assigning the minimum U-values permitted by national building codes. This ensured that all values remained within a realistic, regulatory and compliant range. These regulations provided a reliable benchmark for assigning values to the various components of the building envelope in a way that is consistent with the construction practices and legal requirements of each country.

To further improve representativeness, particularly in countries where thermal performance requirements vary by climate zone, weighted averages were calculated. These averages were based on the distribution of the building stock across different zones, allowing the derived U-values to better reflect national diversity while maintaining harmonisation across datasets.

It is also important to acknowledge that, due to the vast number of variables required, it may not be possible to retrieve or estimate all data types during this phase. In such instances, missing values were left blank or incomplete but structured in a way that allows for integration at later stages. As will be discussed

in the following section, project partners have already made significant efforts to minimise data gaps, often filling them with assumptions supported by national regulations, expert judgment, or default values from official sources.

This flexible yet structured methodology ensures that the database remains operational and scalable, while allowing future research or national updates to further refine the information already in place.

4. Data Population Approach

The data population phase was structured in two main stages, corresponding to the development of the two primary datasets produced in Phase 1 and Phase 2 of the methodology. This process relied on a combination of structured data sources, national regulations, expert knowledge, and a harmonised input strategy to ensure consistency across the different countries involved in the project.

For Phase 1, the initial dataset was built upon the information available from the DG GROW database. This repository served as a shared starting point for all participating partners. Each country partner undertook a thorough review of the dataset entries corresponding to their national context, verifying, correcting, and expanding the information where necessary. This revision was based on official national statistics, previous studies, normative references, and assumptions made by technical experts with in-depth knowledge of the local building stock. The outcome of this step was the completion of two Excel files per country, containing harmonised and structured data on Building Categories and their corresponding physical and performance characteristics.

In Phase 2, the focus shifted to the definition and characterisation of the 30 representative archetypes. To standardise the data compilation and facilitate comparison across countries, a multiple-choice strategy was adopted for many of the fields included in the final Excel template. Variables such as structural systems and energy systems were constrained to predefined lists of options. This approach enabled harmonisation and reduced the ambiguity and variability that often arise when using open and ended qualitative inputs.

Figure 20 provides a sample table showing selected variables for which predefined multiple-choice options were implemented. The first row includes a subset of representative variables, while the subsequent rows illustrate the corresponding available options.

Structural Type	Structural System	Seismic Hazard	Heating Fuel Used	Heating Emission System	Cooling Generator Type
Load-bearing masonry	Burnt clay brick masonry	Very Low	Fossil solid	Radiators	No cooling
Reinforced concrete frame	Concrete block masonry	Low	Fossil liquid	Fan Coil Units	Air–Air Heat Pump
Steel frame	Light metal frames	Moderate	Fossil gas	Radiant system	Air–Water Heat Pump
Wood frame	Load-bearing timber frames	High	Electricity	Split	Water–Water Heat Pump
Steel–concrete composite	Mud (adobe) walls	Very High	Biomass	Multi-Split	Geothermal Heat Pump
	RC moment-resistant frames		Others	Air Vents	Absorption Chiller
	RC shear walls			Diffuser	Electric Chiller
	Steel or steel–concrete composite frames			Grilles	VRF/VRV system
	Stone masonry walls			Indoor Units (VRF/VRV)	Others

Figure 20: Sample of predefined multiple-choice options used in the data entry templates to ensure harmonised input.

Given the sensitive and preliminary nature of some of the quantitative data collected, it was agreed that no specific numerical values would be published at this stage. Instead, the focus was placed on documenting the sources, structure, and logic behind the data population approach, which is detailed in the partner-specific sub-sections that follow.

To complement this documentation and offer a comparative overview of the cross-country alignment, the following heatmap provides a visual summary of the number of pilot countries that selected each combination of Building Category and Building Age Class as part of their national set of representative building archetypes. The green colour intensity reflects how many countries (from 0 to 5) included each specific archetype in their selection.

The residential sector, as evidenced by the consistent value of five for the Single-Family Houses (SFH) and Multi-Family Houses (MFH), has been systematically considered by all partner countries across every Building Age Class.

This reflects the crucial role of residential buildings in the national stock and their central relevance for energy and renovation policies.

In contrast, the Apartment Blocks (ABL) category displays a constant value of three, as it was not included by Greece and Slovenia in their national archetype selection. This exclusion was due either to the limited availability of reliable national data for this typology or to the decision to prioritise other Building Categories that were considered more representative, prevalent, or more methodologically feasible within the modelling assumptions adopted by each country.

The non-residential sector shows more variability across countries and periods. Nevertheless, several Building Categories reach the maximum value of five in specific Building Age Classes. Notably, Trade Buildings (TRA) and Hotels and Restaurants (HOR) categories reach full representation during the 1945 to 2010 period, indicating a shared recognition of their significance in the evolution of the tertiary sector during those decades.

The Education (EDU) category stands out for its consistent inclusion by all five countries from 1850 to 2010, highlighting its central and persistent role in the public building stock. In contrast, the Offices (OFF) reaches the maximum value only between 1980 and 2010, suggesting that this typology becomes more relevant and more homogeneous across countries in more recent construction periods.

The Other Service Buildings (OTH) maintains a stable value of four across all Building Age Classes, reflecting its relevance as a residual category encompassing a wide and heterogeneous group of buildings, such as sports facilities, religious buildings, and community spaces. Its persistent presence across time underlines its structural role despite the diversity it represents.

The Health (HEA) category displays values between three and four, indicating a more limited or inconsistent inclusion across countries. This can be attributed to both the complexity of accessing detailed and harmonised data on healthcare buildings and the intrinsic difficulty of defining a representative archetype for such complex facilities. Hospitals and clinics often present significant variability in terms of technical systems, operational schedules, and energy use patterns, making the modelling process particularly demanding within the assumptions and simplifications adopted by each country.

In summary, the heatmap highlights a strong and consistent alignment among pilot countries in the selection of residential archetypes, particularly SFH and MFH. While certain non-residential categories also show convergence during specific construction periods, their overall representation is more fragmented. This reflects differences in national building stock composition, policy priorities, and available datasets across the partner countries.

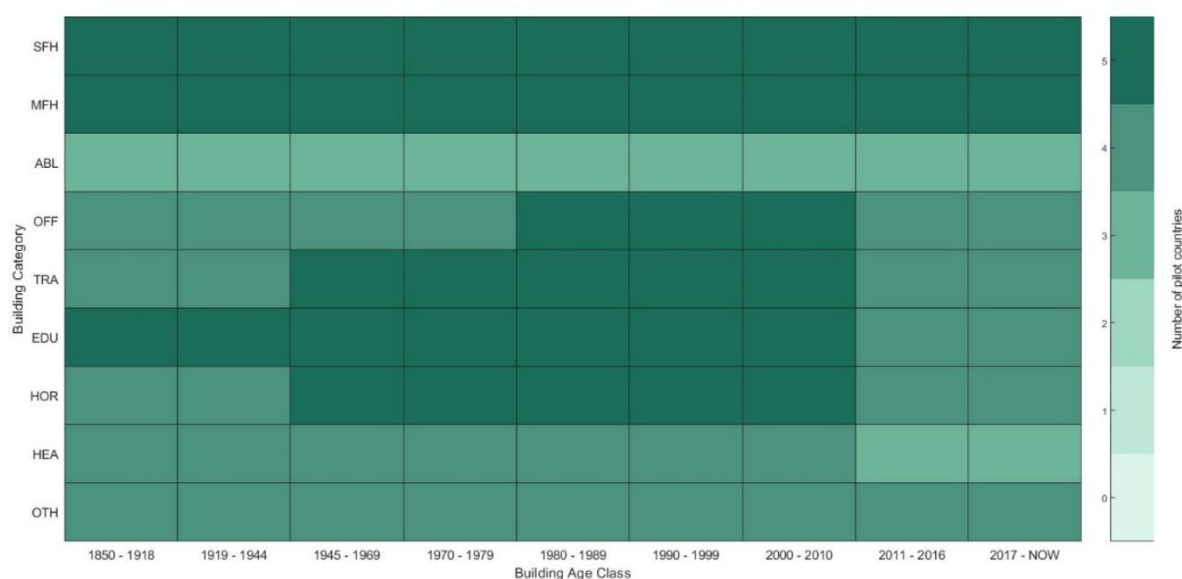


Figure 21: Heat map showing the number of pilot countries selecting each Building Category and Building Age Class combination for their archetypes.

