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Building stock inventory to assess seismic vulnerability across Europe

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Abstract

Exposure data for buildings have been collected from different sources and for various uses. The databanks created for seismic risk assessment comply with the desired taxonomy of exposed buildings for vulnerability studies, but are often developed for specific urban areas. National censuses take place at regular time intervals and collect exhaustive information on a country's housing stock. However, housing censuses are not completely harmonised across European countries and significant efforts are required to collect and process census data for further use in seismic risk studies.

The study of this report aims at inventorying the housing stock in European countries and classifying its seismic vulnerability at a regional level. The first step was the collection of georeferenced data from the 2011 Population and Housing censuses through Eurostat, specifically, the number of dwellings by period of construction at a regional level. Subsequently, the ratio of dwellings to buildings was calculated, considering the degree of urbanisation. Finally, the dwellings were arranged in different classes of vulnerability, based on the seismic design code in force in the country in the year the dwelling was constructed. The analysis of the inventory shows that the majority of existing buildings in Europe are highly vulnerable to earthquakes.

Previous case studies have shown that Eurostat data can be used to assess, with acceptable accuracy, the seismic risk at a regional level. Therefore, the inventory is suitable to be used in further studies for estimating seismic losses across Europe and for prioritising retrofitting strategies for the European building stock.

1 Introduction

An inventory of exposed assets is a key component of seismic risk assessment studies, together with hazard characterisation and vulnerability assessment. Recent research has brought significant advances on hazard analysis, *e.g.* Woessner et al. (2015), and fragility curves, *e.g.* Rossetto et al. (2014). However, detailed and reliable information on exposed structures to be used for large-scale seismic risk assessment is still not widely available. The collection of harmonised data at large scale, such as the European one, represents one of the major challenges in seismic risk assessment studies. For instance, data regarding national housing censuses in Europe are not completely harmonised across countries and significant efforts are required to collect and process census data to be further used in seismic risk studies.

Buildings exposure data for seismic risk assessment have been collected at different spatial disaggregation levels, ranging from fine spatial scale surveys, focusing for instance on specific cities around Europe, *e.g.* Vicente et al. (2011), or on industrial infrastructures (Sousa et al. 2017b), to coarser spatial scale inventories, as in research projects like PAGER – Prompt Assessment of Global Earthquakes for Response system (Jaiswal et al. 2010) – or NERA – Network of European Research Infrastructures for Earthquake Risk Assessment and Mitigation (Crowley et al. 2012). Information on the building stock has been also collected within the framework of projects aiming at assessing the energy performance of buildings, in such cases, aggregated at much larger areas with similar climatic conditions. Another source of detailed information on the building stock, albeit not fully harmonised across countries, are the national housing censuses. A review of several data sources revealed divergences and incompatibilities among them (Tsionis 2015), which raise questions on their aptness for use in the seismic loss estimation at large regions. Frequently the inventories compiled within research projects contain data aggregated at the level of countries, which is not sufficient for seismic risk assessment. Moreover, they are inferred from a variety of sources and they do not account for the distribution of buildings in small geographical units, which is proven to influence the loss estimates.

A case study was performed to examine the influence of the level of detail of the datasets of the building stock on the results of large-scale risk assessment studies in earthquake-prone regions of Europe (Sousa et al 2017a). It consisted in a quantitative risk analysis using a dataset of exposed residential buildings with a high level of geographic detail, originating from the 2011 national census, and the more generic one that is available at the Eurostat Census Hub (ec.europa.eu/CensusHub2). Losses were computed for the scenario corresponding to the national seismic zoning map. The case study showed that loss assessment based on generic data, available at the Eurostat Census Hub (https://ec.europa.eu/CensusHub2), captures the order of magnitude of the losses estimated on the basis of more detailed data. Considering the low level of observed variability of losses (8%) obtained with both datasets, it was concluded that readily available data extracted from the Eurostat Census Hub, combined with expert opinion, can be used to assess, with acceptable accuracy, the seismic risk for all European countries.

The work presented in this report was carried out in the framework of the JRC institutional work that deals with the resilience of the buildings in urban areas across the European Union and aims to provide scientific support for decision-making as regards the seismic retrofit of existing buildings. Increased resilience is an objective of the European strategy for disaster management, which calls for a qualitative shift from reacting to emergencies to a more proactive role of prevention and preparedness. In the global context, the Sendai Framework (UNISDR 2015) aims to prevent new and substantially reduce existing disaster risk and losses through, among other measures, the reduction of exposure and vulnerability.

The aim of this report is to inventory the housing stock in the European Union (EU) and European Free Trade Association (EFTA) Member States, using georeferenced data, harmonised in terms of both procedures and variables collected. The harmonised database

created in this study provides an overview of the vulnerability of the housing stock across Europe.

2 Assessment of seismic vulnerability across Europe

2.1 General aspects

As reported in the previous section, reliable inventories of the building stock represent an important tool to provide scientific support for decision-making with regard to seismic risk assessment, also in terms of expected impact on people and structures (Zuccaro et al. 2012, Tsionis 2015). Recent years have seen a considerable growth in the number of earthquake loss models for several geographic levels. The loss models are of interest for predicting the economic impact of future earthquakes and for risk mitigation (Calvi et al. 2006). Constructing an earthquake loss model for a city, region or country involves compiling databases of, among others, building stock and infrastructure exposure and vulnerability characteristics of the exposed inventory. However, while this activity can be pursued straightforwardly for either limited number of regions with common characteristics or narrow areas, it becomes challenging when developing a building inventory for all European countries at a detailed geographical level. In this context, one of the major drawbacks is giving a harmonized interpretation of data, which are frequently non-homogeneous. As a consequence, three main goals were established in the development of the inventory of this study. As a first step, data from Eurostat Census Hub has been used in order to overcome the inhomogeneity of data collected, both in methodology and topics. Subsequently, an indicator to assess the number of buildings given the number of dwellings was developed to face the significant divergences in the building stock between urban and rural areas and between towns in the same country. Moreover, the knowledge of the number of buildings is useful to make comparisons with different sources of data. Finally, with the aim of providing a consistent but simplified characterisation of the vulnerability of buildings across Europe, with high level of geographic detail, the evolution of seismic design code provisions in each country was examined.

2.2 Data from Eurostat Census Hub

As shown in the previous section, the activity of collecting data is performed by a multitude of organisations with several methodologies and geographic resolution, which vary according to the specific goals. Housing census may be regarded as a comprehensive source of data for the development of building inventories at different geographical levels. However, national housing censuses are not completely harmonised across countries and collecting data is often difficult and time consuming. On the other hand, Eurostat, i.e. the statistical office of the European Union, provides online high-quality statistics for Europe on several topics, characterised by homogeneity in terms of data collection procedures and outputs. The whole range of harmonised data offered by Eurostat is widely used by institutions and by the general public and allow reliable comparisons of statistics between countries and regions. As a consequence, this study uses Eurostat data, in order to overcome the major disadvantages associated with non-homogeneity of data across countries.

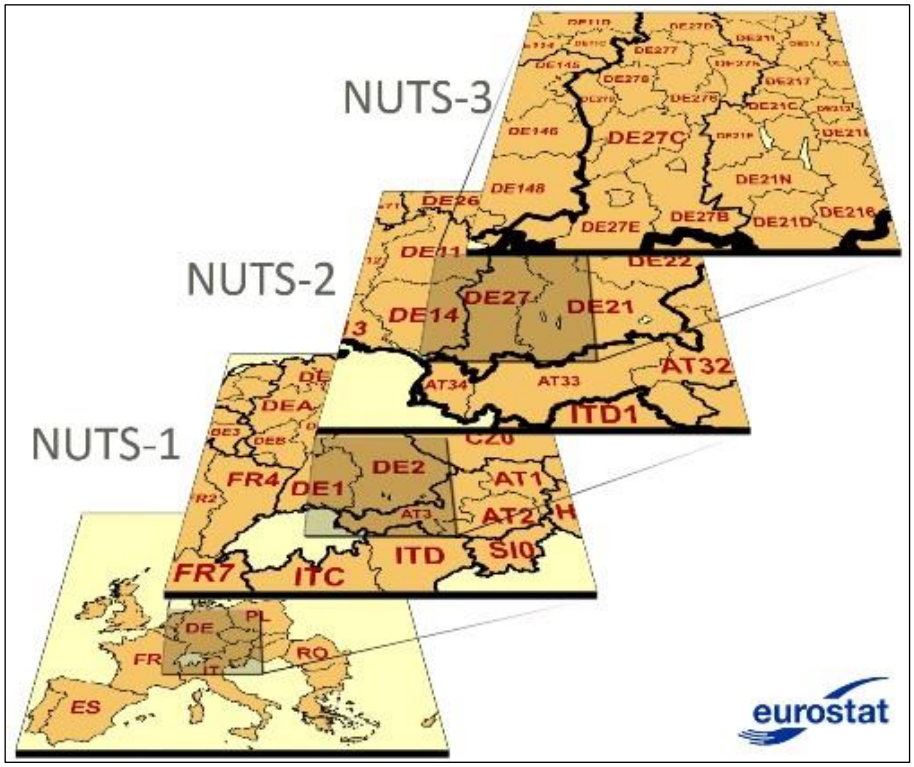
The online tool Census Hub, which provides data regarding the 2011 Census for the whole Europe, has been used. The Census Hub has been constructed with the aim of improving dissemination and accessibility of data. It is an IT structure that allows users to quickly and flexibly specify, compile and extract data stored in the different national census databases. National Statistical Institutes provide access to their data according to standard processes, formats and technologies.

Within the framework of this study, the data collected from the Census Hub were the number of "dwellings" by the topic "Period of construction", for the geographical level NUTS3 that corresponds to regions such as provinces and that were the smallest regions available in the surveyed situation. According to Eurostat, a dwelling is defined as "a room or suite of rooms – including its accessories, lobbies and corridors – in a permanent building or a structurally separated part of a building which, by the way it has been built, rebuilt or converted, is designed for habitation by one private household all year round"

(http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Dwelling). The "Period of construction" of the dwellings is defined according to the year in which the building was completed (https://ec.europa.eu/CensusHub2).

The concept of NUTS – Nomenclature of Territorial Units for Statistics – was formulated by Eurostat to divide up the economic territory of the European Union into uniform territorial units to be used for statistical questions (Eurostat 2015). As shown in Figure 1, the territory is classified in three hierarchical levels: NUTS1 that groups a set of regions (*e.g.* Wales or Scotland are classified as NUTS1 in UK), which in turn are subdivided into NUTS2, comprising groups of districts and then are further divided into NUTS3 regions, corresponding to a district level. A specific code and name is allocated to each of these regions. The NUTS are complemented at the lower level by Local Administrative Units (LAU).

Figure 1. The NUTS (Nomenclature of Territorial Units for Statistics) classification



Source: Eurostat, 2015.

The data were collected and organised in a database for the 28 EU countries plus Norway and Switzerland. The database consists of several fields like the code and name of NUTS3 per country, the total number of dwellings, the number of dwellings per period of construction and per type of building, and the population. In total, 1 395 NUTS3 regions across Europe are included in the database. Moreover, the inventory was georeferenced and integrated into a Geographic Information System, that facilitates mapping and analysis of data to support informed decision processes at several scales (Fichera et al. 2016, Palermo and Pappalardo 2016).

2.3 Degree of urbanisation

According to Dijkstra and Poelman (2014), the Degree of Urbanisation (DEGURBA) is an indicator based on the number of people living in a certain area and may be defined as "a classification that indicates the character of an area" (http://ec.europa.eu/eurostat/web/degree-of-urbanisation). For its assessment, a new methodology was released in 2014 by the Directorate-General for Regional and Urban

Policy of European Commission with the aim of providing a harmonized definition of cities and rural areas. The original degree of urbanisation was introduced in 1991 to indicate the character of the area. It distinguished three types of areas: densely populated, intermediate and thinly populated areas. This definition was based on the population size, density and contiguity of local administrative units level 2 (LAU2). Since LAU2s vary considerably in area size, the results of the methodology were distorted and with low level of comparability among countries with different LAU2s extensions. To overcome this distortion, the new degree of urbanisation adopts a defined territorial basis made of smaller units with the same size: the population grid with a resolution of 1 km^2. The new DEGURBA is developed at LAU2 level and LAU2 areas are classified into three types: densely populated areas (cities) where at least 50 % of the population lives in high-density clusters (DEGURBA = 1), intermediate density areas (towns and suburbs) where less than 50 % of the population lives in rural grid cells and less than 50% of the population lives in high-density clusters (DEGURBA = 2), and thinly populated areas (rural areas) where more than 50 % of the population lives in rural grid cells (DEGURBA = 3) (Dijkstra and Poelman 2014). High-density clusters represent contiguous grid cells of 1 km^2 with a density of at least 1 500 inhabitants per km^2 and a minimum population of 50 000.

This classification has been based on population data for 2006 and the LAU2 boundaries of 2011. The new DEGURBA classification provides less distorted and more comparable results than the 1991 version, by taking advantage of the population grid. This allows creating a more accurate classification and a further harmonisation of spatial concepts.

The DEGURBA concept and data have been used in this study to investigate the distribution of population and buildings in urban and rural areas as reported in the following sections.

2.4 Ratio of dwellings to buildings

Generally, the databanks previously created for local seismic risk assessment studies accurately represent the building stock in the area of interest and comply with both the required taxonomy of exposed buildings and the spatial variability of the seismic hazard. However, they refer to rather small geographic areas and are not representative of other similar areas. A number of case studies highlight the significant divergences in the building stock between urban and rural areas, between towns in the same country and between districts of the same town. It is demonstrated that these differences affect the losses estimated in risk studies (Spence et al. 2012). As a consequence, specificities are frequently flattened when investigations at regional and national scale are approached and the interpretation of the spatial distribution of buildings within the geographical region and the relation between dwellings in the buildings are not assessed. As a consequence, although the NUTS 3 geographical level used for the development of the database, as referred in the previous section, is appropriate for the goal of this study of inventorying the housing stock in Europe, the need to handle the divergences in the distribution of dwellings among areas with different Degrees of Urbanisation has arisen. A dwelling, by its definition, may be considered a habitation. This implies that any kind of information on the structure in which the dwellings are located is not provided, as the Census Hub does not allow correlating dwellings to buildings. Therefore, to better investigate the conditions of the building stock, the concept of density of built-up areas has been included in the study. It may also enable to overcome a single building approach, which may not be suitable for the regional scale (NUTS3 level) chosen for the inventory. In this framework, density is a measure of the human presence in a territory. Considering the density of built-up areas allows to investigate the distribution of people and, subsequently, of buildings in an area and to capture the peculiarities of the built environment among different cities and areas across Europe. In particular, to take into account the different levels of urbanisation of regions in Europe, the indicator Degree of Urbanisation (DEGURBA) (Dijkstra and Poelman 2014) has been used to develop a procedure that enables to yield the indicator "number of buildings". This indicator, that relates the number of dwellings to the number of buildings, has been designed in order to provide a more comprehensive representation of the building stock in Europe and to allow comparisons with other studies and data. The

procedure has been applied at a NUTS3 level with the elaboration and aggregation of data developed also at a LAU2 level with the methodology described below.

As a first step, a new database at a finer geographical level was developed. Data regarding "the number of persons with usual residence" were collected for all the countries from the Census Hub at a LAU2 level, which corresponds to municipalities or equivalent units, together with the Degree of Urbanisation (DEGURBA). In this study, the DEGURBA indicator has been integrated in the procedure to supply data on the spatial distribution of inhabitants and, hence, applied to evaluate the peculiarities of European regions with regard to the distribution of buildings within countries. Data for population and DEGURBA classification were integrated to provide a new georeferenced dataset for each country at the LAU2 geographical level which contains the following information: the degree of urbanisation, the population, the area, both name and code of LAU2 and the NUTS3 to which the LAU2 belongs to. This implied a database containing more than 100 000 records.

The second step of the procedure consisted in the collection of data regarding the number of buildings at a NUTS3 level. Such data collected from the 2011 national census are available at the websites of the National Statistical Institutes of six out of the 30 countries considered, namely Austria, Belgium, Germany, Greece, Italy and Portugal.

In the third step, a mathematical procedure was applied to the data regarding the aforementioned six countries in order to yield an average ratio of dwellings per building, Ndwg/Nbld, to be subsequently extended to the other countries. Since the number of dwellings, Ndwg, is well related to population, the number of dwellings at a LAU2 unit was calculated by distributing the dwellings of a NUTS3 area to the corresponding LAU2 areas proportionally to the population living in that area. As a consequence, the number of dwellings was integrated in the database containing information at a LAU2 level. In particular, the municipalities were characterised and organised according to the three classes of LAU characterised by a value of Degree of Urbanisation (1 or 2 or 3). This step allowed to infer the number of dwellings at the LAU2 level, in addition to the NUTS3 level. Then, data regarding the number of dwellings and population at a LAU2 level were aggregated (by summing them up) according to NUTS3 per each DEGURBA type, thereby summing also the areas of each LAU2 belonging to the same NUTS3 and sharing the same value of DEGURBA. In the next step, the number of buildings was computed per each of the three classes of Degree of Urbanisation by distributing the total number of buildings, collected from the census data, in proportion to the area of the territories of LAU2. However, despite the outlined methodology has provided an overview of the number of buildings per each DEGURBA category at a NUTS3 level, the comparison between the results of this procedure and information from censuses showed significant differences. As a consequence, two further steps were performed. For the rural areas (DEGURBA = 3) the number of dwellings per building, Ndwg/Nbld, was assumed equal to 1.0, as expressed in Equation 1.

$$\mathrm{Ndwg}_3 = \mathrm{Nbld}_3 \tag{1}$$

Finally, the remaining dwellings were redistributed to the other classes of DEGURBA proportionally to the surface area of their territories and to an empirical multiplying factor (Equations 2 to 4), calculated through an iterative procedure that allowed to reach a good confidence level as reported in Figure 2.

For $\mathrm{Ndwg}_{3,0}/\mathrm{Nbld}_{3.0} < 1$

$$\mathrm{Nbld}_1 = \left[\mathrm{Nbld}_{1,0} + \left|\mathrm{Nbld}_{3,0} - \mathrm{Ndwg}_{3,0}\right| 0.02\ \frac{\mathrm{A}_1}{\mathrm{A}_1+\mathrm{A}_2}\right] \tag{2a}$$

$$\mathrm{Nbld}_2 = \left[\mathrm{Nbld}_{2,0} + \left|\mathrm{Nbld}_{3,0} - \mathrm{Ndwg}_{3,0}\right| \left(1 - \left(0.02\ \frac{\mathrm{A}_1}{\mathrm{A}_1+\mathrm{A}_2}\right)\right)\right] \tag{2b}$$

$$\mathrm{Nbld}_3 = \mathrm{Ndwg}_{3,0} \tag{2c}$$

and for $\mathrm{Ndwg}_{3,0}/\mathrm{Nbld}_{3.0} > 1$

$$\mathrm{Nbld}_1 = \left[\mathrm{Nbld}_{1,0} + \left|\mathrm{Ndwg}_{3,0} - \mathrm{Nbld}_{3,0}\right| 0.02\ \frac{\mathrm{A}_1}{\mathrm{A}_1+\mathrm{A}_2}\right] \tag{3a}$$

$$\mathrm{Nbld}_2 = \left[\mathrm{Nbld}_{2,0} + \left|\mathrm{Ndwg}_{3,0} - \mathrm{Nbld}_{3,0}\right| \left(1 - \left(0.02\ \frac{\mathrm{A}_1}{\mathrm{A}_1+\mathrm{A}_2}\right)\right)\right] \tag{3b}$$

$$\mathrm{Nbld}_3 = \mathrm{Ndwg}_{3,0} - 2\mathrm{Nbld}_{3,0} \tag{3c}$$

where

$$\mathrm{Ndwg}_1 = \left[\mathrm{Ndwg}_3 + \left|\mathrm{Nbld}_{3,0} - \mathrm{Ndwg}_{3,0}\right| \left(0.02\ \frac{\mathrm{A}_1}{\mathrm{A}_1+\mathrm{A}_2}\right)\right] + \mathrm{Ndwg}_{1,0} \tag{4a}$$

$$\mathrm{Ndwg}_2 = \left[\mathrm{Ndwg}_3 + \left|\mathrm{Nbld}_{3,0} - \mathrm{Ndwg}_{3,0}\right| \left(1 - \left(0.02\ \frac{\mathrm{A}_1}{\mathrm{A}_1+\mathrm{A}_2}\right)\right)\right] + \mathrm{Ndwg}_{2,0} \tag{4b}$$

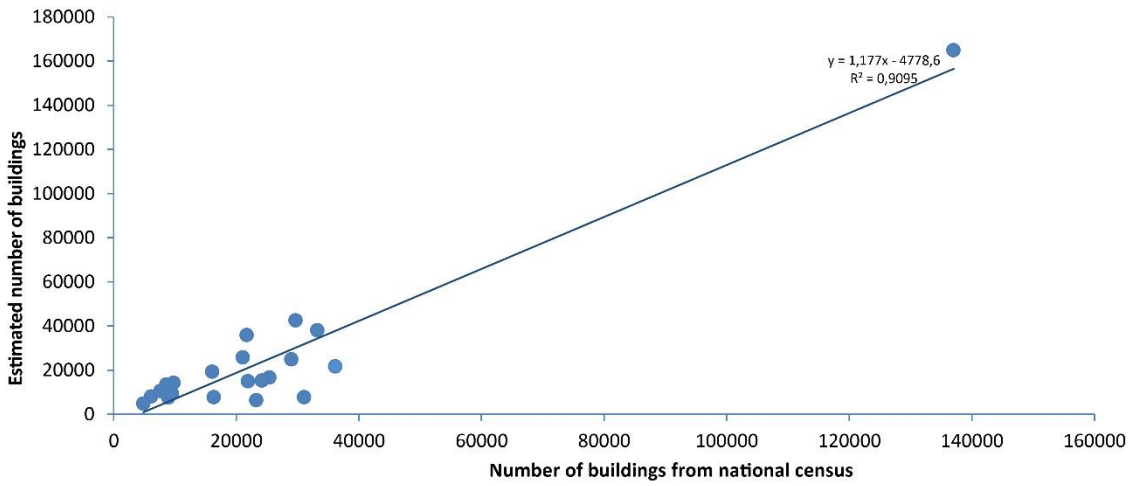
$$\mathrm{Ndwg}_3 = \mathrm{Ndwg}_{3,0} \tag{4c}$$

Where:

Ndwg is the number of dwellings, Nbld is the number of buildings, the subscripts 1, 2 and 3 refer to the DEGURBA class, the subscript 0 refers to the values of Ndwg and Nbld assessed before imposing the condition of Equation (1), A_1 is the area of territories classified as DEGURBA 1 and A_2 is the area of territories classified as DEGURBA 2.