4.1. Data Sources for Greece

Initially, it was necessary to identify the type of constructions that would be finally chosen for the selection of archetypes (e.g., education, hotels and restaurants, multifamily houses). From 1850 to present, in Greece, only single-family houses and multifamily houses appear (with differentiated form of structural system and materials). Subsequently, around the early 1920s, construction for education made their appearance, while almost 30 years later (from 1945 onwards), the first offices, hotels and trades were constructed. Regarding the General Building Structural Type of these constructions in Greece, it is a fact that the main construction method in 1850 to 1944 was load-bearing masonry. Gradually, the method was modified and reinforced concrete (RC) constructions with infill walls were typically being built. However, from 2010 onwards, several steel constructions with light steel frames also appeared and even more recently from 2017, steel-concrete composite constructions as well (mainly make their appearance in purposes such as trades, hotels and restaurants rather than residences). In more detail, with the aim of determining the specific structural system of these constructions and mainly for the load-bearing masonry and the reinforced concrete which have different types, it is worth noting that regarding the first case, the two main types of construction which were used were either with natural stone and mortar (as the earlier or traditional method) or with fired clay bricks as the primary building material. Regarding RC constructions, two systems are common, and these are RC moment-resistant frames and RC shear walls, which depends on the structural

system and more specifically on the percentage of shear walls presence relative to the total vertical structural elements (as it affects the reception of shear force exerted on the construction). Finally, it is worth making a brief reference to the way the time periods were divided and distributed. Mainly 10 basic regulations were considered which have been established from 1980 to the present day concerning the construction method of buildings, urban planning characteristics as well as seismic regulations (It is worth emphasizing that the regulation which established the application of Eurocodes in constructions in Greece is also included). To the above regulations, 2 more are added that concern the energy sector but affect the structural character of constructions as well.

As for the energy-related aspects of the selected archetypes, different data sources and methodological approaches were combined to estimate the building envelope characteristics and system configurations. Specifically, regarding the thermal transmittance (U-value) of the various envelope components (walls, roofs, windows, etc.), values were derived through regression analysis, taking into account both the evolution of national regulatory constraints over time and the indicative values provided by the TABULA project [24].

In terms of the energy performance class distribution across the national building stock, the primary reference used was the official national study “Buildings’ Energy Performance in Greece” [45]. For the most recent period (2017–present), where empirical data is still limited, trends were inferred based on expert judgement and by considering the increasing penetration of nearly Zero Energy Buildings (nZEB) requirements as per updated national regulations.

To characterize the building systems, assumptions were made to define typical system configurations according to the building’s energy class and construction period. These assumptions were guided by expert knowledge and cross-checked with available datasets from the previously cited sources, while always respecting the corresponding regulatory constraints.

For instance, for archetypes constructed after 2010, solar thermal collectors were always included among the installed systems for domestic hot water (DHW) production, in accordance with the provisions of the KENAK regulation [26], which mandates the use of renewable energy sources in new buildings.

4.2. Data Sources for Italy

The definition of building archetypes for the Italian context was based on a combination of multiple data sources [46, 47, 48], including:

- The **Global Exposure Model** developed by the **GEM Foundation**, providing structural and typological data for seismic risk assessment [49];
- **ISTAT** statistics, offering detailed national data on building characteristics and distribution [50];
- **Case studies** from prior research by the **University of Naples Federico II**, used to fill specific data gaps;
- Supplementary information from **cadastral archives**, where accessible;
- **Seismic hazard data** from the **Italian Civil Protection Department**, used for territorial seismic classification and vulnerability assessment [51].

Regarding the assumptions adopted in the development of national building archetypes for Italy, a structured and transparent methodology was applied to ensure consistency, representativeness, and technical robustness of the selected archetypes.

The final selection of the 30 archetypes was conducted through a process of controlled aggregation, based on clearly defined technical criteria. This methodology aimed to ensure that each aggregated archetype maintains internal consistency while representing a meaningful portion of the national building stock. The main constraints applied during the aggregation process were as follows:

- **Structural Use Category:** Archetypes were grouped based on their functional classification (e.g., residential, office, service sector), ensuring that each selected archetype refers to buildings with comparable intended use and load-bearing configurations.
- **Construction Period:** Aggregation was performed by merging archetypes from adjacent or overlapping time periods to preserve historical continuity and reflect common construction practices across successive decades.
- **Seismic Code Level:** Archetypes were grouped according to their seismic design code classification (e.g., no-code, low-code, high-code), as this parameter significantly influences both structural characteristics and retrofitting needs.
- **Stock Size Consideration:** The number of buildings associated with each archetype was also taken into account. Archetypes that already represented a substantial portion of the building stock were not further aggregated, in order to preserve the resolution and specificity of high-impact categories.

In cases where multiple combinations met the above criteria and a definitive choice was not immediately evident, additional technical considerations were applied to guide the selection:

- **Prevalent Construction Materials:** Preference was given to groupings where dominant material types (e.g., concrete, brick, stone) were consistent, enhancing the internal coherence of the modelled archetype.
- **Structural and Dimensional Homogeneity:** Attention was paid to the uniformity in terms of building size, form, and structural typology, so that the selected archetype could realistically represent the aggregate set.

The selection of a representative archetype for modelling purposes was guided by a structured hierarchy of criteria, applied in the following order of priority:

Criterion 0 – Unique Archetype Available

When a single archetype was available for a given category or combination, it was selected by default.

Criterion 1 – Highest Representation in the Building Stock

When multiple archetypes were available, priority was given to the one with the greatest presence in terms of building stock share. This ensures that the selected archetype is statistically representative of the most common real-world scenario.

Criterion 2 – Best Alignment with Average Characteristics

If no single archetype dominated in frequency, the selection focused on the archetype whose technical and energy-related characteristics best reflected the average of the group. This approach aims to maximize representativeness across combined archetypes.

Criterion 3 – Conservative Energy Modeling

In the absence of a clearly dominant or representative archetype, preference was given to the archetype with the highest energy demand (i.e., the least efficient), in order to adopt a precautionary approach in modelling and avoid underestimating energy needs.

However, several **limitations** should be acknowledged:

- The available datasets were not updated beyond 2020, resulting in limited information for the 2021–2025 period.
- The GEM database does not report specific data related to educational buildings; therefore, analyses in this sector were based on a sample of

schools from different construction periods, which may not be statistically representative.

- Differences in the time ranges defined by ISTAT and GEM required the adoption of assumptions to harmonize classification and aggregation criteria.
- OSB category (Office and Service Buildings) are highly heterogeneous in nature, and their structural typologies may vary significantly, introducing potential uncertainty in archetype definition and generalization.

In this section, it is necessary to highlight also the main assumptions, hypotheses and simplifications adopted for the energy aspects of the building types considered in this study. The primary sources used were the national SIAPE database and the Ministerial Decree of 26 June 2015 on minimum requirements.

The SIAPE database enables differentiation of buildings by use type and construction period, allowing The SIAPE database makes it possible to differentiate buildings by use type and construction period, allowing residential buildings to be classified by representative ranges of dispersing surface area: 50–100 m², 100–200 m² and 1,000–5,000 m² for apartment buildings; 200–500 m² for single-family houses; and 500–1,000 m² for multifamily houses. For the period from 2011 to the present, the average of the values from the 2006–2015 and post-2015 intervals was used. For earlier periods, the closest available SIAPE range was selected.

Since no Italian database is publicly accessible that provides thermal transmittance (U-value) values based on energy class (EPC), an indirect methodology was applied. Specifically, reference U-values set out in 2015 Decree were multiplied by class-specific scaling factors derived from national EPC guidelines.

Table 3 shows these coefficients.

Table 3: Scaling factors for estimating class-specific U-values, based on EPC guidelines.

EPC Class	Scaling Coefficients
A4	0.30
A3	0.50
A2	0.70

A1	0.90
B	1.10
C	1.35
D	1.75
E	2.30
F	3.05
G	3.60

For building components not explicitly addressed in the Decree, such as external doors, the same U-value as that for windows was assumed. Minimum and maximum values for glazing systems were adjusted based on engineering judgement and physical plausibility to ensure consistency. The efficiency of HVAC and DHW systems was expressed as the ratio of the useful thermal energy delivered to the non-renewable primary energy consumed, taking into account all system components (generation, regulation, distribution and emission). These values were derived from the 2015 Decree, based on system configurations representative of standard buildings in energy classes A1 to B. Efficiency values were then linearly interpolated between the standard values and the minimum and maximum achievable values. This reflects the realistic range of available technologies and is aligned with normative benchmarks. Electricity was converted into non-renewable primary energy using a factor of 1.95, as established by the same Decree. Useful energy demand for heating, cooling and DHW was obtained from the archetypal stock dataset based on reference building characteristics and useful surface area. This was then scaled for each energy class using the aforementioned coefficients. For residential buildings, it is important to note that electricity demand for internal lighting is not considered in EPC assessments, as it is relatively insignificant compared to other energy uses and was thus not included.

Four technology scenarios were defined for the residential sector based on regulatory benchmarks and design expertise. In particular, the installation of monocrystalline photovoltaic panels was assumed for energy classes higher than B. Installed power was calculated according to Legislative Decree 199/2021 using the following formula:

$$P_{PV} \geq \text{floor area} \cdot k$$

The coefficient k is set to 0.05 for new buildings and 0.025 for existing ones. To estimate energy production, a standard value of 7 m² per kWp installed was assumed, with an average producibility of 1300 kWh/kWp in Italy. The residential scenarios include:

- One based entirely on fossil fuels featuring gas boilers and radiators for heating and domestic hot water (DHW), as well as electric chillers (split system) for cooling.
- An identical scenario without cooling.
- Two fully electrified scenarios using heat pumps for both heating and DHW: one with cooling and one without. In the latter case, cooling is also provided by electric chillers.

System efficiencies were scaled from the reference values indicated in the D.M. June 26, 2015. Two main technological scenarios were assumed for non-residential use: one based entirely on fossil fuels with centralized gas boilers for heating and DHW (with higher-efficiency systems for better EPC classes, ranging from non-condensing to condensing boilers) and a fully electrified scenario, with central heat pumps for heating and DHW. Electric cooling was included in both cases, as it is essential for ensuring workplace comfort throughout the year, as mandated by Legislative Decree 81/2008. Photovoltaic systems were included for buildings in classes above B for these archetypes, with the installed capacity calculated in accordance with Legislative Decree 199/2021 mentioned above. Finally, mechanical ventilation systems were only considered for non-residential buildings constructed after 2011, in line with prevailing design practices and regulatory requirements.

4.3. Data Sources for Belgium

To identify the 30 most representative archetypes for the Flemish building stock, several key databases were consulted, including BSO, AmBIENCE, TABULA, STATBEL, DG GROW. These sources provided a basis for the analysis of the 66 initially defined archetypes in these databases. However, as most of the data in these databases is available only at the national (Belgian) level, the first step involved updating and extrapolating the data to reflect the regional (Flemish) context.

For certain building types, such as single family houses (SFH), the national database STATBEL contains specific data for Flanders, which enabled direct regionalisation. For other building types, an alternative approach was used using data from the Federal Public Service Finance [52], which publishes data on cadastral parcel characteristics. These datasets include the number of parcels built for a specific building type during specific periods for each region in Belgium. This allowed for the calculation of Flemish shares as a percentage of the national stock, which was then applied to the other stock data to estimate Flemish-specific data.

With the Flemish building stock more accurately characterised, the most common archetypes were selected. Instead of using the number of buildings as a metric, the analysis focused on the constructed area. Relying solely on building counts would overemphasize smaller structures and underestimate larger ones. Given that environmental impacts such as material use and embodied carbon are closely linked to building size, accounting for the built area is essential for a representative assessment. The analysis revealed that residential buildings (e.g. single family houses, multifamily houses and apartment blocks) account for more than 75% of the constructed area in Flanders. Non-residential building types represent a much smaller share, approximately 2% for various categories, with offices alone accounting for 7%. Based on these insights, the 30 representative archetypes were defined following a clear guiding principle. Given the dominance of residential buildings in the stock, it is important to preserve variation in building characteristics across construction periods. As such, each of the three main residential buildings was modelled with distinct archetypes per age class. For example, if the modelling of a single-family house differs significantly between two construction periods, this variation was retained to reflect its substantial construction to the overall stock. In contrast, for building types with smaller presence, such as hotels and restaurants, minor differences between construction periods were considered negligible. In such cases, the corresponding age classes were combined into a single archetype.

With the archetypes defined, additional data was collected. First, seismic and climatic conditions were established. Flanders is not subject to significant seismic activity, so all archetypes were classified under a low seismic hazard category. Climatically, Flanders falls entirely within the temperate oceanic zone (Cfb) [53]. The distribution of EPC (Energy Performance Certificate) classes was then determined for each archetype. The Flemish Energy and Climate Agency's online platform, "Energiekaart Vlaanderen" [54] provides valuable data on EPC distributions by building type and construction period. This dataset, comprising

over one million valid EPCs is based on mandatory energy performance assessments conducted during the sale, rental or renovation of buildings in Flanders. While not exhaustive, its large volume makes it a robust proxy for the overall stock. For the newest building age class, additional data from Flemish energy performance regulation [55] were used to complete the dataset.

EPC classes, which indicate a specific level of energy use per square meter per year were then linked to corresponding U-values of various building elements. For some EPC classes, the best performing ones, these U-values were directly derived from Flemish energy performance regulations [55]. For the remaining classes, estimations were made by the TABULA project and expert judgement. In the case of non-residential buildings, no official data exists linking EPC classes to specific U-values, except for the higher performing classes wherefore regulation exists. For the older and less efficient EPC classes, in the absence of reliable data, it was assumed that their U-values are comparable to those of residential buildings.

To define the technical systems associated with each archetype and EPC class, multiple data sources were consulted, including AmBIENCE, DG GROW, TABULA, “Energiekaart Vlaanderen” and expert input. The assumption was made that the type of technical system depends solely on the building type and EPC class, rather than the year of construction. For instance, a single-family house with an EPC rating of A is assumed to have similar technical installations, whether it was originally constructed in 1950 or 2010. This reflects the reality that an older building achieving a high EPC class has likely undergone major renovation, resulting in a technical system equivalent to that of a newly constructed building.

Based on this assumption, multiple technical systems configurations were defined for each building type, taking into account the most prevalent and commonly occurring combinations. The definition of these technical systems drew on the above-mentioned data sources, complemented by the collection of additional information where necessary. These system definitions were then linked to EPC classes using a combination of expert knowledge, Flemish regulatory guidelines and insights from TABULA and AmBIENCE. To ensure consistency between technical systems and energy performance levels, each configuration was also evaluated through EPC simulations provided by the Flemish government [56]. These simulations assessed whether the defined system setup would realistically result in the intended EPC class, given the building type and other characteristics. This step verified that the selected configurations result in the intended EPC label, ensuring consistency and reliability.

To complete the characterization of technical systems, additional data was gathered concerning solar shading and renewable energy sources. For solar shading, no official datasets were available. Therefore, assumptions were made based on expert judgement, distinguishing between residential and non-residential buildings and the various EPC classes to reflect typical shading configurations. In terms of renewable energy, the “Energiekaart Vlaanderen” platform provides information on the total installed capacity of photovoltaic (PV) and solar collector systems in Flanders. The installed capacity of solar collectors is negligible and was therefore not included in the archetype definitions. The allocation of PV panels across building archetypes was based on a combination of simulation results, regulatory data, and statistical insights to ensure a realistic representation of solar adoption within the Flemish building stock.

For residential buildings, the presence of solar panels was determined through simulations assessing which EPC classes are likely to include PV installations. These simulations evaluated whether the addition of solar panels would enable a building to achieve a given EPC label. Based on these results, PV systems were assigned to specific residential EPC classes where their presence was most plausible. For non-residential buildings, “Energiekaart Vlaanderen” indicates that only around 15% are equipped with solar panels. To reflect this, PV installations were assigned to EPC classes in descending order of efficiency, from the best to the worst, until the 15% coverage threshold was reached. This approach assumes that more energy-efficient buildings are more likely to include renewable technologies. Finally, the resulting distribution of PV installations across all archetypes was used to estimate the total installed capacity within the stock model. This was then compared with the actual reported PV capacity for Flanders to ensure alignment and consistency with regional statistics. This approach ensured that the aggregated PV capacity in the stock model aligns with the reported total capacity.

4.4. Data Sources for Austria

Initially, it was essential to define the dominant building categories to establish representative archetypes of the Austrian building stock. For residential buildings, the stock includes single-family houses (SFH), terraced houses (TEH), multi-family houses (MFH), and apartment blocks (ABL), which have been consistently present since the mid-19th century. For non-residential buildings, typologies such as education (EDU), health (HEA), trade (TRA), hotels and restaurants (HOR), offices (OFF), and other types (OTH) became prominent primarily from the mid-20th century onward, with their structural and functional characteristics evolving over

time. The classification into temporal construction periods reflects historical, architectural, and regulatory shifts. In the residential sector, key periods include the Gründerzeit (1850–1918), interwar (1919–1944), post-war (1945–1960), economic boom (1961–1980), and the post-1980 modern construction phases. For non-residential buildings, a similar but slightly offset categorization is used, reflecting the delayed development and lower standardization across these types.

From a structural perspective, older buildings (until approximately 1960) primarily relied on load-bearing masonry systems, using materials such as natural stone or clay bricks, often with wooden components. With modernization, reinforced concrete (RC) became the predominant construction system, typically in the form of moment-resisting frames or wall-bearing systems depending on the building's function and load-bearing design. In more recent decades, especially post-2010, there has been a growing adoption of alternative construction types such as timber and timber-hybrid systems in both residential and non-residential buildings, with a further trend toward steel or steel-concrete composite structures in commercial applications (e.g., trade, hospitality). The differentiation by structural type and energy standard—standard, advanced, and nearly-zero energy buildings—is used in the model for all post-2010 constructions.