This procedure was tested for one country (Italy) by comparing the number of buildings, for some cities where LAU2 coincides to NUTS3, from the national census (http://dati-censimentopopolazione.istat.it/Index.aspx) with the value obtained with the procedure described above. As shown in Figure 2, a linear correlation with R^2 = 0.9 was obtained between the number of buildings in the census (x-axis) and estimated data (y-axis), which provides a high level of confidence in the procedure. However, Figure 2 also shows great variability of the number of buildings in cities within the same country. The number of buildings in cities belonging to the category DEGURBA 1varies from less than 10 000 to more than 150 000. In Figure 2, the top right point (150 000 buildings) refers to the city of Rome, which is peculiar for being an urban region with metropolitan characteristics and large population. Therefore, the procedure is able to address both the cases of small and thinly-built cities and of metropolitan and densely-built cities.

Figure 2. Comparison of estimated number of buildings with the Italian census data



In the fourth step, the ratio of dwellings to buildings, Ndwg/Nbld was assessed for each DEGURBA class in the six countries, using the previously described procedure. An average value for each class was calculated and assigned to the whole country, as reported in Table 1. The values of Ndwg/Nbld for DEGURBA = 2 are quite similar in all six countries, but diverge significantly for DEGURBA = 1, which is justified by the different conditions regarding the number of cities in each country (*e.g.* 6 in Austria and 127 in Germany), and the density of built-up areas. However, as shown in the last line of Table 1, the average

values of Ndwg/Nbld for all DEGURBA types do not show significant differences in the analysed countries (6.4 and 6.6 for DEGURBA 1 and 2.1 and 2.0 for DEGURBA 2). As a consequence, the following average values for the indicator in each DEGURBA class were adopted for all the 30 countries considered in this study: $Ndwg_1/Nbld_1 = 6.5$, $Ndwg_2/Nbld_2 = 2$ and $Ndwg_3/Nbld_1 = 1$. Using these values, the number of buildings in each NUTS3 was inferred from the number of dwellings for all the countries considered in the inventory.

Table 1. Average values of the ratio Ndwg/Nbld.

Country	**Degree of urbanisation, DEGURBA**			**Country**	**Degree of urbanisation, DEGURBA**		
	1	**2**	**3**		**1**	**2**	**3**
Greece	2.6	2.6	1.0	Austria	11.7	2.6	1.0
Italy	7.1	2.6	1.0	Belgium	4.4	1.0	1.0
Portugal	9.5	1.2	1.0	Germany	4.0	2.3	1.0
Average	**6.4**	**2.1**	**1.0**	**Average**	**6.6**	**2.0**	**1.0**

2.5 Seismic vulnerability classification across Europe

In order to perform the vulnerability assessment of the building stock in Europe, dwellings were arranged in different classes of vulnerability, based on the seismic design code that was in force in each country in the year the building was constructed. Three vulnerability classes were adopted, corresponding to buildings designed with no seismic provisions (VC1), moderate-level (VC2) and high-level seismic code (VC3). Buildings designed without seismic provisions are considered extremely vulnerable and are expected to suffer severe damage even for moderate earthquakes. Moderate-level seismic codes contain some provisions for earthquake resistance, such as a nominal design base shear calculated as a percentage of the total weight of the structure and simple detailing requirements. High-level seismic codes encompass advanced knowledge in the field, *e.g.* limit-state design, modal response spectrum analysis, detailing and other provisions for energy dissipation and ductility, etc. Eurocode 8 (CEN 2004) was introduced in Europe since more than 10 years and several national codes that entered into force after 1990 were aligned with its ENV version.

While a commonly accepted classification of the seismic codes in all European countries is not available, a comprehensive review of all codes (in several languages) and of the differences between consecutive versions is a task beyond the scope of the present study. The evolution of the building codes in the 30 countries was investigated on the basis of the information retrieved in the technical literature regarding i) the entry in force of building / seismic codes in the different countries and ii) the expected seismic performance of buildings designed in a given time period. An additional assumption was that the buildings were designed and constructed in compliance with the requirements of the applicable seismic code.

Figure 3 presents the time periods that are considered in this work for the three levels of seismic design in the different countries and for the associated classification of the seismic vulnerability of buildings. It may be highlighted that the countries with no code provisions and the ones that only recently improved the provisions for seismic design are the ones where the seismic hazard is low *i.e.* Denmark, Estonia, Finland, Ireland, Lithuania, Netherlands, Poland and the United Kingdom. On the contrary, the countries where the seismic hazard levels are higher, are at the forefront of a process of updating the design codes for earthquake resistance of buildings. As a matter of fact, requirements for seismic design were introduced in Greece, Portugal, Romania and Spain in the 1940s and 50s.

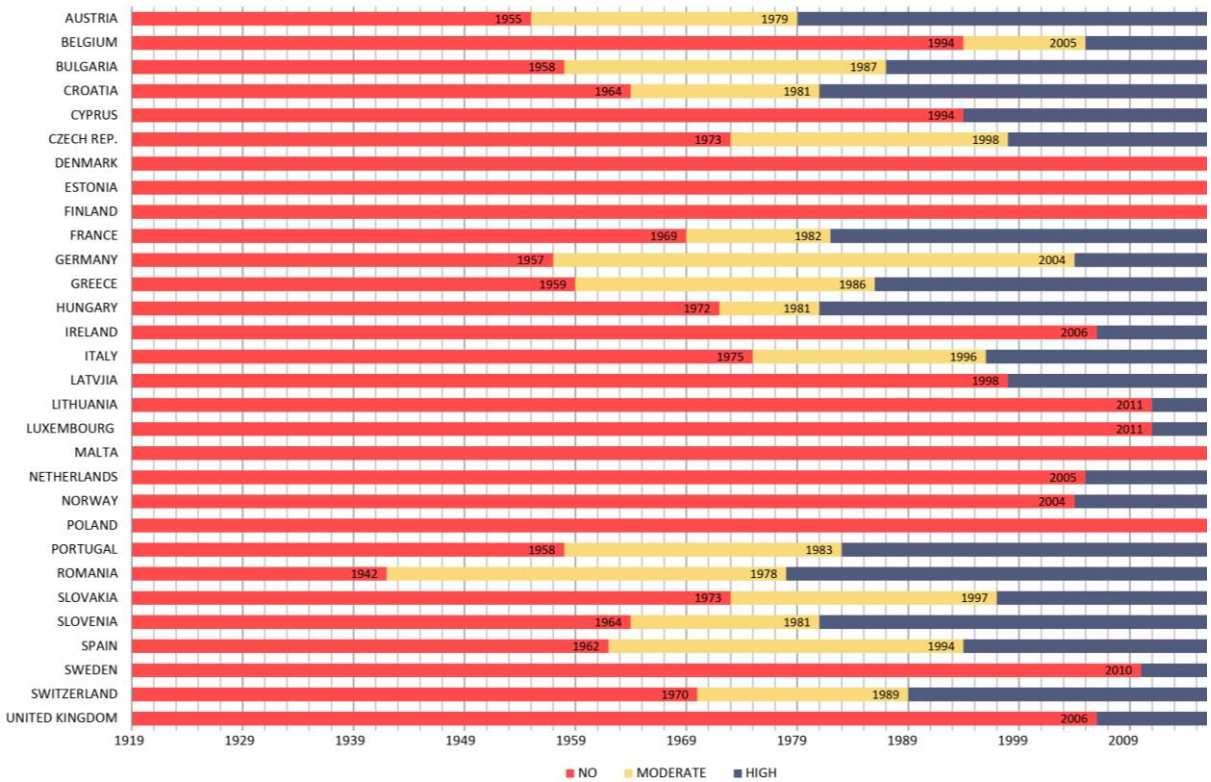
Interestingly, early versions of seismic design were codified in Austria and Germany in the same period. The classification shown in Figure 3 may be further refined after a thorough study, for all countries, of the seismic design codes and an assessment of the seismic performance of buildings constructed in different time periods.

Following the investigation of the seismic codes of each country, a harmonised classification of the seismic vulnerability of the building stock across Europe is proposed. The Eurostat Census Hub provides nine periods to classify the date of building construction: before 1919, 1919-1945, 1946-1960, 1961-1970, 1971-1980, 1981-1990, 1991-2000, 2001-2005 and after 2006. For many countries, the entry into force of the most important codes or laws, considered as "turning point" in the evolution of the construction characteristics relevant for seismic performance (see Figure 3), coincide with a threshold of the intervals in the Census Hub. When the limits of the two intervals (the implementation of a seismic design code and the period of construction) are not coincident, a conservative approach is adopted, *i.e*. the dwellings from a complete period of construction are assigned to the more vulnerable class, which also allows to take into account the period of transition until the effective implementation of a new regulation.

By way of example, Kappos and Panagiotopoulos (2010) reported that the first seismic code was enforced in Greece in 1959 and supplementary clauses were added in 1984, while a modern code equivalent to the ENV version of Eurocode 8 (CEN 2004) was published in 1995 and then updated in 2000. Based on this information, buildings constructed before 1961 are assigned in the low vulnerability class (no seismic provisions), those constructed between 1961 and 1991 are considered to have been designed with a moderate-level seismic code and those constructed after 1991 belong to the class of buildings designed with a high-level seismic code.

This classification does not account for other characteristics of buildings – height, construction material and structural system – that are important for the seismic response. It is noted that reliable information on these characteristics is only available for some countries and often not for all three parameters in the same country.

Figure 3. Evolution of seismic design codes in the European countries



The database described in Section 2.1 was complemented with the following fields: number and percentage of dwellings per vulnerability class, and the vulnerability class of the majority of dwellings in each NUTS3. The information available in the database is summarised in Table 2.

Table 2. Fields of the database at NUTS3 and LAU2 levels.

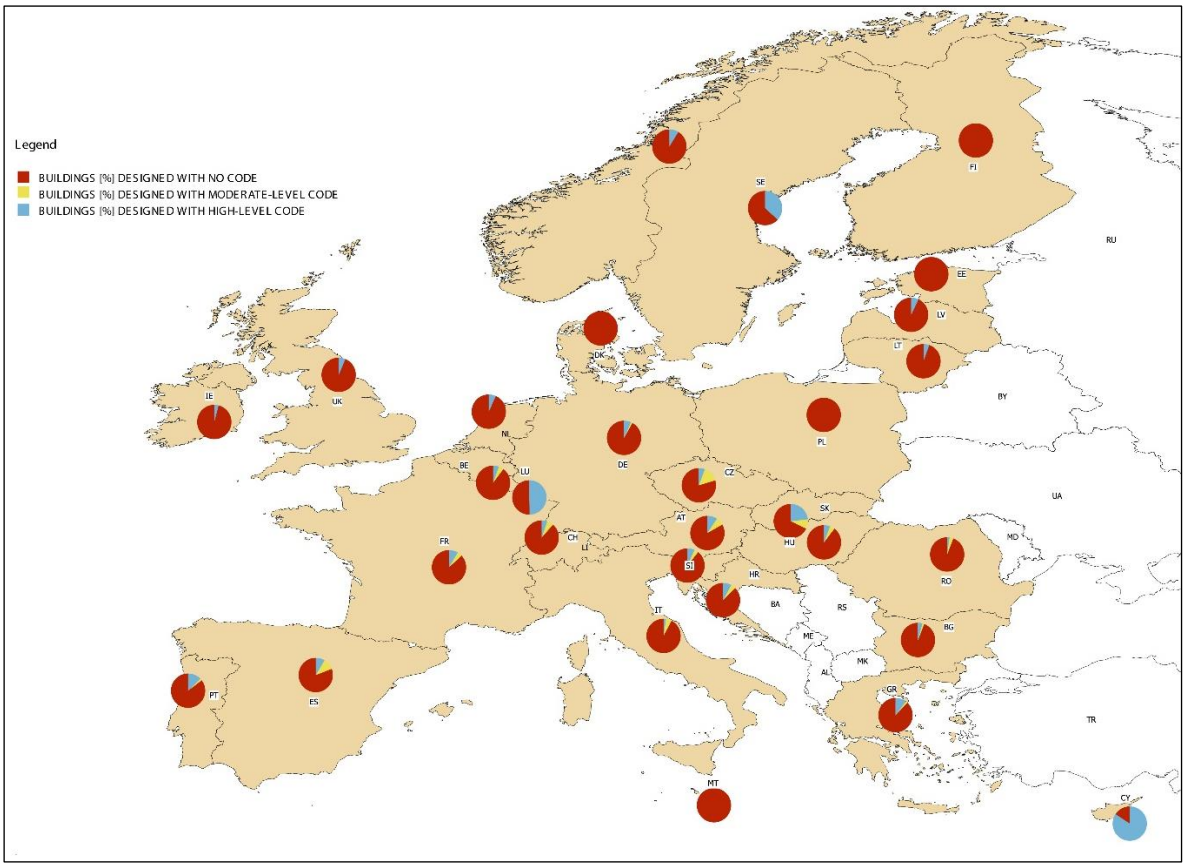
NUTS3 Level			
Geography level[1]	N° of dwellings built before 1919	N° of dwellings built from 2001 to 2005	Percentage of dwellings in VC2
Code of NUTS	N° of dwellings built from 1919 to 1945	N° of dwellings built after 2006	Percentage of dwellings in VC3
Code of Country	N° of dwellings built from 1946 to 1960	Total Number of Buildings	Percentage of dwellings in VC1 and VC2
Name of NUTS3	N° of dwellings built from 1961 to 1970	N° of dwellings in VC1	Most frequent vulnerability class of dwellings
Name of NUTS2	N° of dwellings built from 1971 to 1980	N° of dwellings in VC2	Population (n° of inhabitants in the area)
Name of NUTS1	N° of dwellings built from 1981 to 1990	N° of dwellings in VC3	Area of the NUTS (hectares)
Total number of dwellings	N° of dwellings built from 1991 to 2000	Percentage of dwellings in VC1	
LAU2 Level			
LAU code	Area (square meters)	DEGURBA Class	Population (n° of inhabitants)
Code of Country	NUTS3 Code	Name of LAU2	Reference PGA

Figure 4 summarises the outcome of the procedure described above and shows the distribution of dwellings in each vulnerability class for the 30 countries. These results confirm that the European building stock is old and show that the large majority of buildings across Europe was constructed before the date of entry into force of the first building codes with rules for seismic design. The previous conclusion is supported by the map in Figure 5 that presents the percentage of dwellings in buildings that were designed without seismic provisions or with moderate-level seismic code, in other words, those that would require upgrading their seismic performance. Further considerations towards a qualitative estimation of the seismic risk may be made by observing Figure 6 that maps the reference values of peak ground acceleration (PGA) for the reference return period for the no-collapse requirement in Eurocode 8 (CEN 2004). The PGA values were obtained from the National Annexes of Part 1 of Eurocode 8. The reference return period is 475 years for all countries, except for Romania and the United Kingdom that adopted return periods of 100 and 2500

[1]For every region it is reported the corresponding geographic hierarchical level (Nomenclature of Territorial Units for Statistics). This field is necessary for comparing and joining this dataset with other databases at different geographical levels (i.e. NUTS1, NUTS2, LAU1).

years, respectively. Seismic action for Type 1 spectrum is shown in the map for Portugal, since this county published two seismic zone maps in the National Annex of Eurocode 8. The regions with the highest values of PGA are almost the entire territory of Croatia, Cyprus, Greece, Italy, Slovenia and Romania and parts of France, Spain and Portugal. From the comparison of the three maps in Figures 4 to 6, it may be gathered that the large majority of dwellings in these areas are located in buildings without design for earthquake resistance or in buildings designed with moderate-level seismic codes, and are therefore expected to suffer damage in the event of an earthquake.

Figure 4. Percentage of buildings designed without provisions for earthquake resistance (no code), moderate level and high-level seismic code, © EuroGeographics for the administrative boundaries



The map of Figure 7 presents an overview of the most frequent vulnerability class in each NUTS3 region across the 30 countries examined in this study. Results show that the majority of dwellings in countries in central and north Europe are located in buildings without design for earthquake resistance. As shown in Figure 6, the values of peak ground acceleration in these countries are relatively low and, therefore, the risk of damage is also low. It is nevertheless worth to investigate the seismic risk in the areas of low seismicity and moderate/high vulnerability of the buildings stock. All the maps in Figures 4 to 7 are fully reported in the layouts of Annex 1 of this report. The maps represent the seismic hazard and vulnerability of the building stock in Europe.