In terms of regulatory periods, ten major construction standards and regulations implemented since the 1980s were used to define shifts in building methods, urban design, and particularly seismic and energy-related performance. These include milestones such as the national adoption of the Eurocodes and Austria-specific energy efficiency regulations, as well as key building code updates that affect insulation, heating systems, and renovation incentives. Furthermore, energy-related policies—particularly those implemented after 2010—are treated as essential drivers for structural change and are therefore incorporated into the archetype definitions to better reflect both the material and environmental performance of Austria's evolving building stock [57].

4.5. Data Sources for Slovenia

4.5.1 Energy related data

The development of building archetypes for energy modelling and policy planning in Slovenia relies on the integration of multiple national datasets. These sources provide comprehensive information on the physical characteristics, energy performance, and real-world retrofit activity across the building stock. The three most important data sources are:

1. The **Real Estate Register (REN)** managed by **GURS**
2. The **Energy Performance Certificates (EPC) Database**
3. The **Eco Fund (Eko sklad) Grant and Loan Database**

Together, these sources enable the creation of data-driven, evidence-based archetypes that reflect not just theoretical characteristics, but also real-world energy renovation dynamics.

The following section presents the three most relevant national data sources, accompanied by a summary of their main characteristics and how each contributes to the definition and refinement of building archetypes.

1. GURS – Real Estate Register (REN)

The Real Estate Register is the official and centralised database of buildings and real estate in Slovenia, administered by GURS. It includes a broad set of attributes relevant for archetype definition.

Key Features:

- **Coverage:** All buildings and construction parts in Slovenia, including residential and non-residential buildings.
- **Identification:** Each building or part of a building has a unique ID and is georeferenced.
- **Attributes Available:**
 - **Year of construction**
 - **Gross floor area (GFA) and number of floors**
 - **Use type / functional classification** (e.g., single-family, multi-apartment, office, school)
 - **Construction materials (wall and roof types)** – where available
 - **Renovation status** – in some cases
 - **Ownership type and occupancy**
 - **Address and cadastral data**
- **Data Format:** Structured geospatial database, accessible via the GURS geoportal or through bulk requests to the Surveying and Mapping Authority.

Use in Archetype Definition:

- REN data enables statistical classification of the building stock by age, size, type, and use. It is typically used to:
 - Define frequency distributions of buildings across categories
 - Allocate building types to construction periods
 - Link to climate zones and location-based characteristics

2. Energy Performance Certificates (EPCs) Database

Slovenia introduced mandatory energy certification of buildings in line with the EU Energy Performance of Buildings Directive (EPBD). The EPCs are registered and stored in a national database managed by the **Ministry of the Environment, Climate and Energy**.

Key Features:

- **Coverage:** All new buildings and existing buildings undergoing major renovation or sale/rent (increasing annually)
- **Attributes Available:**
 - **Energy class** (A+ to G)
 - **Calculated energy demand** for heating, cooling, ventilation, hot water, lighting
 - **Envelope characteristics:** U-values of walls, roofs, windows, floors
 - **Installed technical systems:** heating systems, boilers, heat pumps, solar thermal, etc.
 - **Renovation and retrofit data** (e.g., insulation upgrades, window replacements)
 - **Primary energy consumption** and **CO₂ emissions**
 - **Building use and size**
- **Data Format:** Structured database; anonymised datasets are available for research and policy planning.

Use in Archetype Definition:

- EPCs provide **energy-relevant parameters** for building typologies and allow validation of simulation models.
- Enables clustering of buildings with similar energy performance and system configurations.

- Used to develop average performance values by building type and age class.

3. Eco Fund – Database of Implemented EE and RES Measures

The **Eco Fund (Eko sklad)** is Slovenia's national financial mechanism for supporting energy efficiency and renewable energy investments. Its database contains records of all **grants, subsidies, and soft loans** disbursed to households, companies, and municipalities.

Key characteristics of the Eco Fund data:

- **Project-level records** of implemented measures (e.g., façade insulation, window replacement, boiler replacement, solar PV installation, heat pumps)
- **Time series:** project data by year and location (municipality or building)
- **Measure-specific details:** including system type, capacity, building type, and scope
- **Beneficiary profiles:** residential vs. public sector, single- vs. multi-family homes
- **Grant amount and cost share**, which enables cost-effectiveness analysis

Use in archetype development:

- Provides **empirical insight into renovation trends** and technology adoption rates
- Allows tracking of **implementation gaps** and **renovation depth** across building types
- Supports calibration of **renovation scenarios** in modelling exercises (e.g. for NECP or long-term renovation strategies)

These datasets are increasingly being linked through building IDs or geographic references, which allows researchers and policymakers to build more sophisticated archetype libraries – essential for energy modelling tools (like PHPP, TABULA, or national simulation platforms).

Slovenia is geographically diverse, and its climate is influenced by Alpine, Mediterranean, and continental (Pannonian) factors. To account for this variability in building energy design and regulation, the country is divided into **climatic zones** based primarily on **heating degree days (HDD)** and **elevation**. These zones are used for determining the thermal performance requirements of building envelopes and systems.

The Slovenian **building code PURES (Regulation on the Efficient Use of Energy in Buildings)** defines three main climatic zones for the purposes of energy performance requirements:

Zone I: Mild / Coastal

- **Regions:** Primorska (e.g., Koper, Nova Gorica)
- **Characteristics:**
 - Mediterranean climate
 - Mild winters, warm summers
 - Lowest heating demand
- **Heating Degree Days (HDD):** Below ~2,200 (base 20°C)
- **Impact on Buildings:**
 - Less insulation required compared to other zones
 - Greater focus may be placed on summer overheating risk

Zone II: Moderate / Central

- **Regions:** Most of central Slovenia (e.g., Ljubljana, Celje, Novo mesto)

- **Characteristics:**

- Temperate continental climate
- Moderate winters and warm summers

- **HDD:** Approximately 2,200–3,000

- **Impact on Buildings:**

- Balanced heating and cooling needs
- Standard insulation requirements as per national average

Zone III: Cold / Alpine

- **Regions:** Gorenjska, Koroška, parts of Notranjska and Štajerska (e.g., Jesenice, Maribor – higher altitudes)

- **Characteristics:**

- Alpine and sub-Alpine climate
- Cold winters, significant snow load

- **HDD:** Above ~3,000

- **Impact on Buildings:**

- High insulation and airtightness required
- Specific design requirements for moisture and ventilation
- Focus on heating system efficiency

Despite Slovenia's division into three official climatic zones: **Zone I**, **Zone II** and **Zone III**; this study adopts **Zone II** as a uniform reference climate for building energy modelling. This approach is justified based on the following key arguments:

1. **Representativeness of the Building Stock:** Zone II includes the majority of Slovenia's urban and suburban areas, such as **Ljubljana, Celje, and Novo mesto**, where a substantial portion of the population and building stock is concentrated. These areas exhibit typical central European heating needs and construction patterns.
2. **Climatic Balance Across Extremes:** Zone II reflects a **moderate thermal demand profile** between the low-heating Zone I (Mediterranean) and high-heating Zone III (Alpine). This makes it suitable for representing average conditions in national-level simulations, avoiding regional bias.

3. **Consistency and Simplicity in Modelling:** Using one climate zone enables consistent use of input parameters (temperature, solar radiation, heating degree days) across all building archetypes. This simplifies the calculation workflow, especially for large-scale scenario analyses and cost-benefit assessments.
4. **Regulatory and Analytical Compatibility:** Slovenian and EU policy modelling tools (e.g. **PHPP, EPC methodologies, NECP simulations**) frequently default to **Ljubljana-based climate data**, which belongs to Zone II. This enhances compatibility and transparency in comparative evaluations.
5. **Policy Neutrality:** Selecting the continental zone ensures that no specific geographic or socioeconomic group is disproportionately favoured in standardised analysis. It aligns with principles of fairness in public investment and building code implementation.

By using **Zone II (Continental)** as a national proxy, the model maintains methodological rigor while achieving practical efficiency and policy relevance.

4.5.2 Seismic safety related data

In terms of vertical structure materials, the most prevalent types are stone masonry, brick masonry, reinforced concrete (RC), and combined systems that incorporate both masonry load-bearing walls and vertical RC elements. Timber structures, mostly used in single-family houses, and metal structures, typically found in industrial buildings, are comparatively rare.

Stone and brick masonry buildings from before 1895 (the year of the most intense earthquake in Ljubljana), were constructed based on practical experience. From 1896 (first seismic code), to 1920, predominantly solid brick masonry structures were built. These buildings were typically constructed with steel ties and exhibited significantly improved structural regularity.

From 1921 to 1965, solid brick masonry continued to be widely used for load bearing walls, typically combined with timber floor structures and poor structural connections between elements. Starting in 1982, the use of hollow brick masonry structural walls in combination with RC floor structures and mandatory RC tie-beams became common. Since 2008, these systems have included also mandatory RC tie-columns, providing additional confinement.

Some buildings constructed before 1965, mostly public buildings, feature RC columns or RC walls. However, after 1965, the use of RC wall structures became

more widespread, in particular for larger residential buildings with 5 to 12 floors above ground. RC frame structures, whether without or with brick masonry infill, were then up to 2008 relatively rare.

Several methods for the assessment of seismic resistance and vulnerability have been developed in Slovenia, suitable for different types of load-bearing structures. So far, these methods have been applied to over 1600 existing buildings, and the resulting data form the basis of the POTROG model. This model, which is the basis for GreenRenoV8 seismic vulnerability data population, enables a rough estimate of seismic vulnerability, taking into account three key parameters for which reliable data exists in the national Real Estate Register: construction period, structural type and number of floors. To account for the milestones that influence the seismic resistance of buildings in Slovenia (described above and in 2.2.5), six construction periods were defined within the POTROG model: up to 1895, 1896–1920, 1921–1945, 1946–1965, 1966–1981 and 1982–2008.

The GreenRenoV8 archetypes have been basically set considering the types of building use and the construction periods. For each of the eight most common types of buildings use, three to six construction periods were defined. They were determined by merging some of the adjacent previously established six periods, and by adding a period covering the construction after 2009. For each pair of building use and construction period, the most common combination of structural type and number of floors, based on the Slovenian building stock, was identified and set as typical for that specific archetype. On the other hand, the seismic vulnerability of the specific archetype was evaluated as a weighted average, taking into account seismic resistance for all combinations of three seismic parameters, that are included in the archetype, and total floor area of buildings as weights. In the developed dataset, seismic vulnerability according to the POTROG model is considered for buildings constructed in periods up to 2008, whereas for newer buildings it is considered that they fulfil the requirements of Eurocode 8.

The same seismic hazard is possible for buildings of all archetypes, as they are all present throughout the country. Considering the map from 2011 (Figure 10), a good half of the buildings are according to **EMS-98** located in intensity zones VIII, a good third in intensity zones VII, and the rest in intensity zones VI.

5. Challenges and Recommendations

The development of a harmonised building stock characterisation framework across multiple European countries presented several challenges, many of which

extended beyond the technical dimension. One of the first and most significant difficulties encountered was establishing a common understanding among partners, each of whom approached the task from a different regulatory, cultural, and methodological background. Given that most national practices are deeply rooted in their respective legislative and technical traditions, aligning interpretations and terminology required careful negotiation and iterative refinement.

This divergence was particularly evident in the early stages, when core concepts such as sectoral classification, climate zoning, and even structural typologies were interpreted differently depending on national standards. For instance, although an initial attempt was made to consider the Köppen climate classification [5852] as a unifying reference, it soon became clear that national regulations on thermal transmittance limits are based on their own zoning systems, making the use of local regulatory zones a more practical and accurate solution. A similar issue arose for seismic zoning, which varies significantly across Europe in both its methodology and its implications for building requirements.

Another challenge was the high degree of internal variability within each Building Category. While these categories are defined by common parameters, such as sector, use type, and construction period, they can include buildings with fundamentally different structural characteristics (e.g. masonry, stone, or reinforced concrete), insulation levels, or system configurations. This heterogeneity required a flexible data structure capable of capturing variant cases without compromising the comparability across the stock. In response, the methodology incorporated the use of additional rows or share factors, especially for HVAC systems, to reflect the co-existence of multiple configurations within a single category.

Furthermore, as detailed in the previous sections, the disaggregation by energy performance class was introduced as a crucial step to refine the representation of the existing building stock and to inform future renovation scenarios. However, this level of granularity is not currently supported by any single comprehensive data source. As a result, many of the variables used in the model were necessarily derived from assumptions, expert knowledge, or national averages, introducing a layer of uncertainty that was managed as transparently as possible.

It is important to stress that the templates and the final data structure are the result of several months of intense collaboration, continuous discussion, and refinement. Numerous meetings, written exchanges, and internal validations were necessary to converge on a methodology that, while not entirely standardised

across all national contexts, represents a robust and adaptable platform for cross-country comparison.

Considering these challenges, a key recommendation that emerged from this process is the need for further alignment of regulatory frameworks at the European level. Greater uniformity in the definition of energy classes, climatic zones, and structural typologies, similar to the harmonisation efforts underway for the Energy Performance Certificate (EPC) across Europe, would greatly facilitate future data integration, policy assessment, and scenario development. As the demand for high-resolution and interoperable building stock data continues to grow, fostering such alignment will be essential to support both national strategies and EU-wide decarbonisation goals.

6. Conclusions

This deliverable has presented the development of a harmonised and flexible framework for the categorisation of the building stock into renovation-supporting archetypes across five European countries. The proposed methodology responds to the need for a multidimensional approach that integrates energy efficiency, seismic resilience, and environmental performance—dimensions that are increasingly interlinked in European legislation and long-term renovation strategies.

The adopted approach allows the definition of building archetypes through a structured classification based on building function (sector and subsector) and construction period (age class). This structure reflects both the physical evolution of the building stock and the transformations driven by national regulations. For each country, 30 representative archetypes were developed, capturing the diversity of construction typologies while enabling simplification, harmonisation, and comparability.

The framework was designed to be both technically sound and operationally usable. Each archetype integrates a broad set of descriptors: general stock data, geometry, thermal and energy parameters, technical systems, climatic and seismic zones, allowing it to serve as a robust input for multiple downstream analyses. The consistent structure ensures alignment with the objectives of the Energy Performance of Buildings Directive (EPBD), while also supporting national compliance and policy design.

A major strength of this framework lies in its flexibility. In situations where data were incomplete or heterogeneous, expert-based assumptions, national regulations, and distribution shares were used to ensure consistency. This makes the framework adaptable to different national contexts and capable of absorbing future updates as more detailed or disaggregated data become available. The data collection process, while harmonised across countries, also preserved national specificities and regulatory milestones, ensuring that the archetypes remain representative of local construction practices and policy environments.

The integration of seismic vulnerability indicators into the archetype structure marks an important advancement. Traditionally absent from energy-focused stock models, seismic considerations are increasingly relevant in the context of climate adaptation and risk mitigation. By incorporating structural types, hazard levels, and vulnerability classifications, the framework supports a more

comprehensive assessment of renovation priorities—especially in regions exposed to significant seismic risk.

Furthermore, the inclusion of climatic zoning, energy classes, and technical systems enhances the potential of the archetypes to be used in the design of renovation roadmaps and renovation passports, in line with emerging European requirements. It also enables deeper insights into the interplay between building characteristics, user needs, and regional constraints.

Looking ahead, this framework will play a central role in the upcoming activities of the project. It provides the foundation for scenario modelling, impact evaluation, and the development of cost-effective and climate-resilient renovation strategies. It also offers a common ground for dialogue among stakeholders, including policy makers, planners, researchers, and market actors, by translating complex stock characteristics into accessible, structured information.

In conclusion, the methodology and results presented in this deliverable contribute to bridging data gaps, aligning assessment practices across countries, and supporting the implementation of integrated renovation policies. The building archetype framework developed here is not only a technical tool, but also a strategic enabler for the transformation of Europe's building stock. It supports a transition towards renovation approaches that are more targeted, inclusive, and informed—ultimately contributing to the achievement of decarbonisation and resilience goals at both national and European levels.

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8. Annexes

This annex includes illustrative screenshots of the structured Excel databases developed within Task 2.1 to support the definition and characterisation of building archetypes. The examples shown refer exclusively to the case of Greece and are presented for demonstration purposes only, to help visualise the structure, content, and logic of the harmonised data framework.

In accordance with the data management and confidentiality principles described in the main text, no sensitive, complete, or disaggregated data are shown in these annexes. All numerical values have been partially obscured, redacted, or replaced with placeholders to prevent direct disclosure. The full datasets are stored in the project repository and are accessible to authorised users only, following the procedures agreed among project partners.

The following figures refer to the file *ArchetypeStockData.xlsx*. They illustrate the structure of the dataset used to define each Building Category, including classification fields, general stock data, geometric parameters, and energy indicators.