Figure 5. Percentage of dwellings in buildings designed without provisions for earthquake resistance and with moderate level seismic code, © EuroGeographics for the administrative boundaries

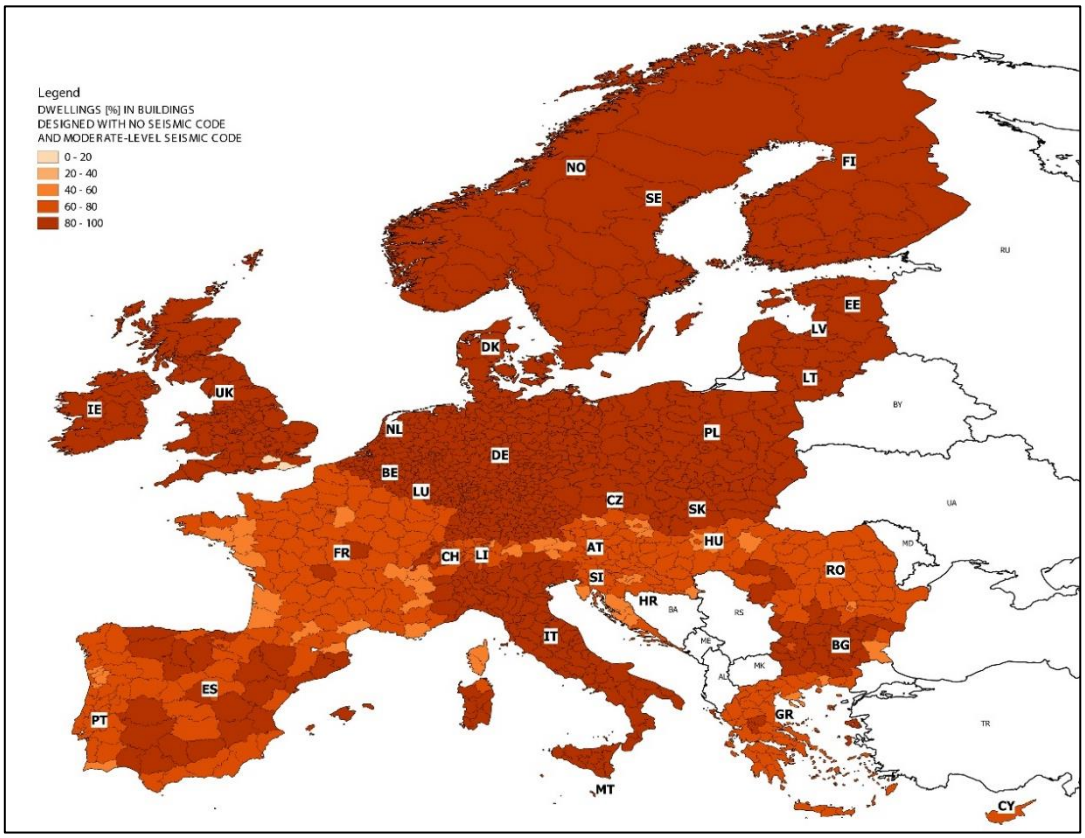


Figure 6. Reference peak ground acceleration (g) for the reference return period of seismic action for the no-collapse requirement in Eurocode 8

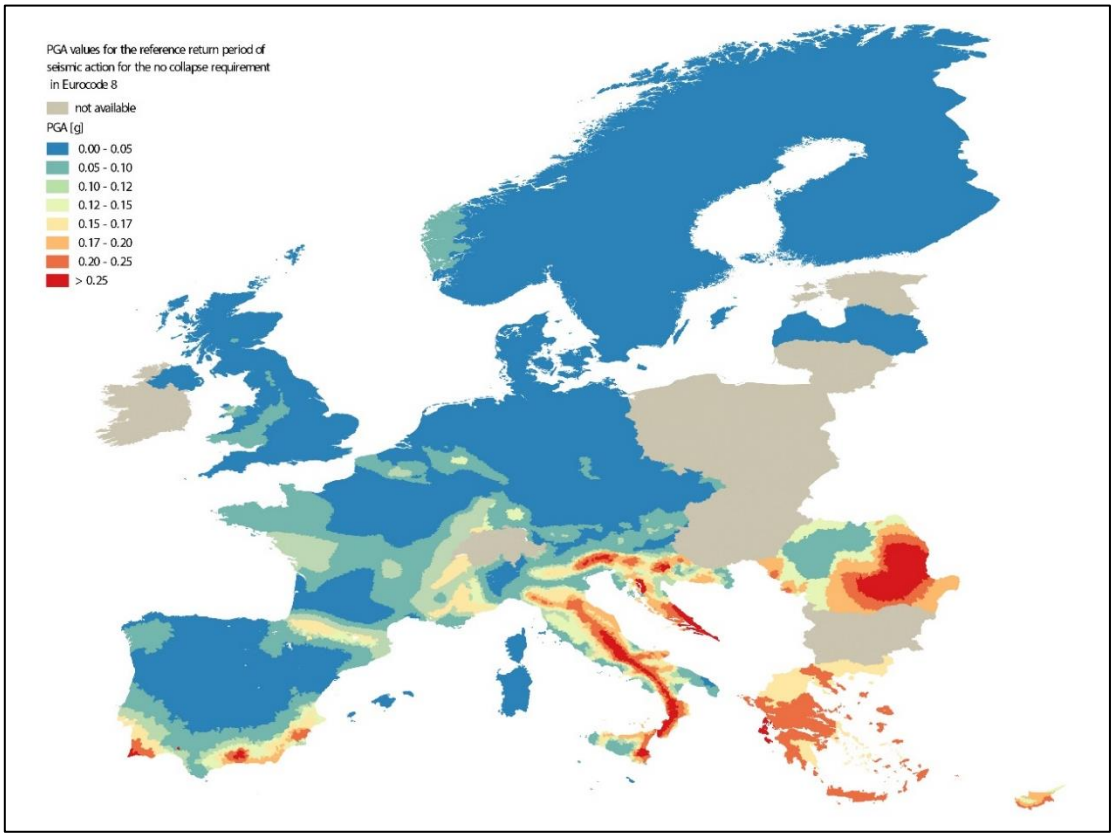
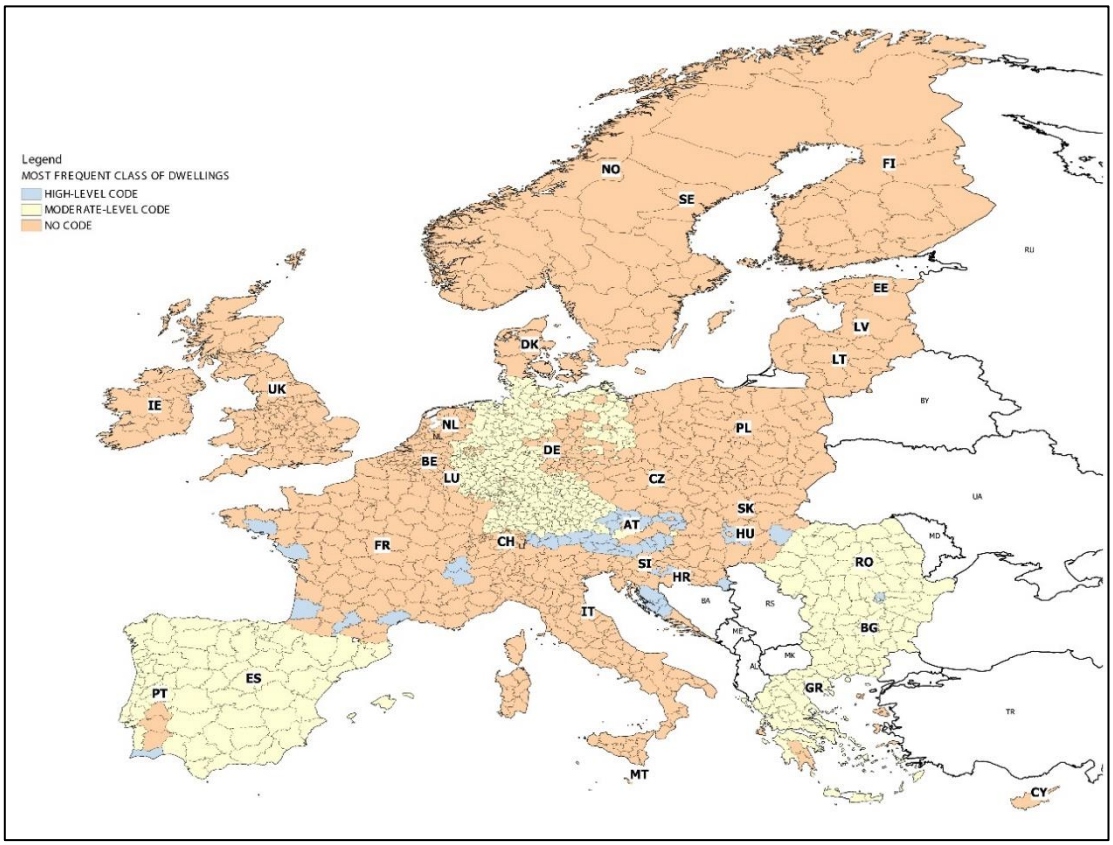
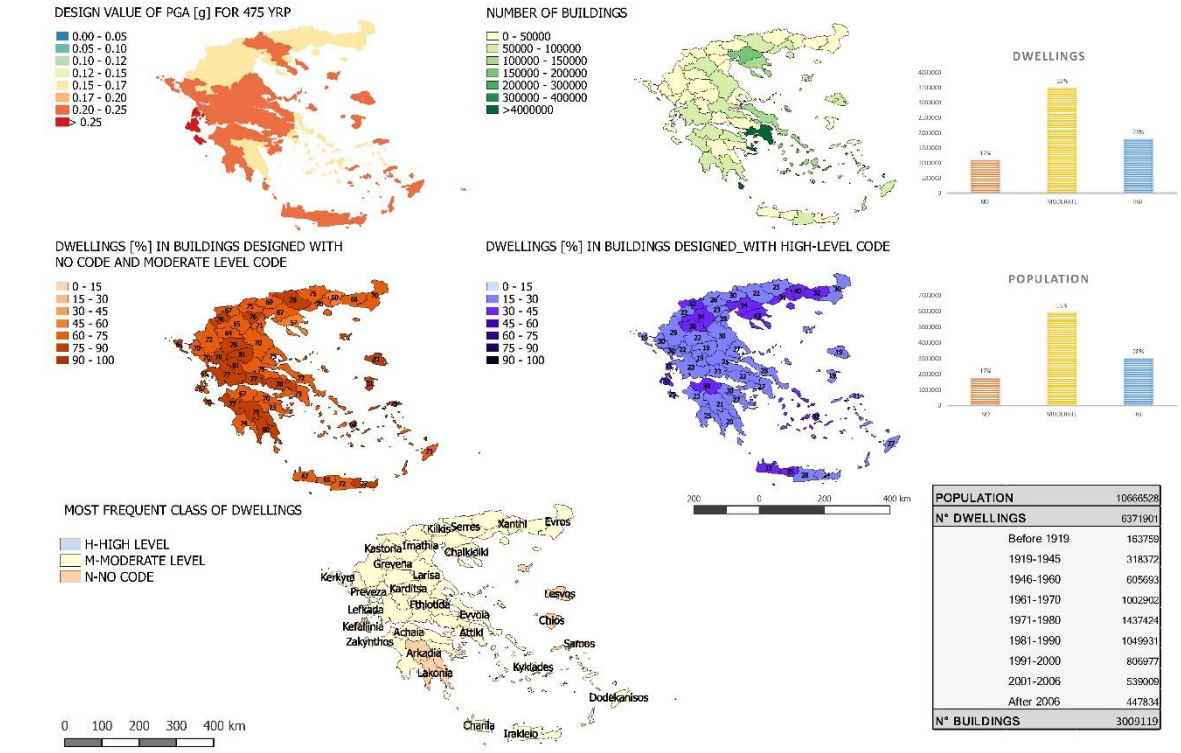


Figure 7. Most frequent vulnerability class of dwellings within the building stock across the EU countries, © EuroGeographics for the administrative boundaries



All the processed data described here are also summarised in a portfolio that includes maps and graphs for each country in order to provide more detailed information which is not clear at larger scales. Figure 8 shows an example of the layout of the portfolio developed in the current study for 38 countries, which is reported in Annex 2.The layout contains: a graph showing the number and percentage of dwellings in the three vulnerability classes and the number and percentage of persons living in dwellings of each class, a table including the number of dwellings by period of construction, the total population and the total number of buildings, and five maps regarding: the reference PGA value, the number of buildings, the percentage of dwellings in buildings designed without provisions for earthquake resistance and with moderate-level code, the percentage of dwellings in buildings designed with high-level code and the most frequent vulnerability class of dwellings. The maps present the PGA values at a LAU2 level and the remaining information at a NUTS3 level. The portfolio facilitates the understanding of the current conditions of the building stock in the seismic risk assessment perspective and, hence, may support decision-making processes.

Figure 8. Layout of the portfolio of hazard, exposure and vulnerability of residential buildings for Greece, © EuroGeographics for the administrative boundaries



3 Conclusions

The collection, analysis and dissemination of data relevant to the reduction of losses is strongly supported by the European policies for resilience against natural disasters. Inventories of buildings are an essential component of every vulnerability assessment. They allow overviewing the conditions of the building stock in a region, provide scenarios, and, hence, are a tool for supporting decision making on seismic risk. In this study, a homogeneous database of the building stock in 30 European countries (the 28 Member States of the European Union plus Norway and Switzerland) was developed. To this aim, data was collected from the Eurostat Census Hub, namely the number of dwellings by period of construction of the building and population. Eurostat Census Hub provides data from the 2011 national housing census in a common harmonised format, according to a consistent methodology, across the 30 countries at a NUTS3 level.

A methodology was developed to infer the number of buildings at a NUTS3 level from the number of dwellings, considering the degree of urbanisation. The methodology was validated against the available data on the number of buildings in six countries in south and central Europe.

Moreover, the evolution of building codes was reviewed, with the goal of classifying the dwellings in three classes of seismic vulnerability, based on the seismic design code in force in each country at the time of the building construction. This classification may be further refined after a deeper analysis of the seismic design codes and their requirements in the different countries and periods of construction.

The developed database contains the following information for each country: number of dwellings, number of dwellings by period of construction, percentage of dwellings in each vulnerability class at a NUTS3 level, degree of urbanisation class, the surface area and the reference value of PGA obtained in the National Annexes of Eurocode 8 at a LAU2 level. All the sources of data used for the whole methodology are consistent and compatible.

All entries in the database are georeferenced, therefore it is possible to facilitate the analysis by generating maps with a compact spatial representation of the data and with high visual impact. Furthermore, to improve the accessibility and readability of data and results, a portfolio containing a layout for every country considered in this study, has been provided.

Results confirm that most of the dwellings across all European countries are located in old buildings that are reaching or have already exceeded their conventional service life. In the seismic-prone regions of Europe, the majority of buildings was designed without provisions for earthquake resistance or with moderate-level seismic codes. They are therefore vulnerable to earthquakes, may have a significant impact on a high percentage of the population and need interventions that will reduce their vulnerability and consequently the risk of socio-economic losses.

The inventory contains useful information for the assessment of the seismic risk across Europe and of socio-economic losses in case of seismic events, but also for risk studies regarding other natural hazards that may impact the built environment and for the assessment of the energy efficiency of buildings. The database may be used for speculative studies of the areas where potential retrofit of buildings would be beneficial, and additionally, it can be used to calibrate risk-based seismic codes for the design of new buildings and for prioritising interventions for risk reduction. It represents, therefore, a useful tool that provides support for the definition and implementation of territorial policies and intervention strategies that take into account the peculiarities at regional level and aim at the prevention and management of risk posed to the European building stock by natural disasters.

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List of abbreviations and definitions

BLD	Buildings
DEGURBA	Degree of Urbanisation
DWG	Dwellings
EFTA	European Free Trade Association
EU	European Union
LAU	Local Administrative Units
NERA	Network of European Research Infrastructures for Earthquake Risk Assessment and Mitigation
NUTS	Nomenclature of Territorial Units for Statistics
PAGER	Prompt Assessment of Global Earthquakes for Response system
PGA	Peak ground acceleration
VC	Vulnerability Class

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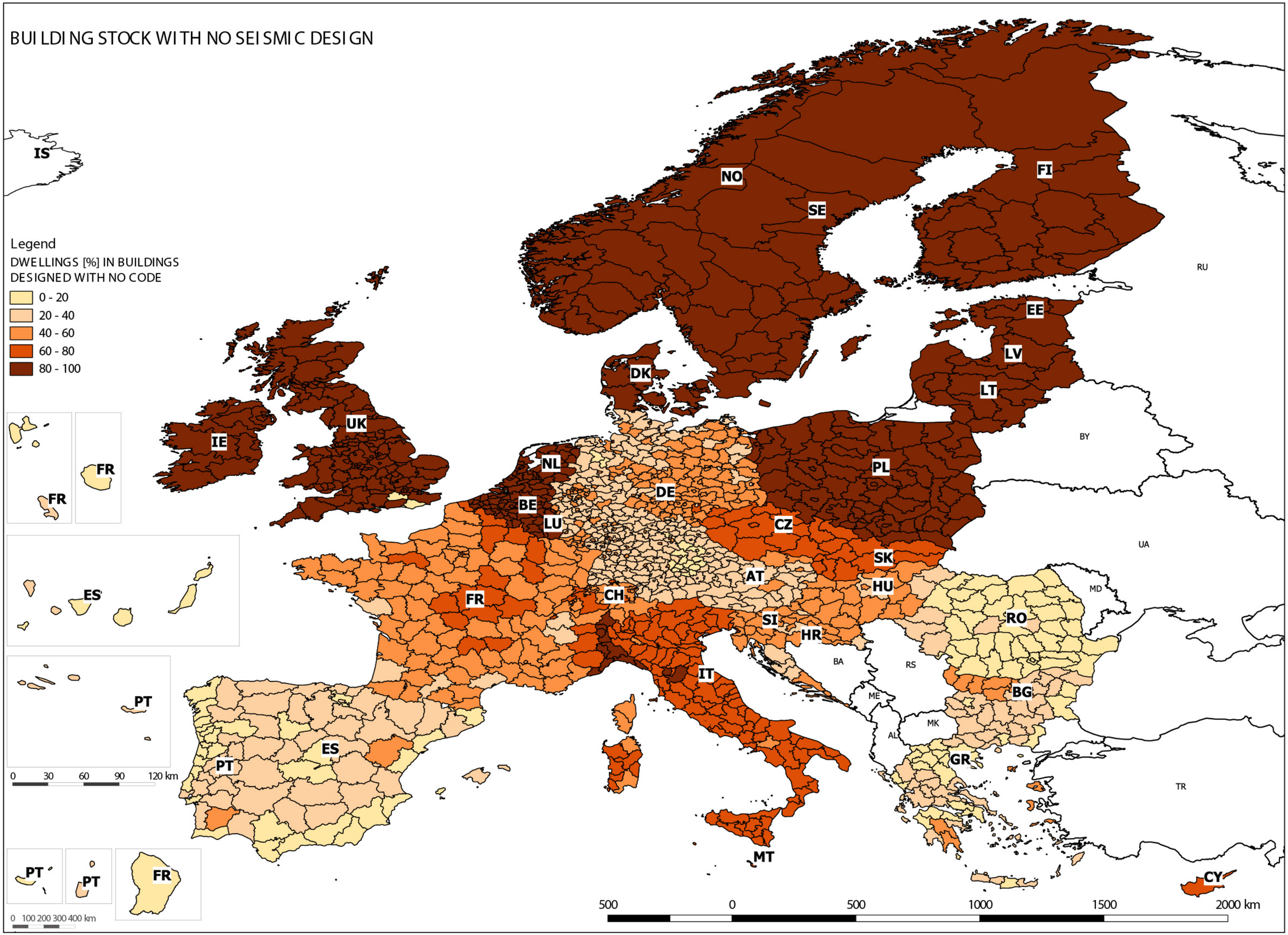
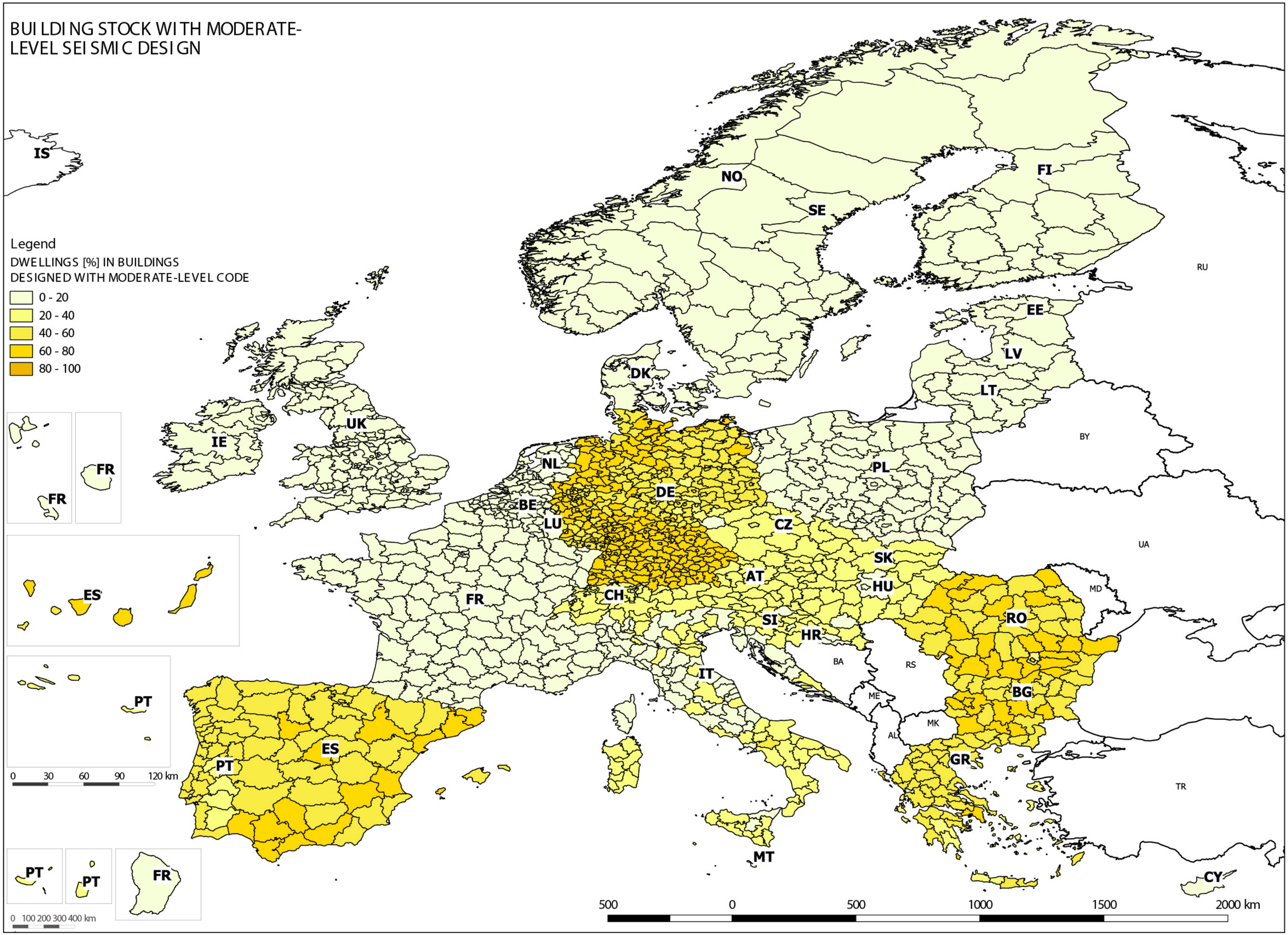
Annex 1. Maps of seismic hazard and vulnerability of residential buildings in Europe