Archetype					Building stock					
building category	sector	subsector	building type	building age class	[n]	[n]	[m ²]	[Mm ²]	[Mm ²]	[n]
					number of buildings	ratio of typology in stock	covered area: constructed	covered area: heated	covered area: cooled	number of dwellings/units
EL-SFH-1850-1918	Residential sector	Single family houses	Single family houses	1850 - 1918						
EL-SFH-1919-1944	Residential sector	Single family houses	Single family houses	1919 - 1944						
EL-SFH-1945-1969	Residential sector	Single family houses	Single family houses	1945 - 1969						
EL-SFH-1970-1979	Residential sector	Single family houses	Single family houses	1970 - 1979						
EL-SFH-1980-1989	Residential sector	Single family houses	Single family houses	1980 - 1989						
EL-SFH-1990-1999	Residential sector	Single family houses	Single family houses	1990 - 1999						
EL-SFH-2000-2010	Residential sector	Single family houses	Single family houses	2000 - 2010						
EL-SFH-2011-2016	Residential sector	Single family houses	Single family houses	2011 - 2016						
EL-SFH-2017-NOW	Residential sector	Single family houses	Single family houses	2017 - NOW						
EL-MFH-1850-1918	Residential sector	Multifamily houses	Multifamily houses	1850 - 1918						
EL-MFH-1919-1944	Residential sector	Multifamily houses	Multifamily houses	1919 - 1944						
EL-MFH-1945-1969	Residential sector	Multifamily houses	Multifamily houses	1945 - 1969						
EL-MFH-1970-1979	Residential sector	Multifamily houses	Multifamily houses	1970 - 1979						
EL-MFH-1980-1989	Residential sector	Multifamily houses	Multifamily houses	1980 - 1989						
EL-MFH-1990-1999	Residential sector	Multifamily houses	Multifamily houses	1990 - 1999						
EL-MFH-2000-2010	Residential sector	Multifamily houses	Multifamily houses	2000 - 2010						
EL-MFH-2011-2016	Residential sector	Multifamily houses	Multifamily houses	2011 - 2016						
EL-MFH-2017-NOW	Residential sector	Multifamily houses	Multifamily houses	2017 - NOW						
EL-ABL-1850-1918	Residential sector	Apartment blocks	Apartment blocks	1850 - 1918						
EL-ABL-1919-1944	Residential sector	Apartment blocks	Apartment blocks	1919 - 1944						
EL-ABL-1945-1969	Residential sector	Apartment blocks	Apartment blocks	1945 - 1969						
EL-ABL-1970-1979	Residential sector	Apartment blocks	Apartment blocks	1970 - 1979						
EL-ABL-1980-1989	Residential sector	Apartment blocks	Apartment blocks	1980 - 1989						
EL-ABL-1990-1999	Residential sector	Apartment blocks	Apartment blocks	1990 - 1999						
EL-ABL-2000-2010	Residential sector	Apartment blocks	Apartment blocks	2000 - 2010						
EL-ABL-2011-2016	Residential sector	Apartment blocks	Apartment blocks	2011 - 2016						
EL-ABL-2017-NOW	Residential sector	Apartment blocks	Apartment blocks	2017 - NOW						

Figure 22: Residential sector classification and part of the General Data group.

D.2.1: Sustainable renovation-supporting building archetypes

Archetype					Reference building						
building category	sector	subsector	building type	building age class	[m ²]	[m ²]	[m ²]	[m ²]	[m ²]	[m ²]	[m ³]
					reference building useful floor area	reference building ground floor area	reference building wall area	reference building window area	reference building roof area	reference building gross floor area	reference building gross volume
EL-SFH-1850-1918	Residential sector	Single family houses	Single family houses	1850 - 1918							
EL-SFH-1919-1944	Residential sector	Single family houses	Single family houses	1919 - 1944							
EL-SFH-1945-1969	Residential sector	Single family houses	Single family houses	1945 - 1969							
EL-SFH-1970-1979	Residential sector	Single family houses	Single family houses	1970 - 1979							
EL-SFH-1980-1989	Residential sector	Single family houses	Single family houses	1980 - 1989							
EL-SFH-1990-1999	Residential sector	Single family houses	Single family houses	1990 - 1999							
EL-SFH-2000-2010	Residential sector	Single family houses	Single family houses	2000 - 2010							
EL-SFH-2011-2016	Residential sector	Single family houses	Single family houses	2011 - 2016							
EL-SFH-2017-NOW	Residential sector	Single family houses	Single family houses	2017 - NOW							
EL-MFH-1850-1918	Residential sector	Multifamily houses	Multifamily houses	1850 - 1918							
EL-MFH-1919-1944	Residential sector	Multifamily houses	Multifamily houses	1919 - 1944							
EL-MFH-1945-1969	Residential sector	Multifamily houses	Multifamily houses	1945 - 1969							
EL-MFH-1970-1979	Residential sector	Multifamily houses	Multifamily houses	1970 - 1979							
EL-MFH-1980-1989	Residential sector	Multifamily houses	Multifamily houses	1980 - 1989							
EL-MFH-1990-1999	Residential sector	Multifamily houses	Multifamily houses	1990 - 1999							
EL-MFH-2000-2010	Residential sector	Multifamily houses	Multifamily houses	2000 - 2010							
EL-MFH-2011-2016	Residential sector	Multifamily houses	Multifamily houses	2011 - 2016							
EL-MFH-2017-NOW	Residential sector	Multifamily houses	Multifamily houses	2017 - NOW							
EL-ABL-1850-1918	Residential sector	Apartment blocks	Apartment blocks	1850 - 1918							
EL-ABL-1919-1944	Residential sector	Apartment blocks	Apartment blocks	1919 - 1944							
EL-ABL-1945-1969	Residential sector	Apartment blocks	Apartment blocks	1945 - 1969							
EL-ABL-1970-1979	Residential sector	Apartment blocks	Apartment blocks	1970 - 1979							
EL-ABL-1980-1989	Residential sector	Apartment blocks	Apartment blocks	1980 - 1989							
EL-ABL-1990-1999	Residential sector	Apartment blocks	Apartment blocks	1990 - 1999							
EL-ABL-2000-2010	Residential sector	Apartment blocks	Apartment blocks	2000 - 2010							
EL-ABL-2011-2016	Residential sector	Apartment blocks	Apartment blocks	2011 - 2016							
EL-ABL-2017-NOW	Residential sector	Apartment blocks	Apartment blocks	2017 - NOW							

Figure 23: Residential sector classification and part of the Geometry group.

Archetype					Reference building			
building category	sector	subsector	building type	building age class	[W/m ² K]	[W/m ² K]	[W/m ² K]	[W/m ² K]
					reference building wall u-value	reference building roof u-value	reference building window u-value	reference building groundfloor u-value
EL-SFH-1850-1918	Residential sector	Single family houses	Single family houses	1850 - 1918				
EL-SFH-1919-1944	Residential sector	Single family houses	Single family houses	1919 - 1944				
EL-SFH-1945-1969	Residential sector	Single family houses	Single family houses	1945 - 1969				
EL-SFH-1970-1979	Residential sector	Single family houses	Single family houses	1970 - 1979				
EL-SFH-1980-1989	Residential sector	Single family houses	Single family houses	1980 - 1989				
EL-SFH-1990-1999	Residential sector	Single family houses	Single family houses	1990 - 1999				
EL-SFH-2000-2010	Residential sector	Single family houses	Single family houses	2000 - 2010				
EL-SFH-2011-2016	Residential sector	Single family houses	Single family houses	2011 - 2016				
EL-SFH-2017-NOW	Residential sector	Single family houses	Single family houses	2017 - NOW				
EL-MFH-1850-1918	Residential sector	Multifamily houses	Multifamily houses	1850 - 1918				
EL-MFH-1919-1944	Residential sector	Multifamily houses	Multifamily houses	1919 - 1944				
EL-MFH-1945-1969	Residential sector	Multifamily houses	Multifamily houses	1945 - 1969				
EL-MFH-1970-1979	Residential sector	Multifamily houses	Multifamily houses	1970 - 1979				
EL-MFH-1980-1989	Residential sector	Multifamily houses	Multifamily houses	1980 - 1989				
EL-MFH-1990-1999	Residential sector	Multifamily houses	Multifamily houses	1990 - 1999				
EL-MFH-2000-2010	Residential sector	Multifamily houses	Multifamily houses	2000 - 2010				
EL-MFH-2011-2016	Residential sector	Multifamily houses	Multifamily houses	2011 - 2016				
EL-MFH-2017-NOW	Residential sector	Multifamily houses	Multifamily houses	2017 - NOW				
EL-ABL-1850-1918	Residential sector	Apartment blocks	Apartment blocks	1850 - 1918				
EL-ABL-1919-1944	Residential sector	Apartment blocks	Apartment blocks	1919 - 1944				
EL-ABL-1945-1969	Residential sector	Apartment blocks	Apartment blocks	1945 - 1969				
EL-ABL-1970-1979	Residential sector	Apartment blocks	Apartment blocks	1970 - 1979				
EL-ABL-1980-1989	Residential sector	Apartment blocks	Apartment blocks	1980 - 1989				
EL-ABL-1990-1999	Residential sector	Apartment blocks	Apartment blocks	1990 - 1999				
EL-ABL-2000-2010	Residential sector	Apartment blocks	Apartment blocks	2000 - 2010				
EL-ABL-2011-2016	Residential sector	Apartment blocks	Apartment blocks	2011 - 2016				
EL-ABL-2017-NOW	Residential sector	Apartment blocks	Apartment blocks	2017 - NOW				

Figure 24: Residential sector classification and part of the Thermal Transmittance group.