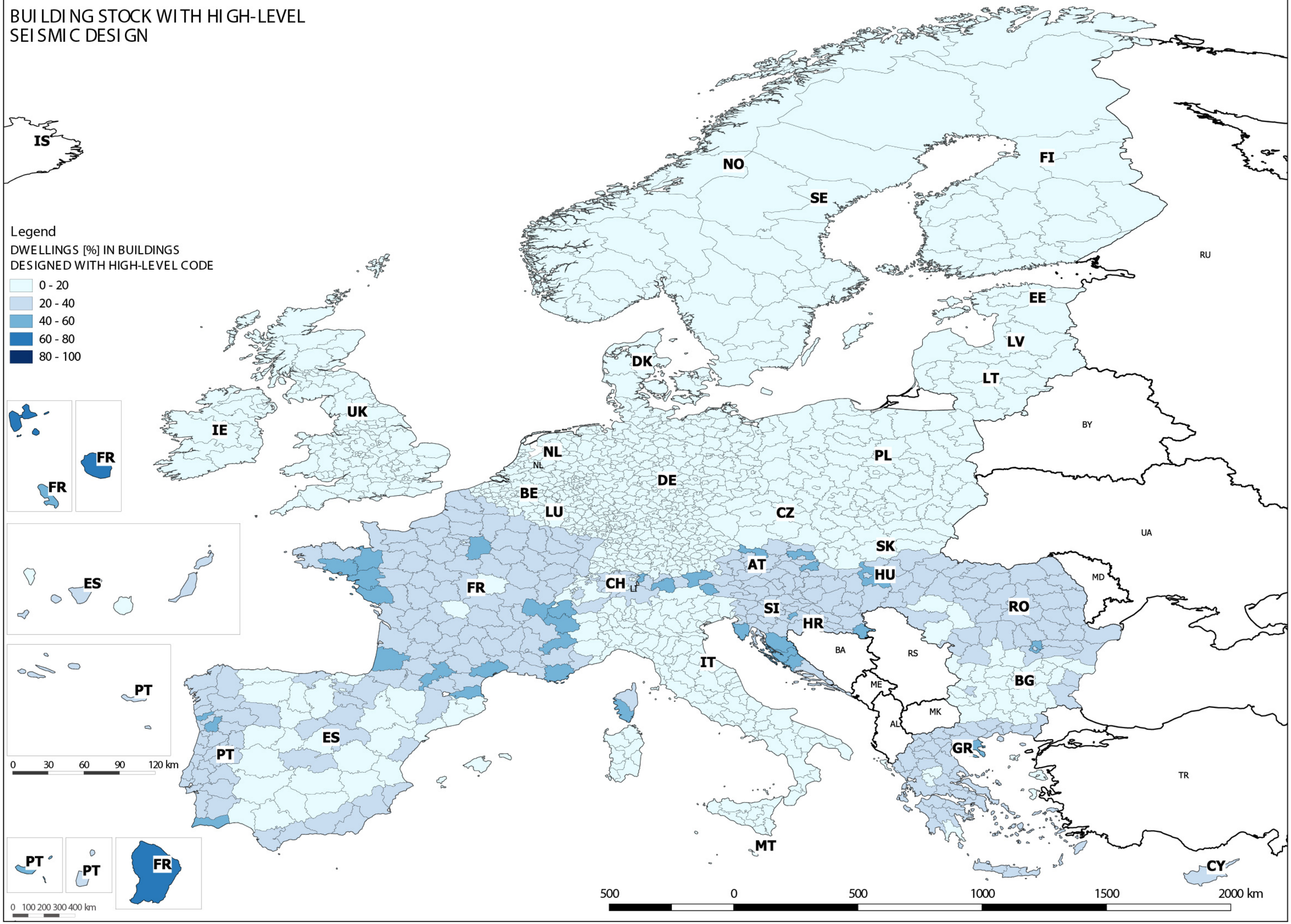
BUILDING STOCK WITH NO SEISMIC DESIGN



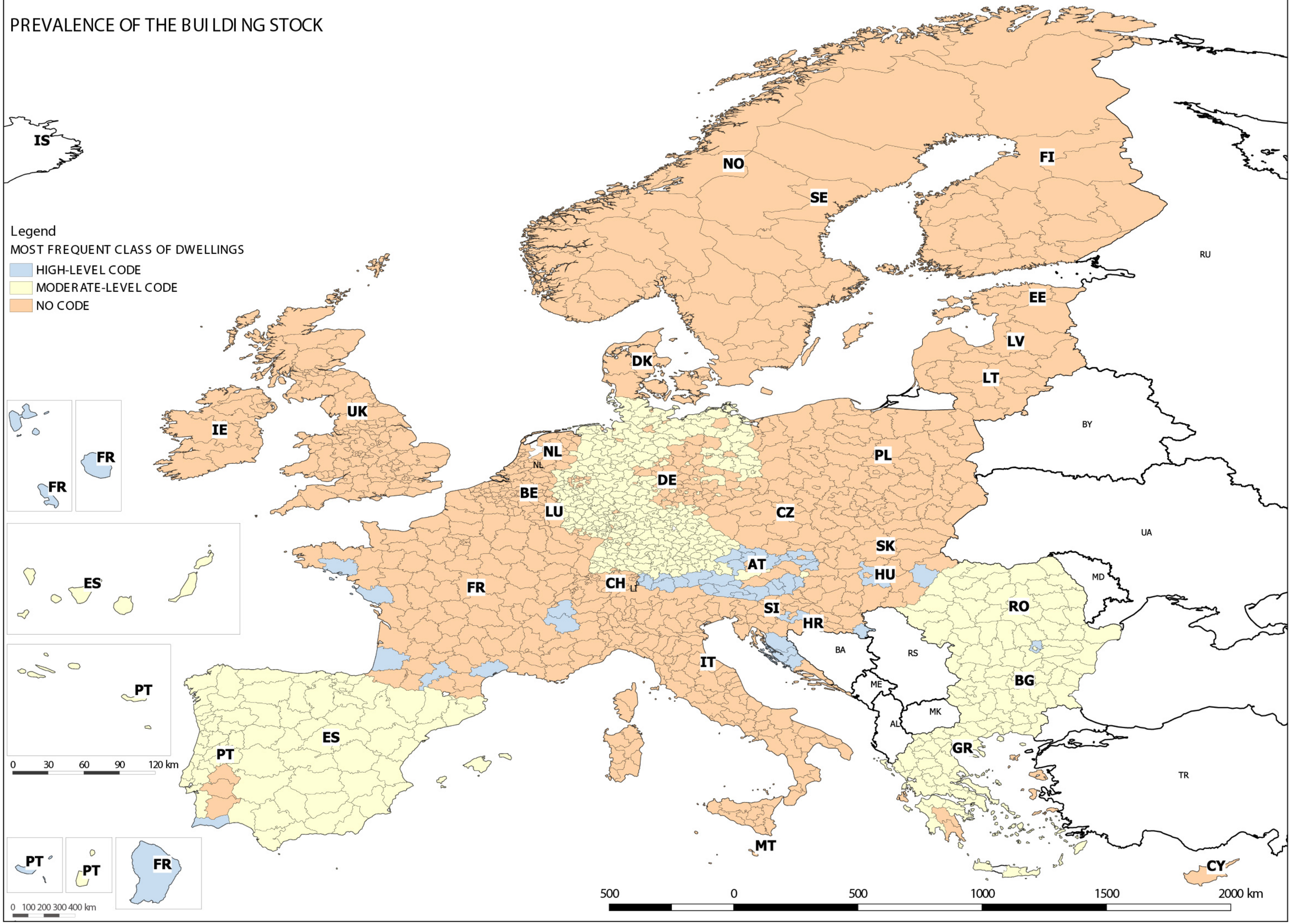
BUILDING STOCK WITH MODERATE-LEVEL SEISMIC DESIGN



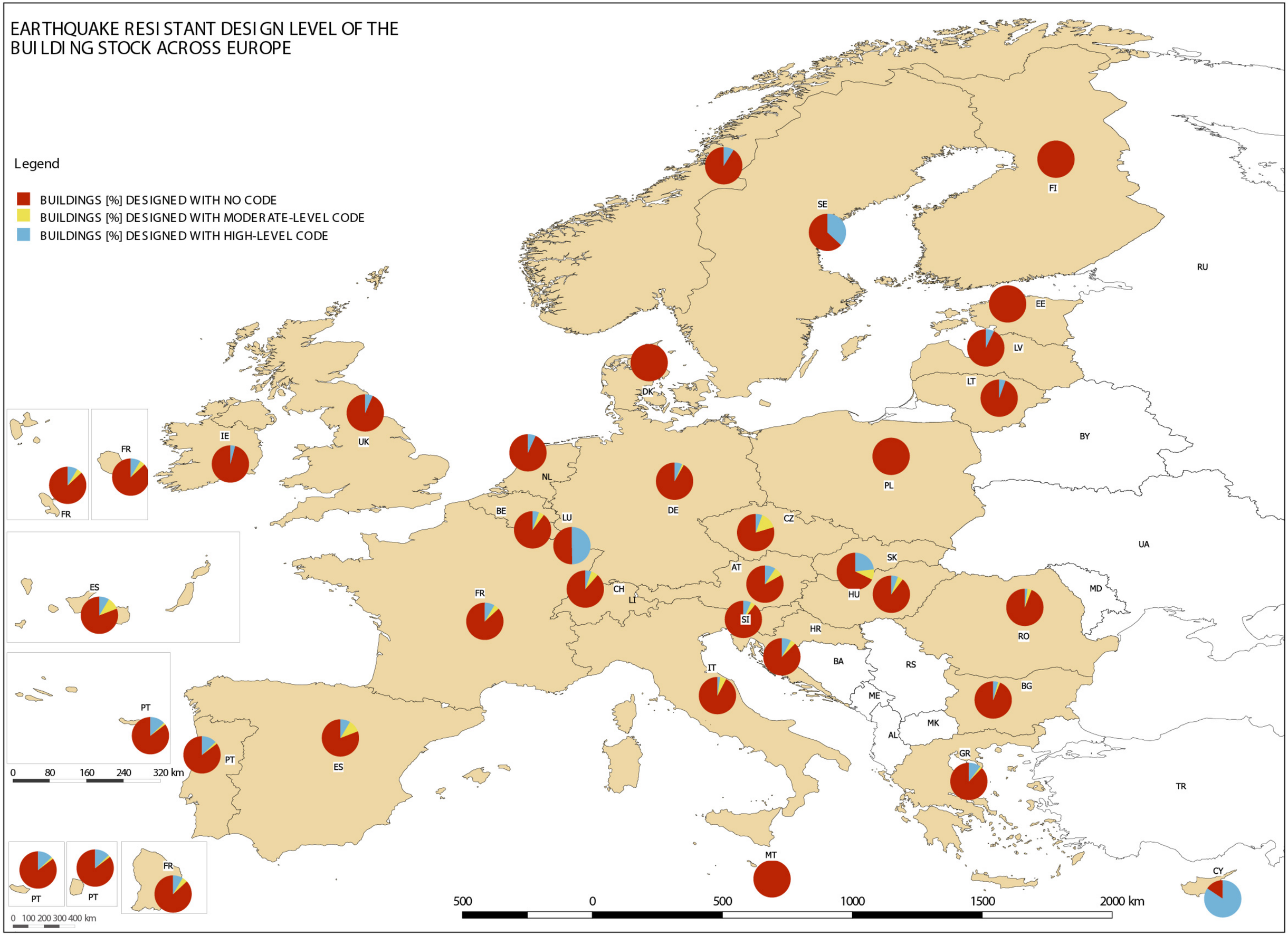
BUILDING STOCK WITH HIGH-LEVEL SEISMIC DESIGN



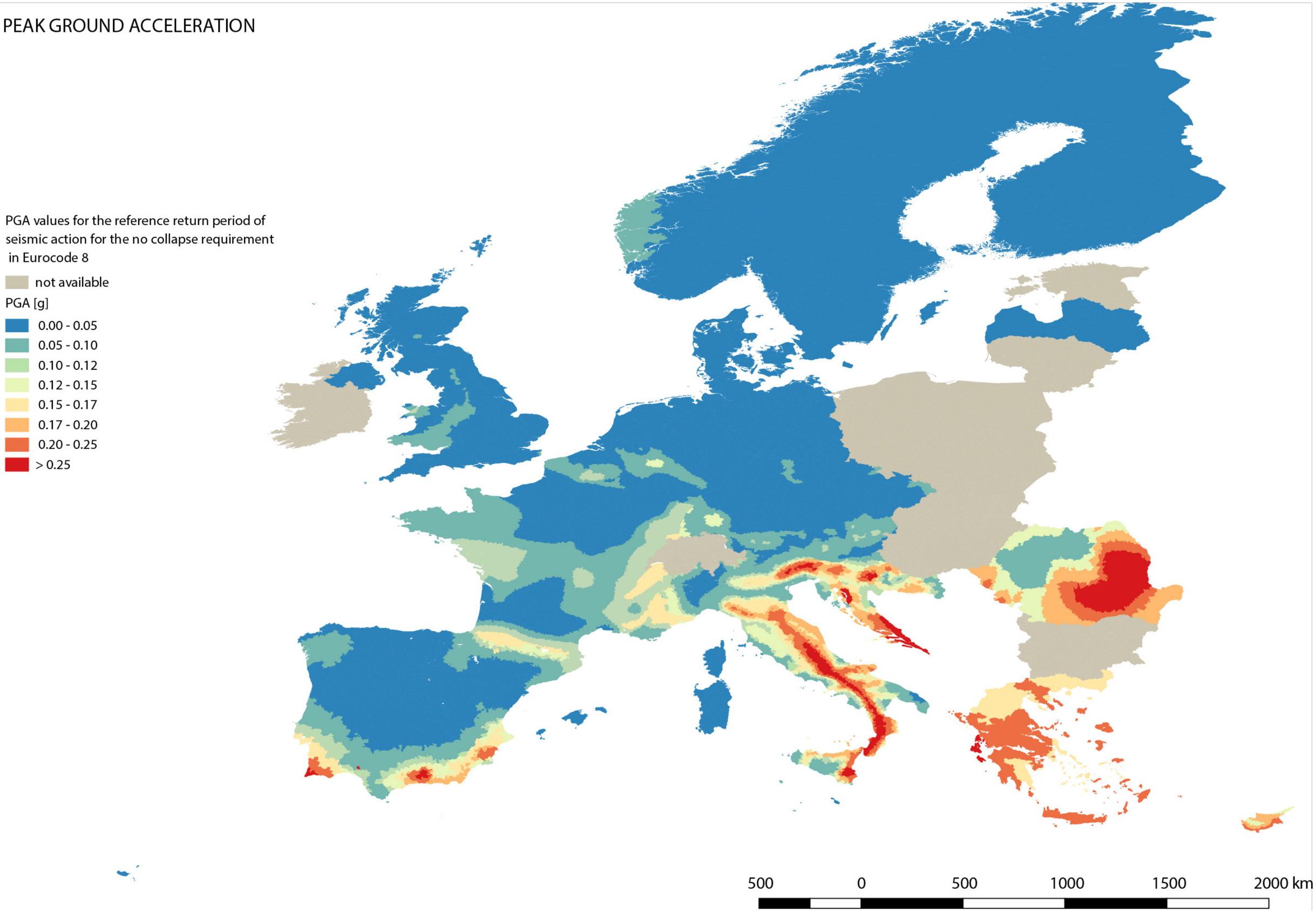
PREVALENCE OF THE BUILDING STOCK



EARTHQUAKE RESISTANT DESIGN LEVEL OF THE BUILDING STOCK ACROSS EUROPE

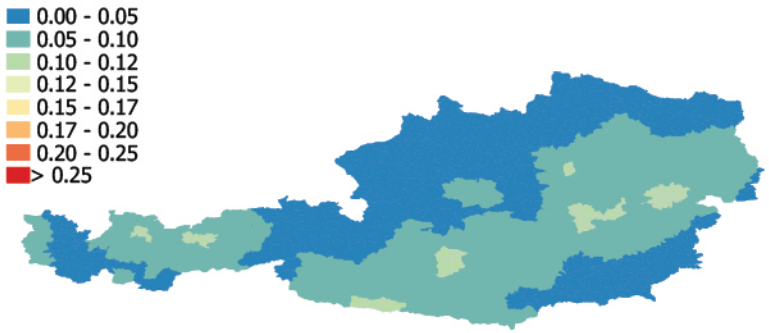


PEAK GROUND ACCELERATION

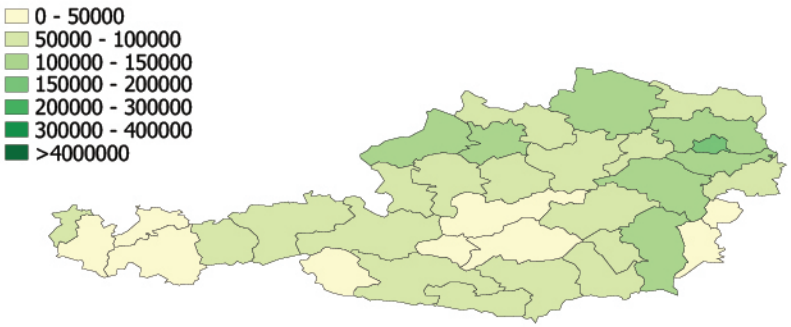


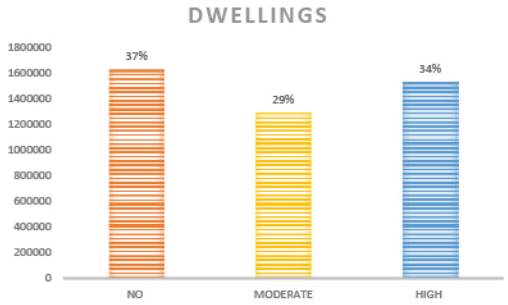
Annex 2. Portfolio of hazard, exposure and vulnerability of residential buildings for countries of Europe

DESIGN VALUE OF PGA [g] FOR 475 YRP

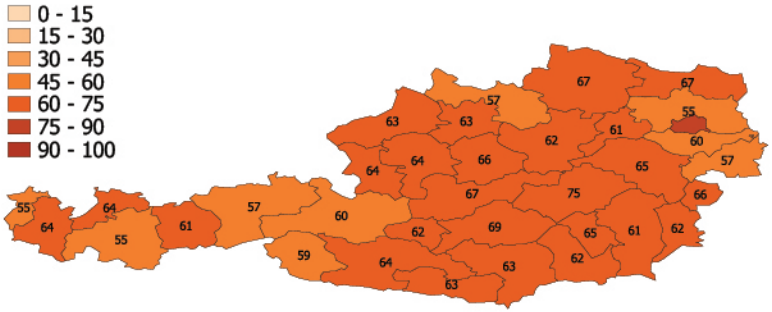


NUMBER OF BUILDINGS

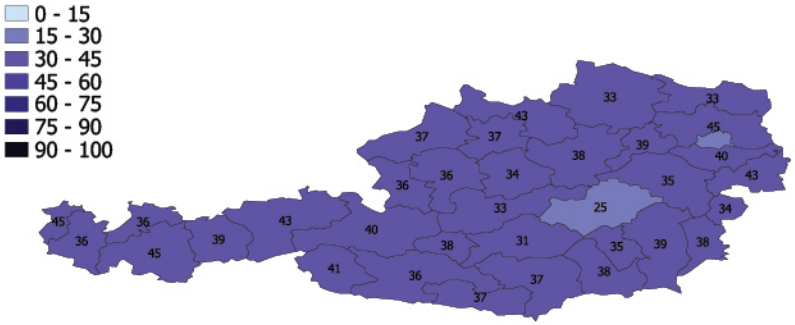


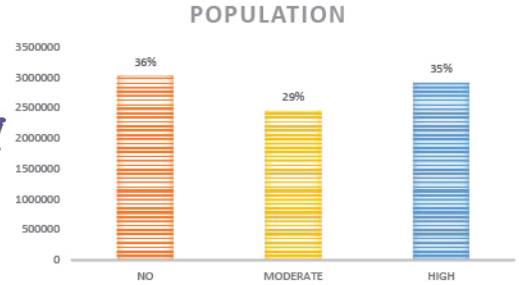


DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE



DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE





MOST FREQUENT CLASS OF DWELLINGS

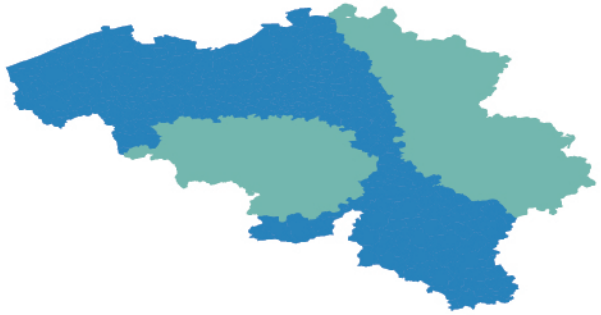
100 0 100 200 km

POPULATION	8401940
N° DWELLINGS	4441408
Before 1919	791264
1919-1945	341264
1946-1960	492249
1961-1970	624730
1971-1980	663001
1981-1990	522565
1991-2000	487725
2001-2006	256931
After 2006	261679
N° BUILDINGS	2572887

AUSTRIA

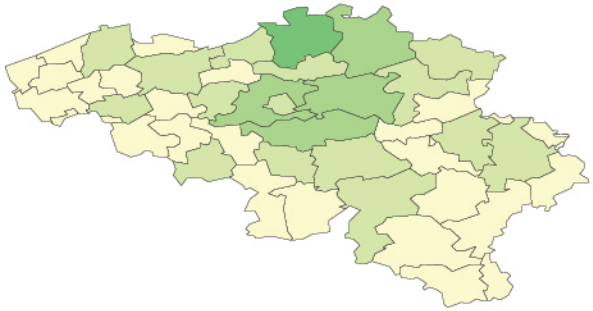
DESIGN VALUE OF PGA [g] FOR 475 YRP

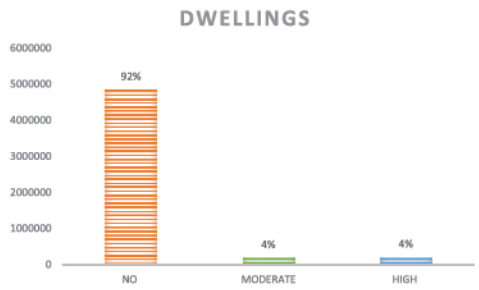
- 0.00 - 0.05
- 0.05 - 0.10
- 0.10 - 0.12
- 0.12 - 0.15
- 0.15 - 0.17
- 0.17 - 0.20
- 0.20 - 0.25
- > 0.25



NUMBER OF BUILDINGS

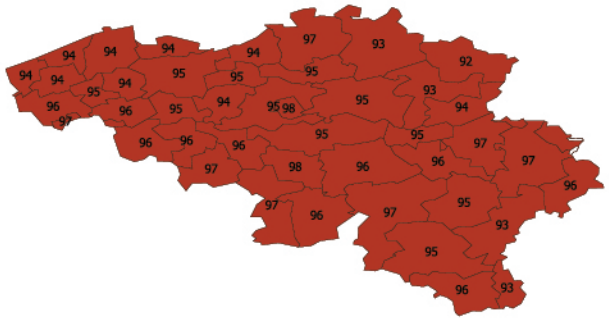
- 0 - 50000
- 50000 - 100000
- 100000 - 150000
- 150000 - 200000
- 200000 - 300000
- 300000 - 400000
- >4000000





DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100



DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE

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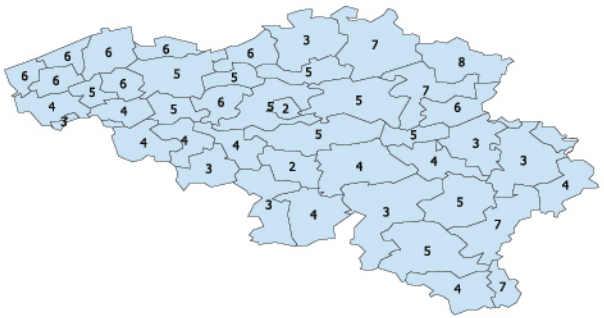
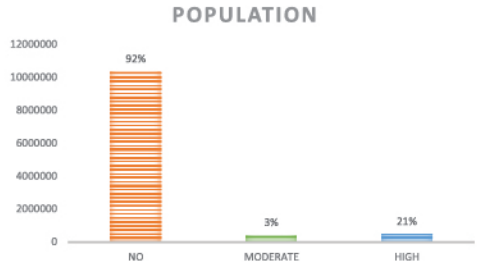
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100

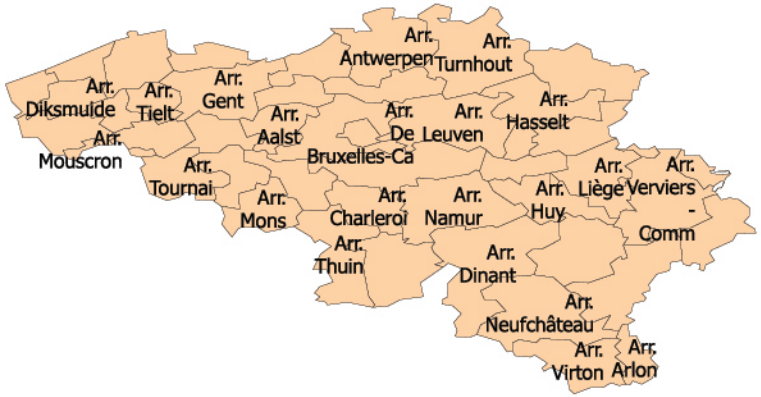




60 0 60 120 km

MOST FREQUENT CLASS OF DWELLINGS

- H-HIGH LEVEL
- M-MODERATE LEVEL
- N-NO CODE



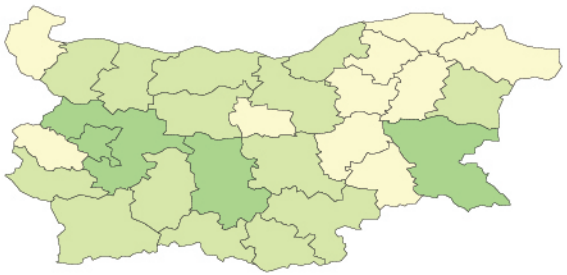
0 30 60 90 120 km

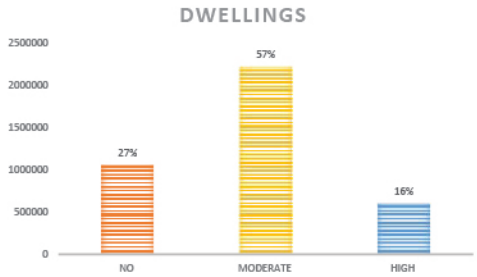
POPULATION	11289853
N° DWELLINGS	5305584
Before 1919	1254727
1919-1945	715491
1946-1960	640034
1961-1970	643584
1971-1980	742173
1981-1990	391726
1991-2000	483773
2001-2006	205384
After 2006	228692
N° BUILDINGS	2466521

BELGIUM

NUMBER OF BUILDINGS

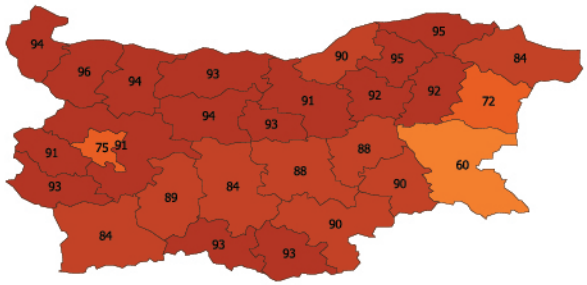
- 0 - 50000
- 50000 - 100000
- 100000 - 150000
- 150000 - 200000
- 200000 - 300000
- 300000 - 400000
- >4000000





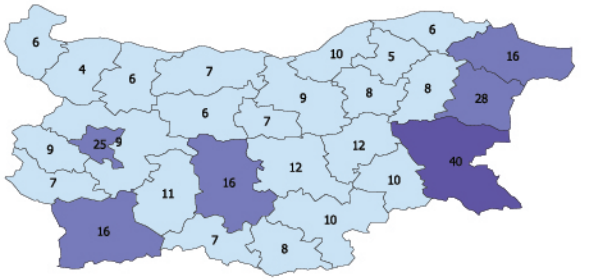
DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE

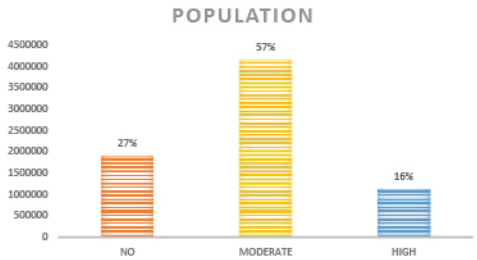
- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100



DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100





100 0 100 200 km

MOST FREQUENT CLASS OF DWELLINGS

- H-HIGH LEVEL
- M-MODERATE LEVEL
- N-NO CODE

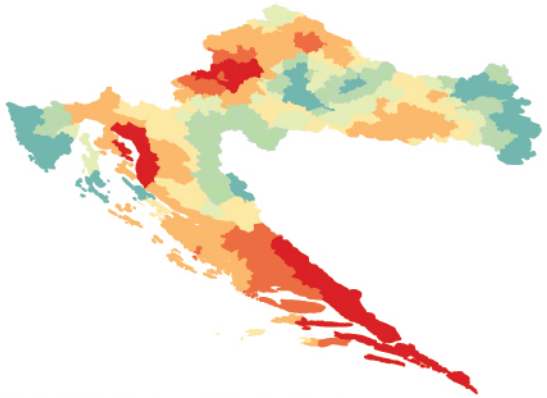
0 60 120 180 240 km

POPULATION	7196537
N° DWELLINGS	3882810
Before 1919	58136
1919-1945	347773
1946-1960	655278
1961-1970	665865
1971-1980	829343
1981-1990	724129
1991-2000	265414
2001-2006	95009
After 2006	239787
Not Stated	2076
N° BUILDINGS	1971855

BULGARIA

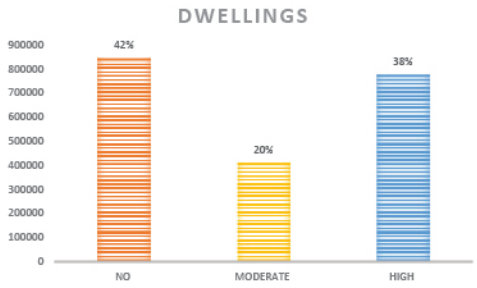
DESIGN VALUE OF PGA [g] FOR 475 YRP

- 0.00 - 0.05
- 0.05 - 0.10
- 0.10 - 0.12
- 0.12 - 0.15
- 0.15 - 0.17
- 0.17 - 0.20
- 0.20 - 0.25
- > 0.25



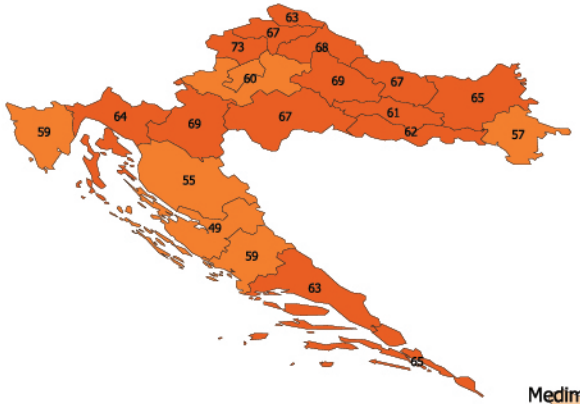
NUMBER OF BUILDINGS

- 0 - 50000
- 50000 - 100000
- 100000 - 150000
- 150000 - 200000
- 200000 - 300000
- 300000 - 400000
- >4000000

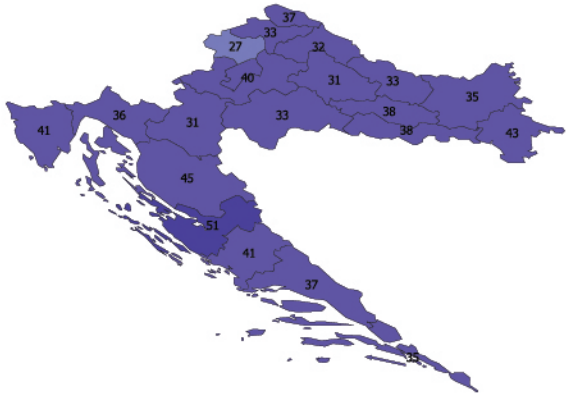


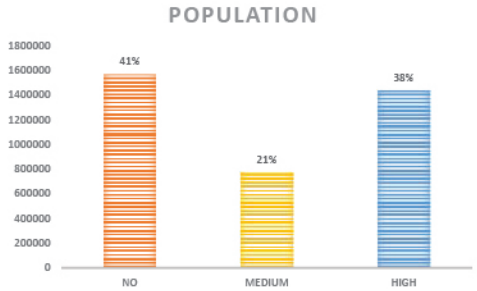
DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100



DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE





MOST FREQUENT CLASS OF DWELLINGS

- H-HIGH LEVEL
- M-MODERATE LEVEL
- N-NO CODE

0 60 120 180 240 km

100 0 100 200 km

POPULATION	3784722
N° DWELLINGS	2246910
Before 1919	181522
1919-1945	123046
1946-1960	188278
1961-1970	354849
1971-1980	412858
1981-1990	335264
1991-2000	195871
2001-2006	112842
After 2006	133738
Not Stated	19294
N° BUILDINGS	1256197

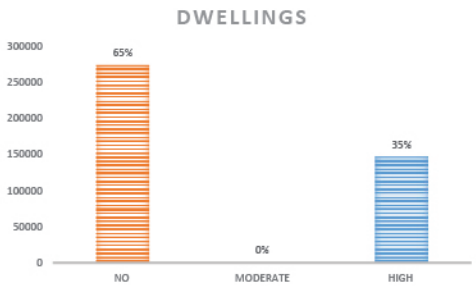
CROATIA

DESIGN VALUE OF PGA [g] FOR 475 YRP

- 0.00 - 0.05
- 0.05 - 0.10
- 0.10 - 0.12
- 0.12 - 0.15
- 0.15 - 0.17
- 0.17 - 0.20
- 0.20 - 0.25
- > 0.25

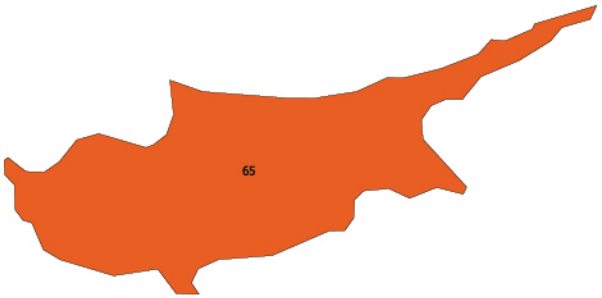
NUMBER OF BUILDINGS

- 0 - 50000
- 50000 - 100000
- 100000 - 150000
- 150000 - 200000
- 200000 - 300000
- 300000 - 400000
- >4000000



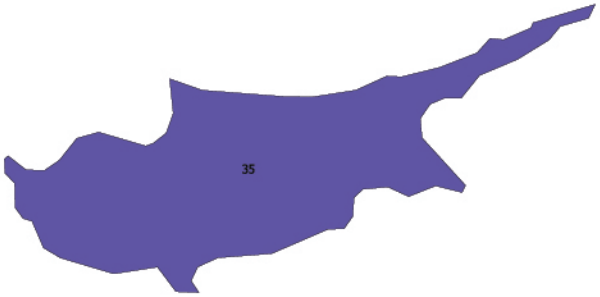
DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE

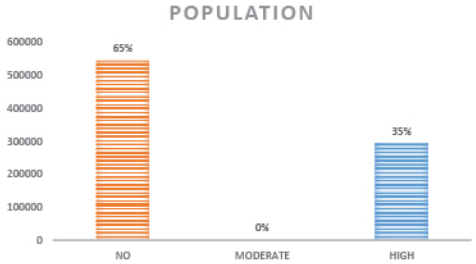
- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100



DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100

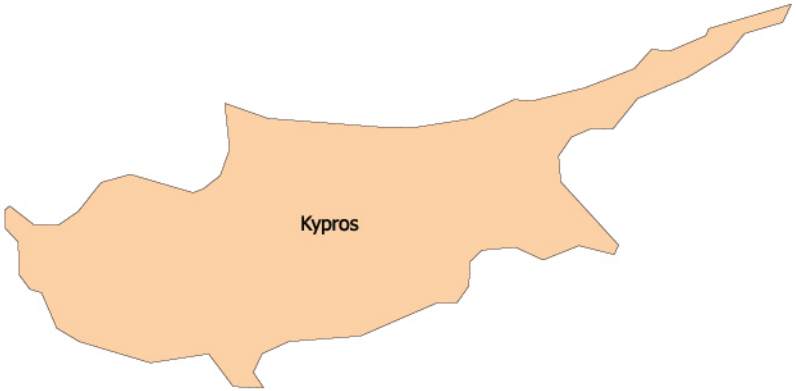




40 0 40 80 km

MOST FREQUENT CLASS OF DWELLINGS

- H-HIGH LEVEL
- M-MODERATE LEVEL
- N-NO CODE



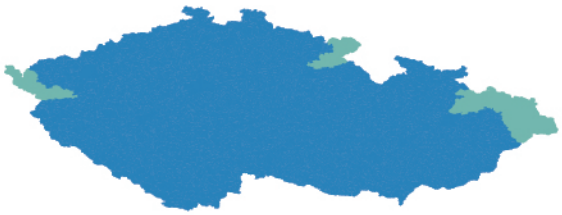
0 20 40 60 80 km

POPULATION	840407
N° DWELLINGS	431059
Before 1919	3968
1919-1945	9129
1946-1960	20343
1961-1970	24255
1971-1980	61247
1981-1990	85503
1991-2000	70094
2001-2006	54897
After 2006	92117
Not Stated	9506
N° BUILDINGS	179848

CYPRUS

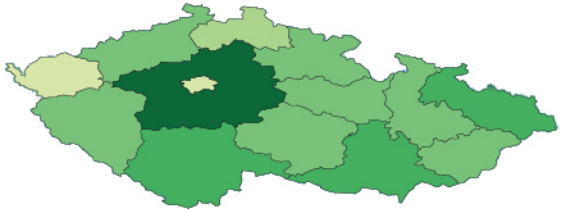
DESIGN VALUE OF PGA [g] FOR 475 YRP

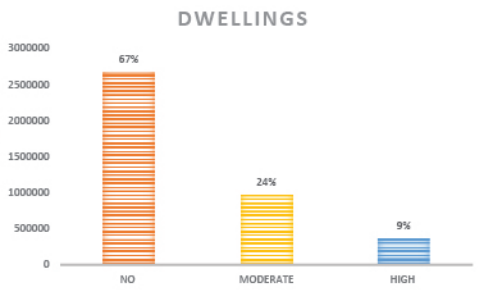
- 0.00 - 0.05
- 0.05 - 0.10
- 0.10 - 0.12
- 0.12 - 0.15
- 0.15 - 0.17
- 0.17 - 0.20
- 0.20 - 0.25
- > 0.25