D.2.1: Sustainable renovation-supporting building archetypes

Archetype					Energy Consumptions					
					[kWh/m² year]	[kWh/m² year]	[kWh/m² year]	[kWh/m² year]	[kWh/m² year]	[kWh/m² year]
building category	sector	subsector	building type	building age class	useful energy demand - space heating	useful energy demand - space cooling	useful energy demand - domestic hot water	final energy consumption - space heating	final energy consumption - space cooling	final energy consumption - domestic hot water
EL-EDU-1850-1944	Service sector	None	Education	1850 - 1944						
EL-EDU-1945-1969	Service sector	None	Education	1945 - 1969						
EL-EDU-1970-1979	Service sector	None	Education	1970 - 1979						
EL-EDU-1980-1989	Service sector	None	Education	1980 - 1989						
EL-EDU-1990-1999	Service sector	None	Education	1990 - 1999						
EL-EDU-2000-2010	Service sector	None	Education	2000 - 2010						
EL-EDU-2011-2016	Service sector	None	Education	2011 - 2016						
EL-EDU-2017-NOW	Service sector	None	Education	2017 - NOW						
EL-HEA-1850-1944	Service sector	None	Health	1850 - 1944						
EL-HEA-1945-1969	Service sector	None	Health	1945 - 1969						
EL-HEA-1970-1979	Service sector	None	Health	1970 - 1979						
EL-HEA-1980-1989	Service sector	None	Health	1980 - 1989						
EL-HEA-1990-1999	Service sector	None	Health	1990 - 1999						
EL-HEA-2000-2010	Service sector	None	Health	2000 - 2010						
EL-HEA-2011-NOW	Service sector	None	Health	2011 - NOW						
EL-HOR-1850-1944	Service sector	None	Hotels and Restaurants	1850 - 1944						
EL-HOR-1945-1969	Service sector	None	Hotels and Restaurants	1945 - 1969						
EL-HOR-1970-1979	Service sector	None	Hotels and Restaurants	1970 - 1979						
EL-HOR-1980-1989	Service sector	None	Hotels and Restaurants	1980 - 1989						
EL-HOR-1990-1999	Service sector	None	Hotels and Restaurants	1990 - 1999						
EL-HOR-2000-2010	Service sector	None	Hotels and Restaurants	2000 - 2010						
EL-HOR-2011-2016	Service sector	None	Hotels and Restaurants	2011 - 2016						
EL-HOR-2017-NOW	Service sector	None	Hotels and Restaurants	2017 - NOW						

Figure 25: Not-residential sector classification and part of the Energy Consumptions group.

The following figures refer to the file *ElementModelling.xlsx*. They illustrate the structure of the dataset used to describe the physical composition of envelope components for each Building Category, including the core structure, insulation layers, and finishing materials. As an example, the figures shown refer to the Ground Floor component. However, the same file contains separate sheets for all other parts of the building envelope.

Archetype				GROUND FLOOR				
Sector	Building type	Building age class	Building Category	Structural				
				Floor material type	Floor material share	Structural - material	Structural - form	Structural - thickness [m]
Service sector	Education	1850 - 1944	EL_EDU_1850_1944					
Service sector	Education	1945 - 1969	EL_EDU_1945_1969					
Service sector	Education	1970 - 1979	EL_EDU_1970_1979					
Service sector	Education	1980 - 1989	EL_EDU_1980_1989					
Service sector	Education	1990 - 1999	EL_EDU_1990_1999					
Service sector	Education	2000 - 2010	EL_EDU_2000_2010					
Service sector	Education	2011 - 2016	EL_EDU_2011_2016					
Service sector	Education	2017 - NOW	EL_EDU_2017_NOW					
Service sector	Health	1850 - 1944	EL_HEA_1850_1944					
Service sector	Health	1945 - 1969	EL_HEA_1945_1969					
Service sector	Health	1970 - 1979	EL_HEA_1970_1979					
Service sector	Health	1980 - 1989	EL_HEA_1980_1989					
Service sector	Health	1990 - 1999	EL_HEA_1990_1999					
Service sector	Health	2000 - 2010	EL_HEA_2000_2010					
Service sector	Health	2011 - NOW	EL_HEA_2011_NOW					
Service sector	Hotels and Restaurants	1850 - 1944	EL_HOR_1850_1944					
Service sector	Hotels and Restaurants	1945 - 1969	EL_HOR_1945_1969					
Service sector	Hotels and Restaurants	1970 - 1979	EL_HOR_1970_1979					
Service sector	Hotels and Restaurants	1980 - 1989	EL_HOR_1980_1989					
Service sector	Hotels and Restaurants	1990 - 1999	EL_HOR_1990_1999					
Service sector	Hotels and Restaurants	2000 - 2010	EL_HOR_2000_2010					
Service sector	Hotels and Restaurants	2011 - 2016	EL_HOR_2011_2016					
Service sector	Hotels and Restaurants	2017 - NOW	EL_HOR_2017_NOW					

Figure 26: Non-residential sector classification and structural data fields.

D.2.1: Sustainable renovation-supporting building archetypes

Archetype				GROUND FLOOR					
Sector	Building type	Building age class	Building Category	Floor insulation material	Insulation - material	Thermal insulation			
						Insulation - form	Insulation thickness [m]	Position of insulation	reference building floor u-value [W/m²K]
Service sector	Education	1850 - 1944	EL_EDU_1850_1944						
Service sector	Education	1945 - 1969	EL_EDU_1945_1969						
Service sector	Education	1970 - 1979	EL_EDU_1970_1979						
Service sector	Education	1980 - 1989	EL_EDU_1980_1989						
Service sector	Education	1990 - 1999	EL_EDU_1990_1999						
Service sector	Education	2000 - 2010	EL_EDU_2000_2010						
Service sector	Education	2011 - 2016	EL_EDU_2011_2016						
Service sector	Education	2017 - NOW	EL_EDU_2017_NOW						
Service sector	Health	1850 - 1944	EL_HEA_1850_1944						
Service sector	Health	1945 - 1969	EL_HEA_1945_1969						
Service sector	Health	1970 - 1979	EL_HEA_1970_1979						
Service sector	Health	1980 - 1989	EL_HEA_1980_1989						
Service sector	Health	1990 - 1999	EL_HEA_1990_1999						
Service sector	Health	2000 - 2010	EL_HEA_2000_2010						
Service sector	Health	2011 - NOW	EL_HEA_2011_NOW						
Service sector	Hotels and Restaurants	1850 - 1944	EL_HOR_1850_1944						
Service sector	Hotels and Restaurants	1945 - 1969	EL_HOR_1945_1969						
Service sector	Hotels and Restaurants	1970 - 1979	EL_HOR_1970_1979						
Service sector	Hotels and Restaurants	1980 - 1989	EL_HOR_1980_1989						
Service sector	Hotels and Restaurants	1990 - 1999	EL_HOR_1990_1999						
Service sector	Hotels and Restaurants	2000 - 2010	EL_HOR_2000_2010						
Service sector	Hotels and Restaurants	2011 - 2016	EL_HOR_2011_2016						
Service sector	Hotels and Restaurants	2017 - NOW	EL_HOR_2017_NOW						

Figure 27: Non-residential sector classification and thermal insulation data fields.

Archetype				GROUND FLOOR								
Sector	Building type	Building age class	Building Category	Boundary condition	Finishing ceiling 1 - type	Finishing ceiling 1 - share	Finishing ceiling 2 - type	Finishing ceiling 2 - share	Finishing			
									Finishing floor 1 - type	Finishing floor 1 - share	Finishing floor 2 - type	Finishing floor 2 - share
Service sector	Offices	1850 - 1944	EL_OFF_1850_1944									
Service sector	Offices	1945 - 1969	EL_OFF_1945_1969									
Service sector	Offices	1970 - 1979	EL_OFF_1970_1979									
Service sector	Offices	1980 - 1989	EL_OFF_1980_1989									
Service sector	Offices	1990 - 1999	EL_OFF_1990_1999									
Service sector	Offices	2000 - 2010	EL_OFF_2000_2010									
Service sector	Offices	2011 - 2016	EL_OFF_2011_2016									
Service sector	Offices	2017 - NOW	EL_OFF_2017_NOW									
Service sector	Other service buildings	1850 - 1944	EL_OTH_1850_1944									
Service sector	Other service buildings	1945 - 1969	EL_OTH_1945_1969									
Service sector	Other service buildings	1970 - 1979	EL_OTH_1970_1979									
Service sector	Other service buildings	1980 - 1989	EL_OTH_1980_1989									
Service sector	Other service buildings	1990 - 1999	EL_OTH_1990_1999									
Service sector	Other service buildings	2000 - 2010	EL_OTH_2000_2010									
Service sector	Other service buildings	2011 - 2016	EL_OTH_2011_2016									
Service sector	Other service buildings	2017 - NOW	EL_OTH_2017_NOW									
Service sector	Trade	1850 - 1944	EL_TRA_1850_1944									
Service sector	Trade	1945 - 1969	EL_TRA_1945_1969									
Service sector	Trade	1970 - 1979	EL_TRA_1970_1979									
Service sector	Trade	1980 - 1989	EL_TRA_1980_1989									
Service sector	Trade	1990 - 1999	EL_TRA_1990_1999									
Service sector	Trade	2000 - 2010	EL_TRA_2000_2010									
Service sector	Trade	2011 - 2016	EL_TRA_2011_2016									
Service sector	Trade	2017 - NOW	EL_TRA_2017_NOW									

Figure 28: Non-residential sector classification and finishing data fields.