NUMBER OF BUILDINGS

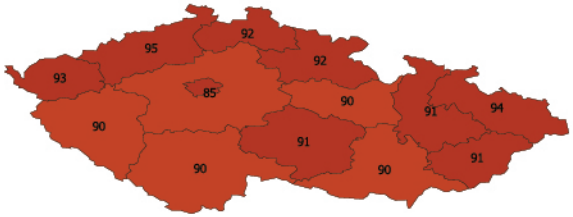
- 0 - 50000
- 50000 - 100000
- 100000 - 150000
- 150000 - 200000
- 200000 - 300000
- 300000 - 400000
- >4000000





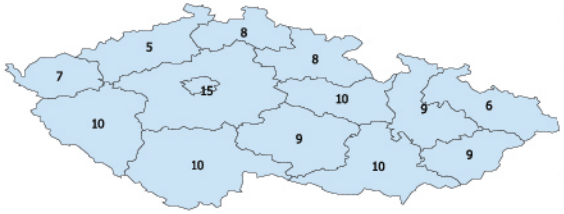
DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE

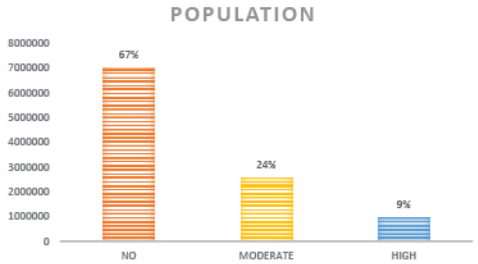
- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100



DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100





100 0 100 200 km

MOST FREQUENT CLASS OF DWELLINGS

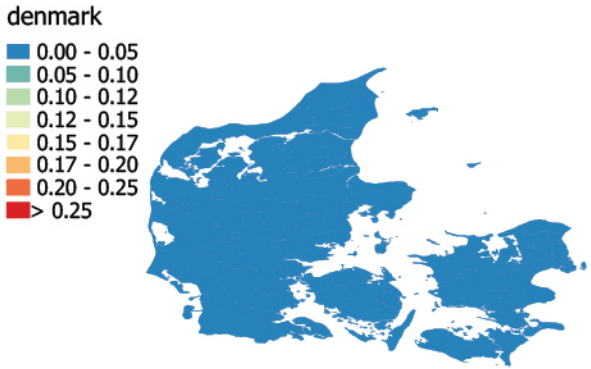
- H-HIGH LEVEL
- M-MODERATE LEVEL
- N-NO CODE

0 60 120 180 240 km

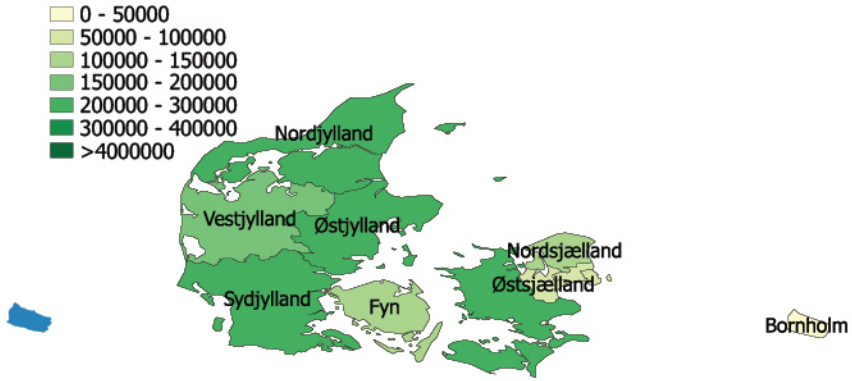
POPULATION	10552361
N° DWELLINGS	4756572
Before 1919	374654
1919-1945	529758
1946-1960	364925
1961-1970	577688
1971-1980	822621
1981-1990	615104
1991-2000	359204
2001-2006	158258
After 2006	206075
Not Stated	748285
N° BUILDINGS	2721958

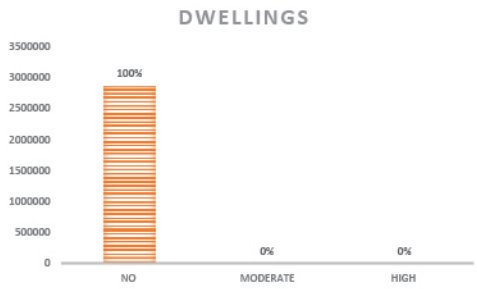
CZECH REPUBLIC

DESIGN VALUE OF PGA [g] FOR 475 YRP

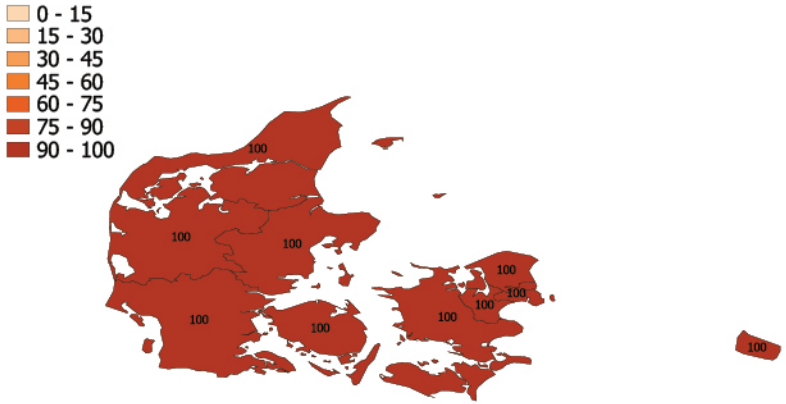


NUMBER OF BUILDINGS

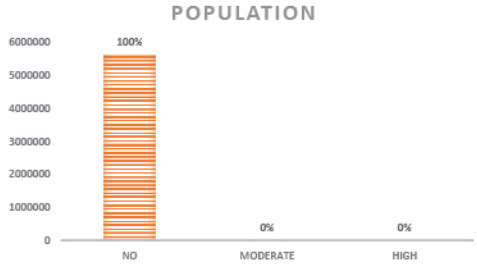




DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE



DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE



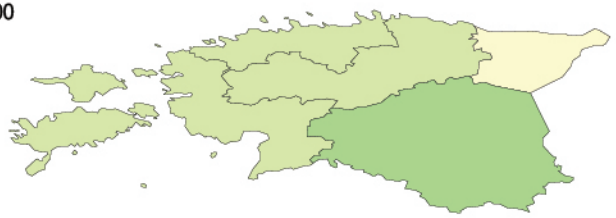
MOST FREQUENT CLASS OF DWELLINGS

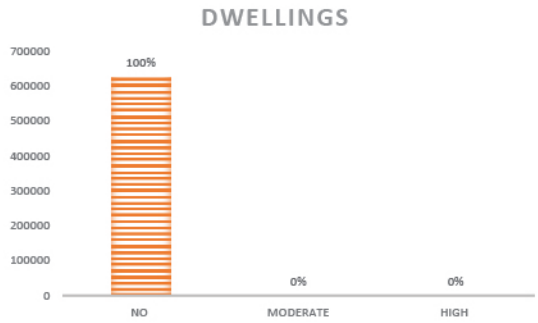
POPULATION	5647783
N° DWELLINGS	2873365
Before 1919	524694
1919-1945	456245
1946-1960	356556
1961-1970	455384
1971-1980	469960
1981-1990	257764
1991-2000	143513
2001-2006	99909
After 2006	107787
Not stated	1553
N° BUILDINGS	1640490

DENMARK

NUMBER OF BUILDINGS

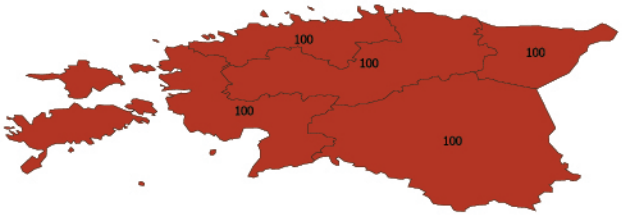
- 0 - 50000
- 50000 - 100000
- 100000 - 150000
- 150000 - 200000
- 200000 - 300000
- 300000 - 400000
- >4000000





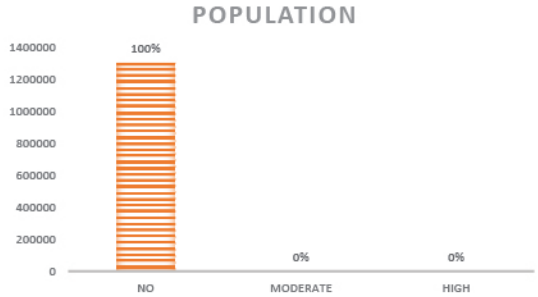
DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100



DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100



MOST FREQUENT CLASS OF DWELLINGS

- H-HIGH LEVEL
- M-MODERATE LEVEL
- N-NO CODE

0 30 60 90 120 km

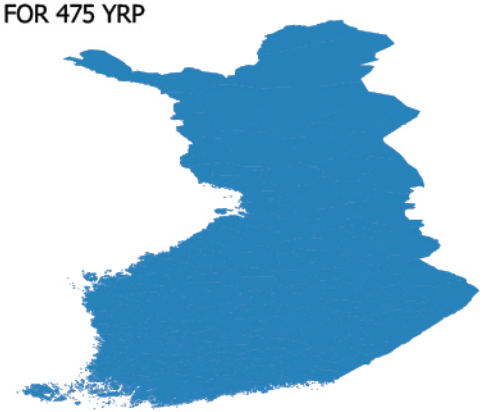
80 0 80 160 km

POPULATION	1307284
N° DWELLINGS	649746
Before 1919	39899
1919-1945	70547
1946-1960	57101
1961-1970	116654
1971-1980	132597
1981-1990	122526
1991-2000	25777
2001-2006	20033
After 2006	41320
Not stated	23292
N° BUILDINGS	339971

ESTONIA

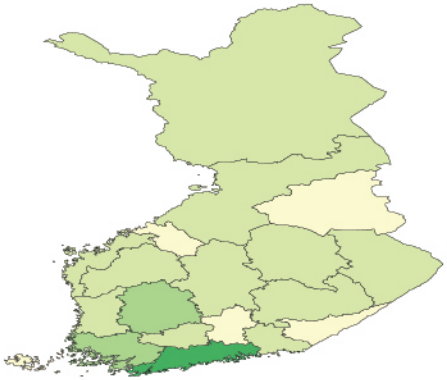
DESIGN VALUE OF PGA [g] FOR 475 YRP

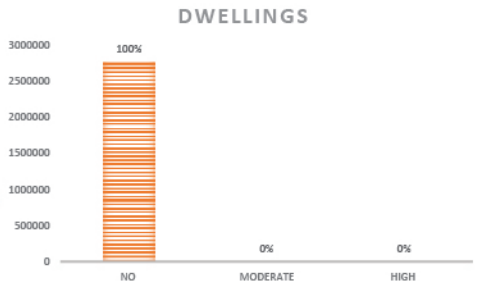
- 0.00 - 0.05
- 0.05 - 0.10
- 0.10 - 0.12
- 0.12 - 0.15
- 0.15 - 0.17
- 0.17 - 0.20
- 0.20 - 0.25
- > 0.25



NUMBER OF BUILDINGS

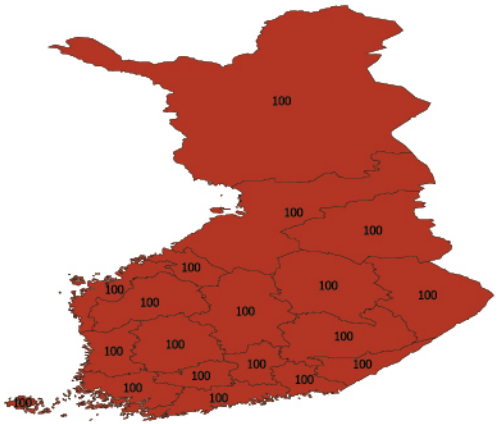
- 0 - 50000
- 50000 - 100000
- 100000 - 150000
- 150000 - 200000
- 200000 - 300000
- 300000 - 400000
- >4000000



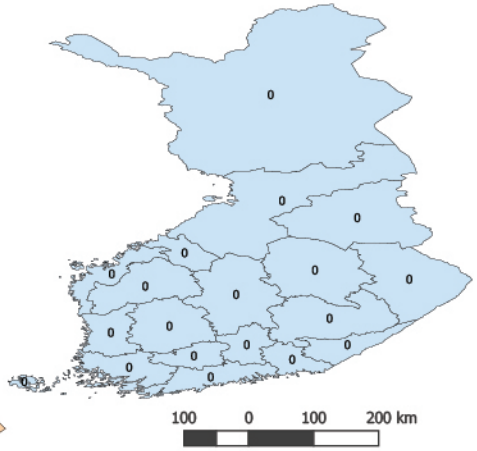


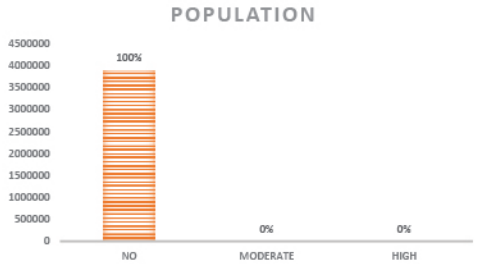
DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100



DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE





MOST FREQUENT CLASS OF DWELLINGS

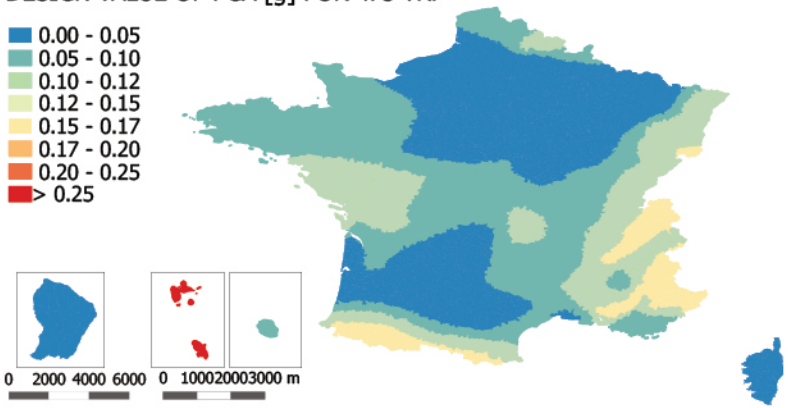
- H-HIGH LEVEL
- M-MODERATE LEVEL
- N-NO CODE

0 100 200 300 400 km

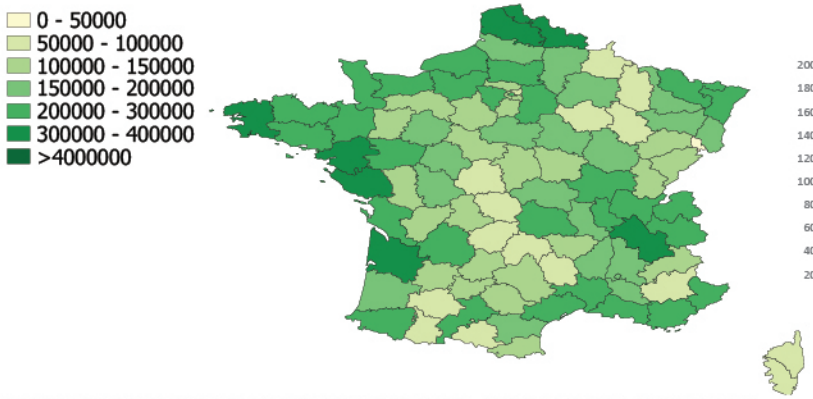
POPULATION	5487308
N° DWELLINGS	2807505
Before 1919	43020
1919-1945	226037
1946-1960	377532
1961-1970	389604
1971-1980	598793
1981-1990	514309
1991-2000	320885
2001-2006	157044
After 2006	143626
Not stated	36655
N° BUILDINGS	1431127

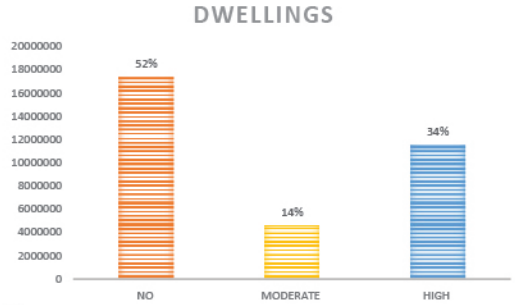
FINLAND

DESIGN VALUE OF PGA [g] FOR 475 YRP

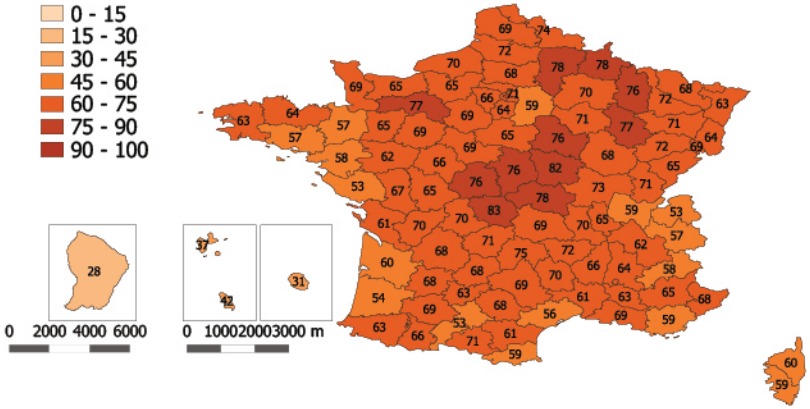


NUMBER OF BUILDINGS

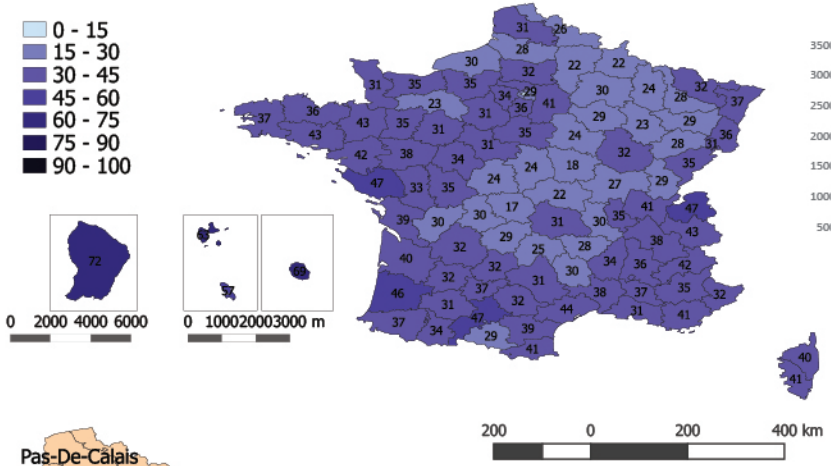


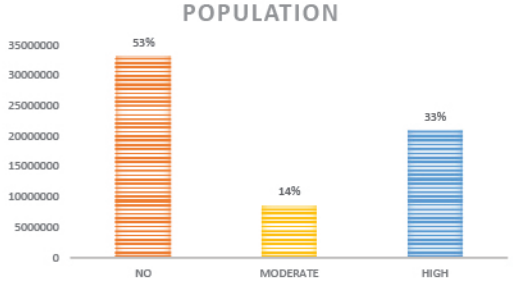


DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE

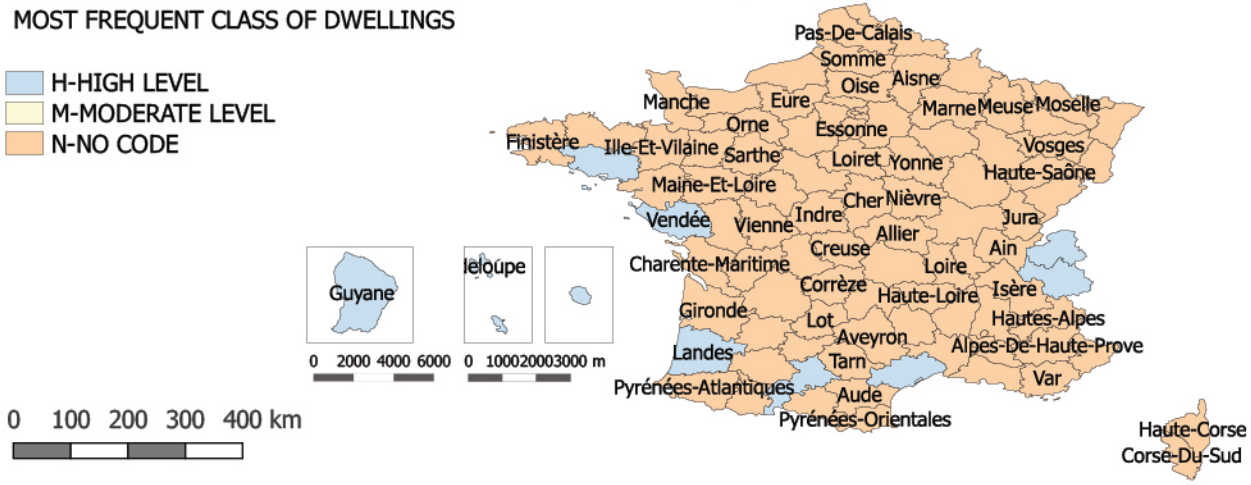


DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE





MOST FREQUENT CLASS OF DWELLINGS

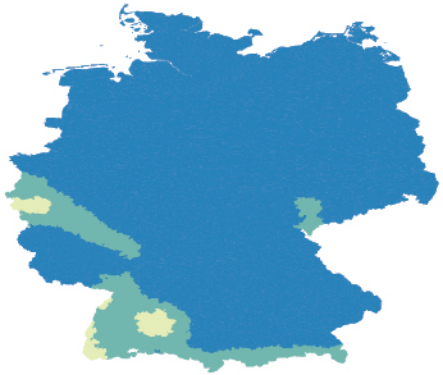


POPULATION	62765214
N° DWELLINGS	32741091
Before 1919	6164977
1919-1945	3450832
1946-1960	4587561
1961-1970	3061627
1971-1980	4489127
1981-1990	4489565
1991-2000	3188264
2001-2006	1594125
After 2006	1715010
Not stated	3
N° BUILDINGS	16991374