The following figures show excerpts from the main Excel file (*GRV8_Archetypes.xlsx*) used to summarise the 30 national archetypes.

Archetypes		Seismic				
Number	Archetype ID	Seismic Zone	Building Structural Type			Seismic vulnerability
[number]	[text]	[text]	[text]	[text]	[text]	[text]
No. Archetype		Seismic Hazard	General Building Structural Type	Specific Structural system	Specific Structural Type	Seismic vulnerability of construction type
1	EL-SFH-1850-1944-EXB					
2	EL-SFH-1945-1969-EXB					
3	EL-SFH-1970-1979-EXB					
4	EL-SFH-1980-1989-EXB					
5	EL-SFH-1990-2010-EXB					
6	EL-SFH-2011-2016-EXB					
7	EL-SFH-2017-NOW-EXB					
8	EL-MFH-1850-1944-EXB					
9	EL-MFH-1945-1969-EXB					
10	EL-MFH-1970-1979-EXB					
11	EL-MFH-1980-1989-EXB					
12	EL-MFH-1990-2010-EXB					
13	EL-MFH-2011-2016-EXB					
14	EL-MFH-2017-NOW-EXB					

Figure 29: Greek archetypes with seismic characterisation fields.

Archetypes		Climatic Zones			
Number	Archetype ID	Climatic Zone A (choose from source tab and insert here)	Climatic Zone B (choose from source tab and insert here)	Climatic Zone C (choose from source tab and insert here)	Climatic Zone D (choose from source tab and insert here)
[number]	[text]	Share %	Share %	Share %	Share %
No. Archetype		Share of Archetype to climate Zone A	Share of Archetype to Climate Zone B	Share of Archetype to Climate Zone C	Share of Archetype to Climate Zone D
1	EL-SFH-1850-1944-EXB				
2	EL-SFH-1945-1969-EXB				
3	EL-SFH-1970-1979-EXB				
4	EL-SFH-1980-1989-EXB				
5	EL-SFH-1990-2010-EXB				
6	EL-SFH-2011-2016-EXB				
7	EL-SFH-2017-NOW-EXB				
8	EL-MFH-1850-1944-EXB				
9	EL-MFH-1945-1969-EXB				
10	EL-MFH-1970-1979-EXB				
11	EL-MFH-1980-1989-EXB				
12	EL-MFH-1990-2010-EXB				
13	EL-MFH-2011-2016-EXB				
14	EL-MFH-2017-NOW-EXB				

Figure 30: Greek archetypes with climatic zone characterisation fields.

EPC			U Values					
FILL THIS ROW WITH SOURCES								
		[kwh / m ² year]	W/m ² ·K	W/m ² ·K	W/m ² ·K	W/m ² ·K	W/m ² ·K	W/m ² ·K
Sector	EPC class	Energy use	U-value external wall	U-value ground floor	U-value attic floor	U-value roof	U-value windows (as a whole)	U-value external doors
Residential	A+							
	A							
	B+							
	B							
	C							
	D							
	E							
	F							
non-Residential	G							
	A+							
	A							
	B+							
	B							
	C							
	D							
	E							
	F							
	G							

Figure 31: Energy performance classes and corresponding U-values for residential and non-residential sectors.

Archetypes		Energy performance classes								
FILL THIS ROW WITH SOURCES										
Number	Archetype ID	Energy performance classes								
[number]		Share %	Share %	Share %	Share %	Share %	Share %	Share %	Share %	Share %
No. Archetype		Share A+	Share A	Share B+	Share B	Share C	Share D	Share E	Share F	Share G
1	EL-SFH-1850-1944-EXB									
2	EL-SFH-1945-1969-EXB									
3	EL-SFH-1970-1979-EXB									
4	EL-SFH-1980-1989-EXB									
5	EL-SFH-1990-2010-EXB									
6	EL-SFH-2011-2016-EXB									
7	EL-SFH-2017-NOW-EXB									
8	EL-MFH-1850-1944-EXB									
9	EL-MFH-1945-1969-EXB									
10	EL-MFH-1970-1979-EXB									
11	EL-MFH-1980-1989-EXB									
12	EL-MFH-1990-2010-EXB									
13	EL-MFH-2011-2016-EXB									
14	EL-MFH-2017-NOW-EXB									

Figure 32: Greek archetypes and associated share distribution across energy performance classes.

Archetypes		EPC		HVAC SYSTEM 1						
				It indicates the system share	It indicates the type of system used for space heating: <i>individual, central</i>	It indicates the type of generator used for space heating: boiler non-condensing, boiler condensing, combined, stove, electric heating, heat pump	It indicates the size of the generator system	It indicates the type of fuel used for space heating:	It indicates the efficiency of the generator system	It indicates the emission system type: Radiators, underfloor heating, fan coil, <i>convectors and forced</i>
	FILL THIS ROW WITH SOURCES									
Number		Archetype ID		HVAC SYSTEM 1						
				Share	HEATING (H)					
[number]		[text]		[%]	[text]	[text]	[kW]	[text]	[%]	[text]
No. Archetype		Energy performance class	Share	System Variant Share 1	H1 type	H1 technology	H1 dimensions	H1 fuel used	H1 efficiency	H1 Emission system
1	EL-SFH-1850-1944-EXB	A+	0%							
1	EL-SFH-1850-1944-EXB	A	0%							
1	EL-SFH-1850-1944-EXB	B+	0%							
1	EL-SFH-1850-1944-EXB	B	0%							
1	EL-SFH-1850-1944-EXB	C	0%							
1	EL-SFH-1850-1944-EXB	D	0%							
1	EL-SFH-1850-1944-EXB	E	0%							
1	EL-SFH-1850-1944-EXB	F	0%							
1	EL-SFH-1850-1944-EXB	G	0%							

Figure 33: Example of heating system characterisation linked to archetypes and energy performance classes.

Archetypes		EPC		HVAC SYSTEM 1				
				It indicates the type of generator used forDHW: boiler non-condensing, boiler condensing, combined, stove, electric heating, heat pump	It indicates the size of the generator system	It indicates the type of fuel used for DHW:	It indicates the efficiency of the generator system	It indicates if DHW system is combined with Heating system
	FILL THIS ROW WITH SOURCES							
Number		Archetype ID		HVAC SYSTEM 1				
				DHW				
[number]		[text]		[text]	[kW]	[text]	[%]	
No. Archetype		Energy performance class	Share	DHW1 technology	DHW1 dimensions	DHW1 fuel used	DHW1 efficiency	DHW1 Combined with Heating?
1	EL-SFH-1850-1944-EXB	A+	0%					
1	EL-SFH-1850-1944-EXB	A	0%					
1	EL-SFH-1850-1944-EXB	B+	0%					
1	EL-SFH-1850-1944-EXB	B	0%					
1	EL-SFH-1850-1944-EXB	C	0%					
1	EL-SFH-1850-1944-EXB	D	0%					
1	EL-SFH-1850-1944-EXB	E	0%					
1	EL-SFH-1850-1944-EXB	F	0%					
1	EL-SFH-1850-1944-EXB	G	0%					

Figure 34: Example of DHW system characterisation linked to archetypes and energy performance classes.

Archetypes		EPC		HVAC SYSTEM 1				
				It indicates the type of generator used for Cooling:	It indicates the size of the generator system	It indicates the type of fuel used for Cooling:	It indicates the efficiency of the generator system	It indicates the emission system type:
				FILL THIS ROW WITH SOURCES				
Number		Archetype ID		HVAC SYSTEM 1				
				COOLING (C)				
[number]		[text]		[text]	[kW]	[text]	[%]	[text]
No. Archetype		Energy performance class	Share	C1 technology	C1 dimensions	C1 fuel used	C1 efficiency	C1 Emission system
1	EL-SFH-1850-1944-EXB	A+	0%					
1	EL-SFH-1850-1944-EXB	A	0%					
1	EL-SFH-1850-1944-EXB	B+	0%					
1	EL-SFH-1850-1944-EXB	B	0%					
1	EL-SFH-1850-1944-EXB	C	0%					
1	EL-SFH-1850-1944-EXB	D	0%					
1	EL-SFH-1850-1944-EXB	E	0%					
1	EL-SFH-1850-1944-EXB	F	0%					
1	EL-SFH-1850-1944-EXB	G	0%					

Figure 35: Example of cooling system characterisation linked to archetypes and energy performance classes.