FRANCE

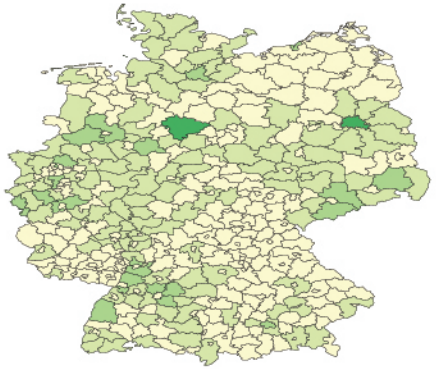
DESIGN VALUE OF PGA [g] FOR 475 YRP

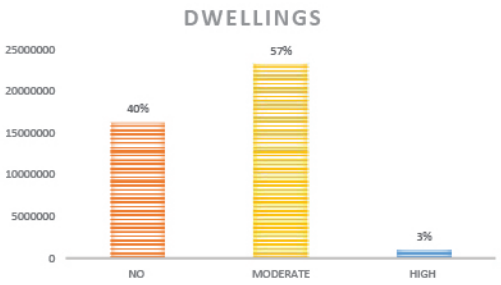
- 0.00 - 0.05
- 0.05 - 0.10
- 0.10 - 0.12
- 0.12 - 0.15
- 0.15 - 0.17
- 0.17 - 0.20
- 0.20 - 0.25
- > 0.25



NUMBER OF BUILDINGS

- 0 - 50000
- 50000 - 100000
- 100000 - 150000
- 150000 - 200000
- 200000 - 300000
- 300000 - 400000
- >4000000



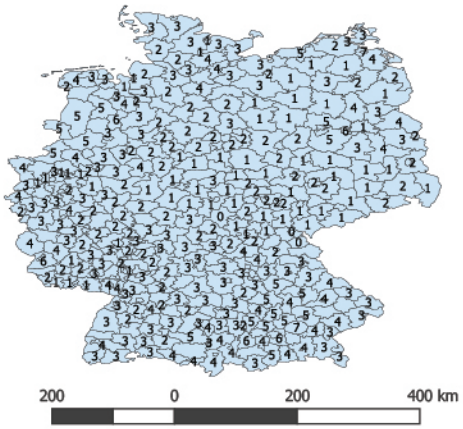


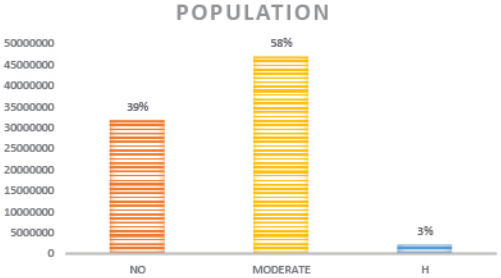
DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100

DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100





MOST FREQUENT CLASS OF DWELLINGS

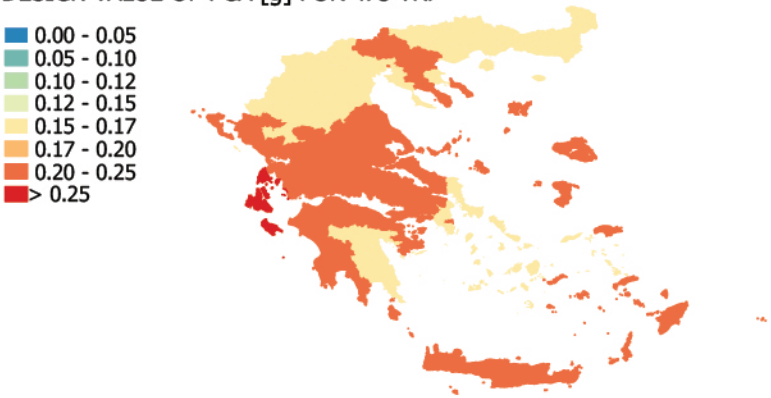
- H-HIGH LEVEL
- M-MODERATE LEVEL
- N-NO CODE

0 100 200 300 400 km

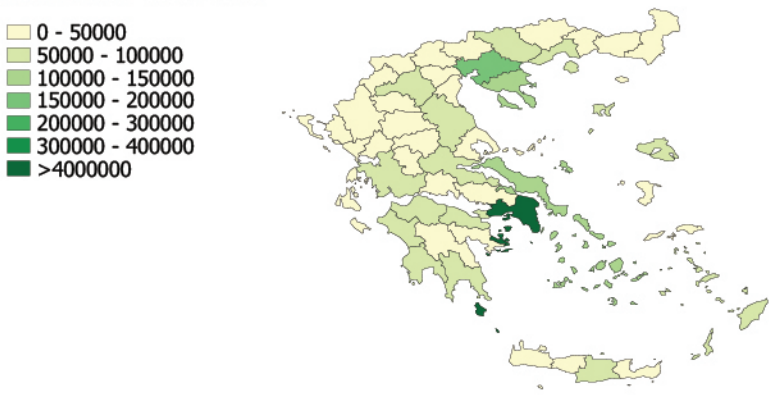
POPULATION	80717278
N° DWELLINGS	40563313
Before 1919	5683647
1919-1945	4169081
1946-1960	6423880
1961-1970	6341340
1971-1980	6082648
1981-1990	4075319
1991-2000	5293217
2001-2006	1472715
After 2006	1021466
N° BUILDINGS	18640507

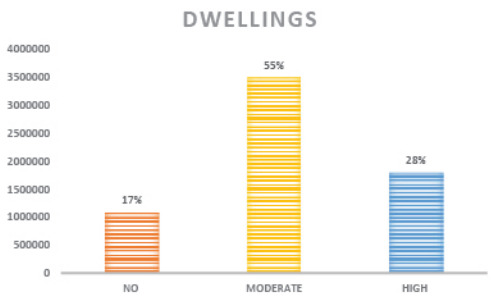
GERMANY

DESIGN VALUE OF PGA [g] FOR 475 YRP

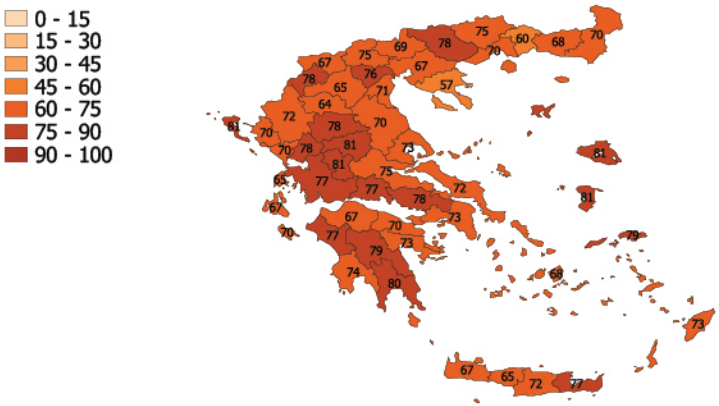


NUMBER OF BUILDINGS

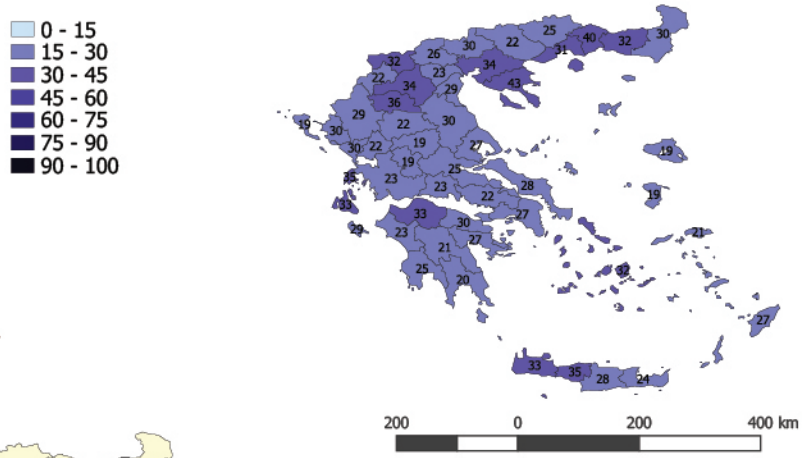


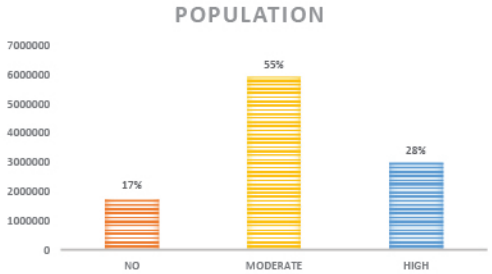


DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE



DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE





MOST FREQUENT CLASS OF DWELLINGS

- H-HIGH LEVEL
- M-MODERATE LEVEL
- N-NO CODE

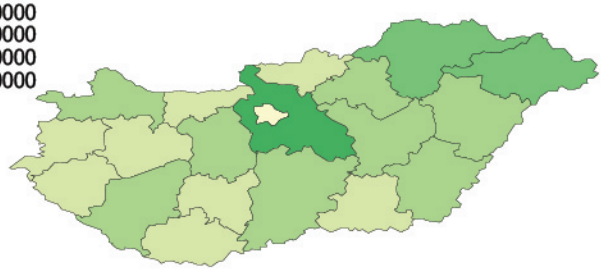
0 100 200 300 400 km

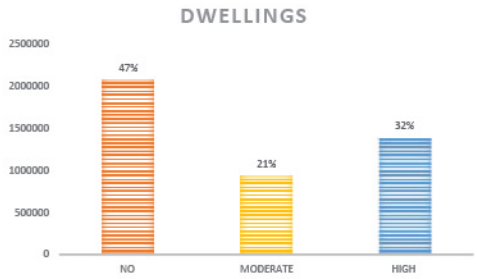
POPULATION	10666528
N° DWELLINGS	6371901
Before 1919	163759
1919-1945	318372
1946-1960	605693
1961-1970	1002902
1971-1980	1437424
1981-1990	1049931
1991-2000	806977
2001-2006	539009
After 2006	447834
N° BUILDINGS	3009119

GREECE

NUMBER OF BUILDINGS

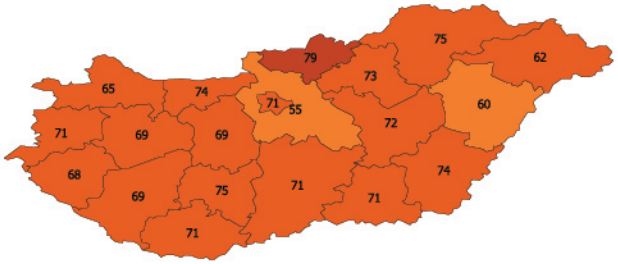
- 0 - 50000
- 50000 - 100000
- 100000 - 150000
- 150000 - 200000
- 200000 - 300000
- 300000 - 400000
- >4000000





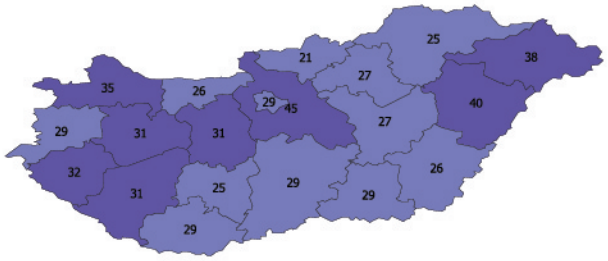
DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE

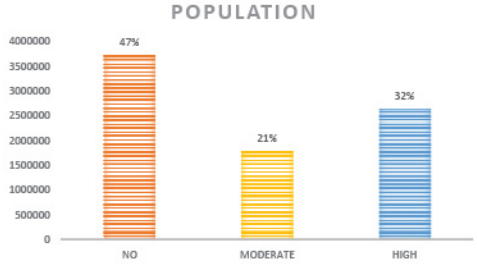
- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100



DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100





100 0 100 200 km

MOST FREQUENT CLASS OF DWELLINGS

- H-HIGH LEVEL
- M-MODERATE LEVEL
- N-NO CODE

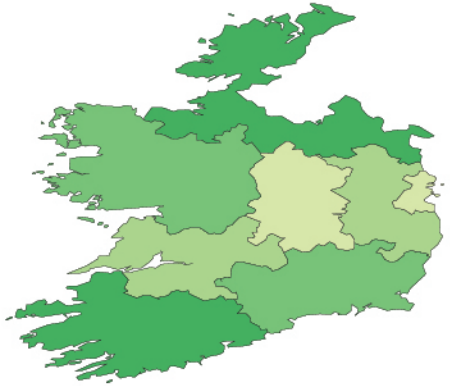
0 60 120 180 240 km

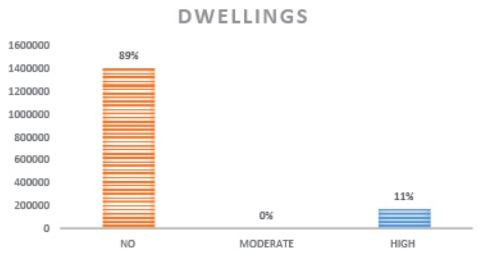
POPULATION	8173087
N° DWELLINGS	4390302
Before 1919	377336
1919-1945	514866
1946-1960	530957
1961-1970	653376
1971-1980	934214
1981-1990	673405
1991-2000	280091
2001-2006	239225
After 2006	186832
N° BUILDINGS	2189018

HUNGARY

NUMBER OF BUILDINGS

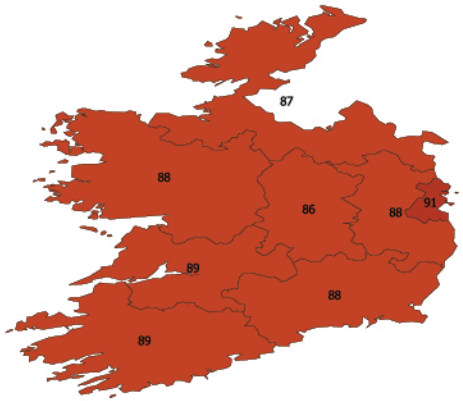
- 0 - 50000
- 50000 - 100000
- 100000 - 150000
- 150000 - 200000
- 200000 - 300000
- 300000 - 400000
- >4000000





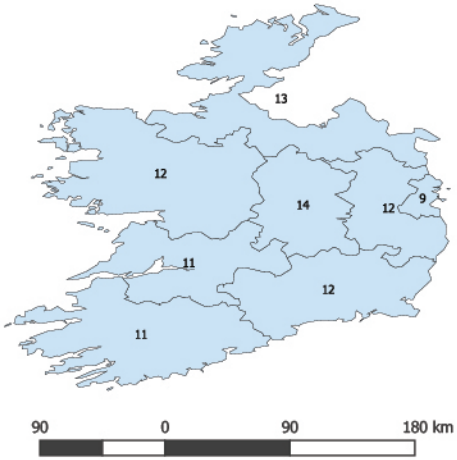
DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE

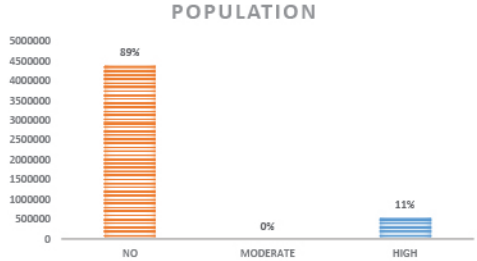
- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100



DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100





MOST FREQUENT CLASS OF DWELLINGS

- H-HIGH LEVEL
- M-MODERATE LEVEL
- N-NO CODE

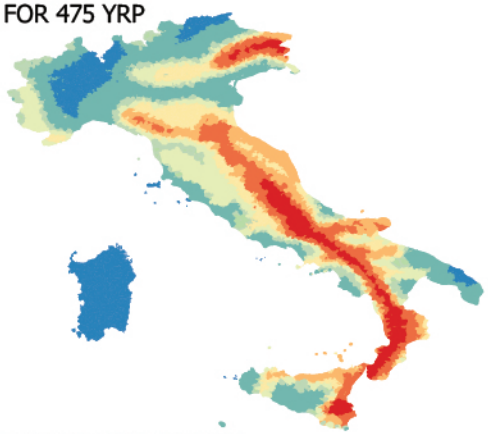
0 50 100 150 200 km

POPULATION	4952687
N° DWELLINGS	1994968
Before 1919	150516
1919-1945	115153
1946-1960	127987
1961-1970	114796
1971-1980	214663
1981-1990	172929
1991-2000	239565
2001-2006	267311
After 2006	172102
N° BUILDINGS	1204935

IRELAND

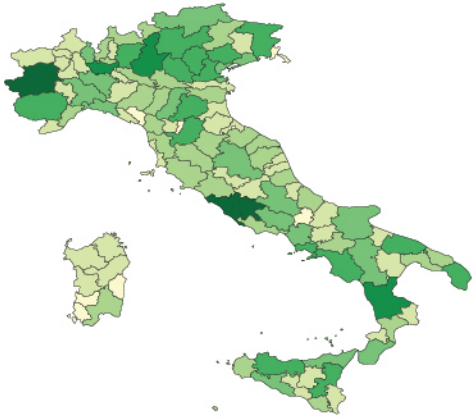
DESIGN VALUE OF PGA [g] FOR 475 YRP

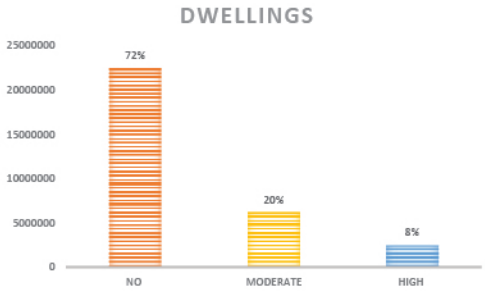
- 0.00 - 0.05
- 0.05 - 0.10
- 0.10 - 0.12
- 0.12 - 0.15
- 0.15 - 0.17
- 0.17 - 0.20
- 0.20 - 0.25
- > 0.25



NUMBER OF BUILDINGS

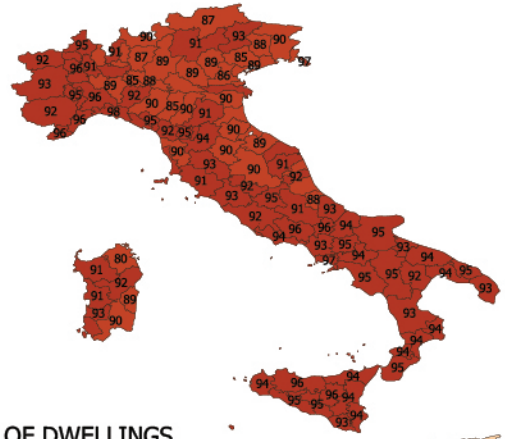
- 0 - 50000
- 50000 - 100000
- 100000 - 150000
- 150000 - 200000
- 200000 - 300000
- 300000 - 400000
- >4000000





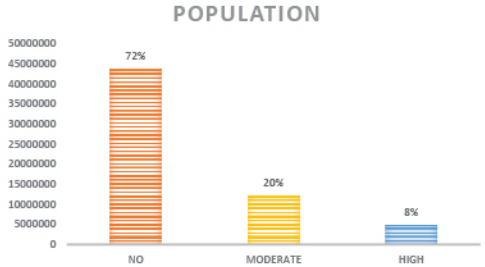
DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100



DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100



MOST FREQUENT CLASS OF DWELLINGS

- H-HIGH LEVEL
- M-MODERATE LEVEL
- N-NO CODE

0 200 400 600 800 km

POPULATION	60782668
N° DWELLINGS	31208161
Before 1919	3656542
1919-1945	2799407
1946-1960	4268838
1961-1970	5986048
1971-1980	5770951
1981-1990	3874961
1991-2000	2311576
2001-2006	1348445
After 2006	1121510
Not Stated	69883
N° BUILDINGS	15231976

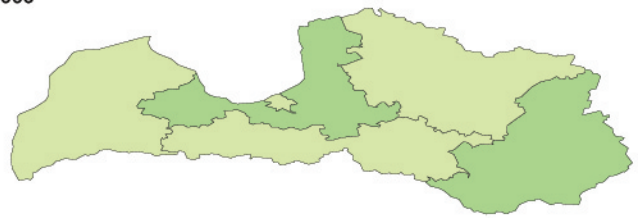
ITALY

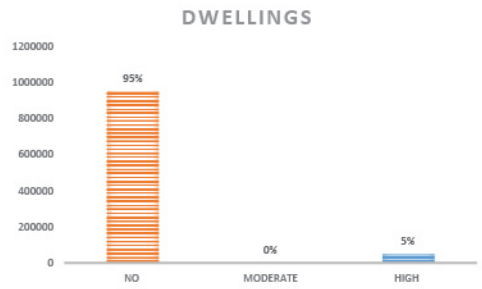
DESIGN VALUE OF PGA [g] FOR 475 YRP

- 0.00 - 0.05
- 0.05 - 0.10
- 0.10 - 0.12
- 0.12 - 0.15
- 0.15 - 0.17
- 0.17 - 0.20
- 0.20 - 0.25
- > 0.25

NUMBER OF BUILDINGS

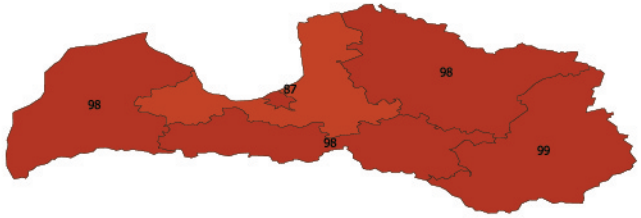
- 0 - 50000
- 50000 - 100000
- 100000 - 150000
- 150000 - 200000
- 200000 - 300000
- 300000 - 400000
- >4000000





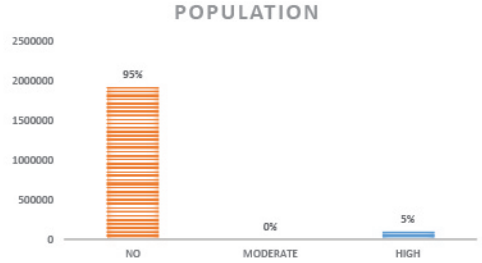
DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100



DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100



90 0 90 180 km

MOST FREQUENT CLASS OF DWELLINGS

- H-HIGH LEVEL
- M-MODERATE LEVEL
- N-NO CODE

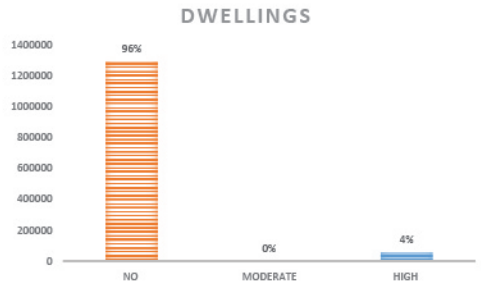
0 40 80 120 160 km

POPULATION	2023825
N° DWELLINGS	1018532
Before 1919	105390
1919-1945	126004
1946-1960	93297
1961-1970	170822
1971-1980	210439
1981-1990	200056
1991-2000	47187
2001-2006	15169
After 2006	36322
Not Stated	13846
N° BUILDINGS	536731

LATVIA

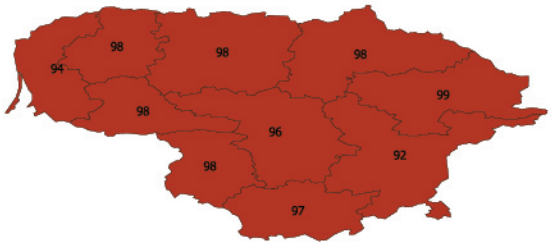
NUMBER OF BUILDINGS

- 0 - 50000
- 50000 - 100000
- 100000 - 150000
- 150000 - 200000
- 200000 - 300000
- 300000 - 400000
- >4000000



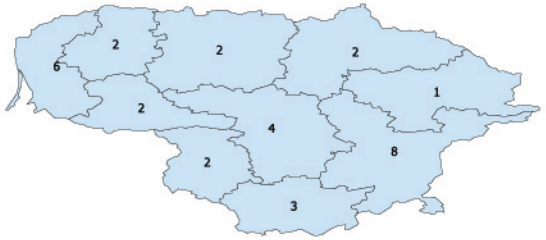
DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE

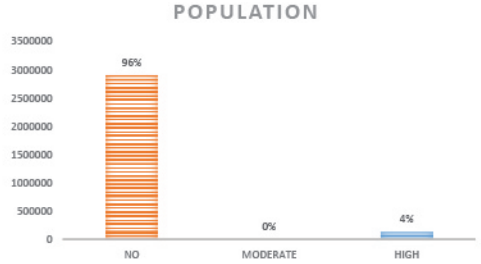
- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100



DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100





90 0 90 180 km

MOST FREQUENT CLASS OF DWELLINGS

- H-HIGH LEVEL
- M-MODERATE LEVEL
- N-NO CODE

0 40 80 120 160 km

POPULATION		3043429
N° DWELLINGS		1374233
	Before 1919	45612
	1919-1945	139489
	1946-1960	132496
	1961-1970	237070
	1971-1980	311622
	1981-1990	300861
	1991-2000	96014
	2001-2006	29556
	After 2006	55877
	Not Stated	25636
N° BUILDINGS		729215

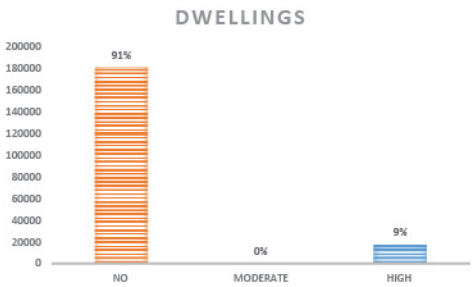
LITHUANIA

DESIGN VALUE OF PGA [g] FOR 475 YRP

- 0.00 - 0.05
- 0.05 - 0.10
- 0.10 - 0.12
- 0.12 - 0.15
- 0.15 - 0.17
- 0.17 - 0.20
- 0.20 - 0.25
- > 0.25

NUMBER OF BUILDINGS

- 0 - 50000
- 50000 - 100000
- 100000 - 150000
- 150000 - 200000
- 200000 - 300000
- 300000 - 400000
- >4000000

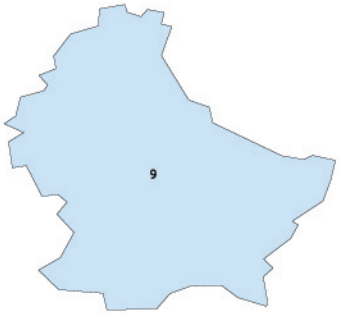


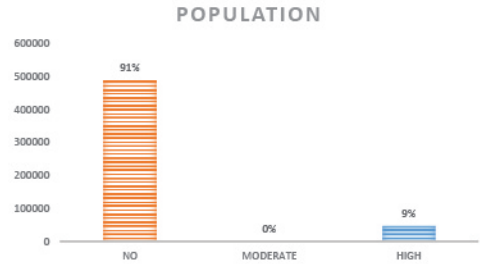
DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100

DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100





20 0 20 40 km

MOST FREQUENT CLASS OF DWELLINGS

- H-HIGH LEVEL
- M-MODERATE LEVEL
- N-NO CODE

0 10 20 30 40 km

POPULATION	537039
N° DWELLINGS	1374233
Before 1919	22557
1919-1945	26053
1946-1960	24942
1961-1970	19766
1971-1980	25435
1981-1990	20038
1991-2000	28078
2001-2006	14228
After 2006	17083
Not Stated	24766
N° BUILDINGS	137652

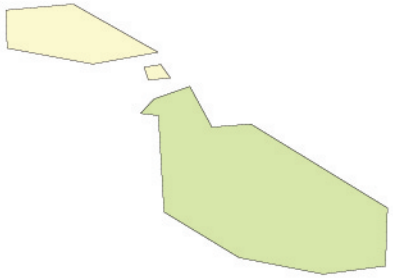
LUXEMBOURG

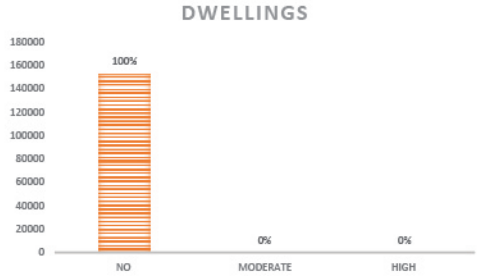
DESIGN VALUE OF PGA [g] FOR 475 YRP

- 0.00 - 0.05
- 0.05 - 0.10
- 0.10 - 0.12
- 0.12 - 0.15
- 0.15 - 0.17
- 0.17 - 0.20
- 0.20 - 0.25
- > 0.25

NUMBER OF BUILDINGS

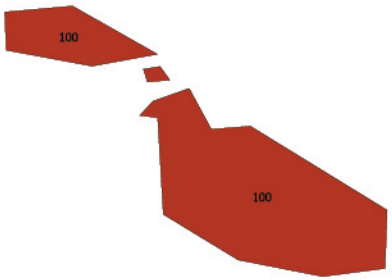
- 0 - 50000
- 50000 - 100000
- 100000 - 150000
- 150000 - 200000
- 200000 - 300000
- 300000 - 400000
- >4000000





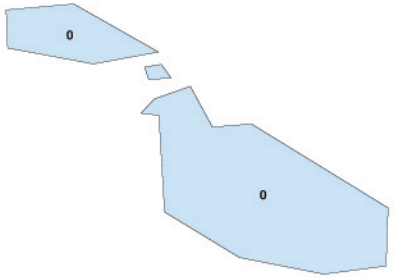
DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE

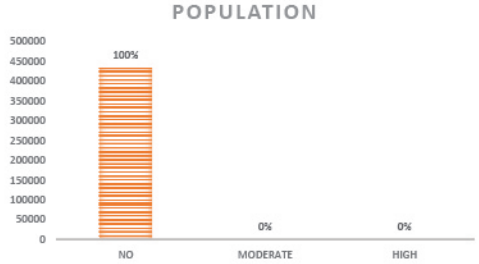
- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100



DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100





MOST FREQUENT CLASS OF DWELLINGS

- H-HIGH LEVEL
- M-MODERATE LEVEL
- N-NO CODE

0 10 20 30 40 km

10 0 10 20 km

POPULATION	434403
N° DWELLINGS	223850
Before 1919	15755
1919-1945	13330
1946-1960	15640
1961-1970	13865
1971-1980	22485
1981-1990	28886
1991-2000	23386
2001-2006	10820
After 2006	8603
Not Stated	71080
N° BUILDINGS	76329

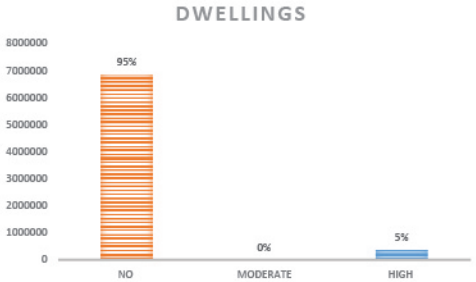
MALTA

DESIGN VALUE OF PGA [g] FOR 475 YRP

- 0.00 - 0.05
- 0.05 - 0.10
- 0.10 - 0.12
- 0.12 - 0.15
- 0.15 - 0.17
- 0.17 - 0.20
- 0.20 - 0.25
- > 0.25

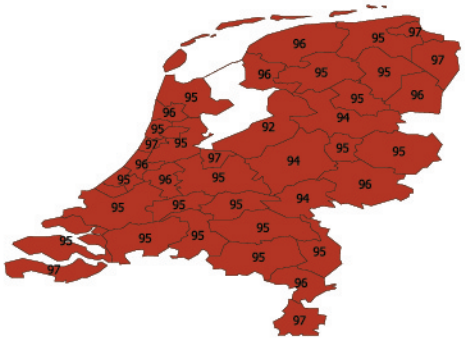
NUMBER OF BUILDINGS

- 0 - 50000
- 50000 - 100000
- 100000 - 150000
- 150000 - 200000
- 200000 - 300000
- 300000 - 400000
- >4000000



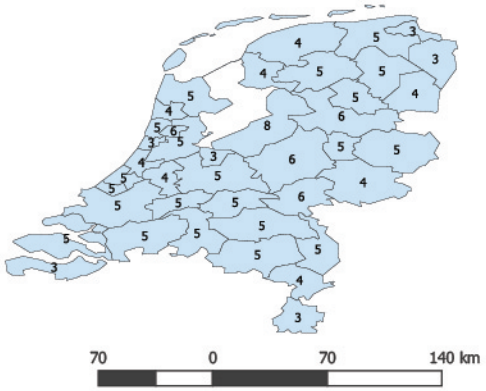
DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE

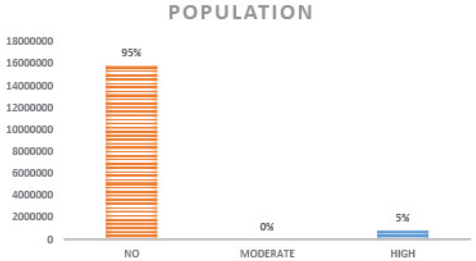
- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100



DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100





MOST FREQUENT CLASS OF DWELLINGS

- H-HIGH LEVEL
- M-MODERATE LEVEL
- N-NO CODE

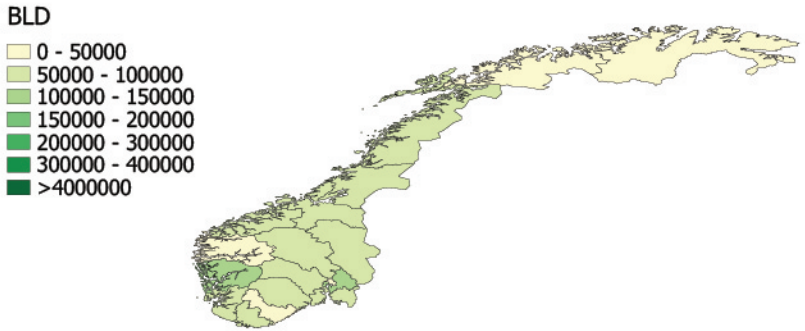
0 40 80 120 160 km

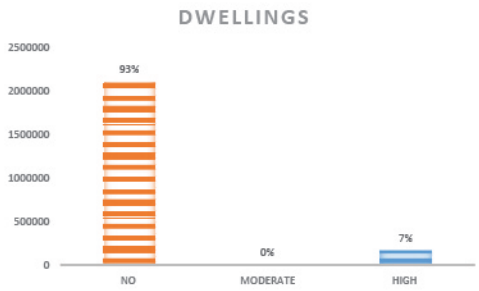
POPULATION		16673551
N° DWELLINGS		7459694
	Before 1919	546580
	1919-1945	865751
	1946-1960	850734
	1961-1970	1069878
	1971-1980	1205509
	1981-1990	1084910
	1991-2000	884260
	2001-2006	348187
	After 2006	360375
	Not Stated	243510
N° BUILDINGS		2862582

NETHERLANDS

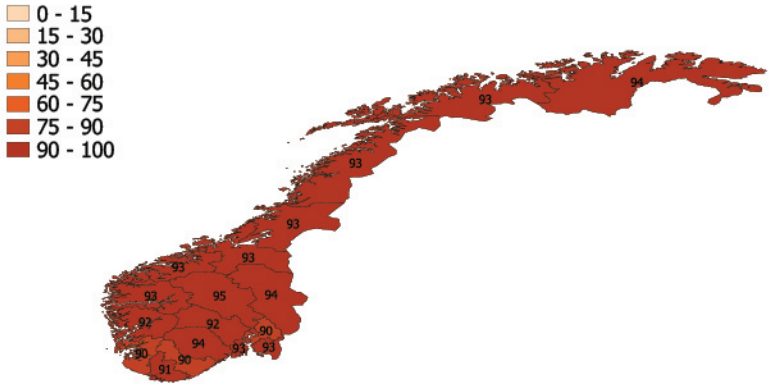
DESIGN VALUE OF PGA [g] FOR 475 YRP

NUMBER OF BUILDINGS

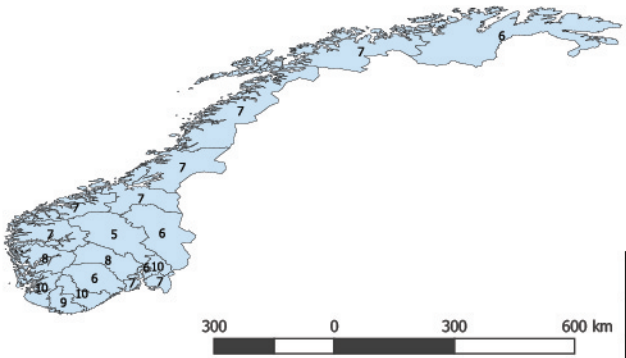


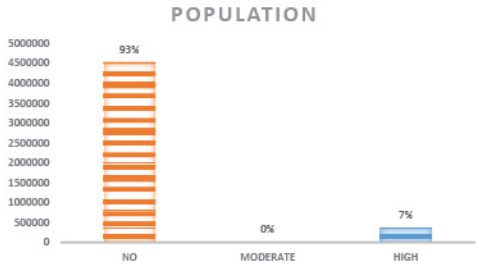


DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE



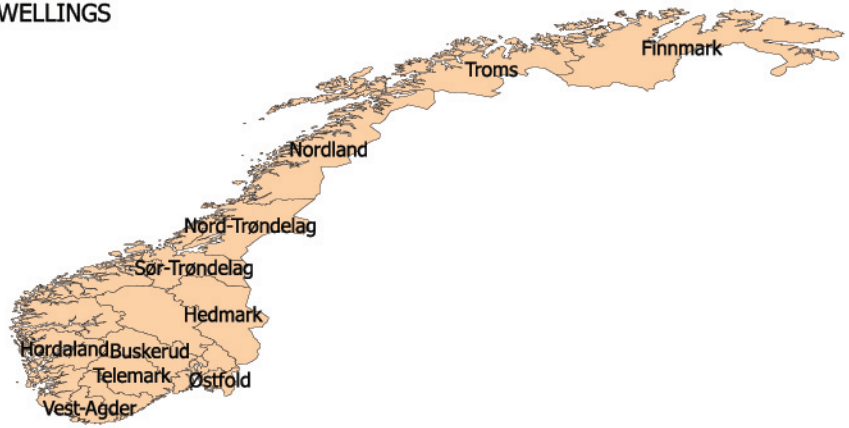
DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE





MOST FREQUENT CLASS OF DWELLINGS

- H-HIGH LEVEL
- M-MODERATE LEVEL
- N-NO CODE



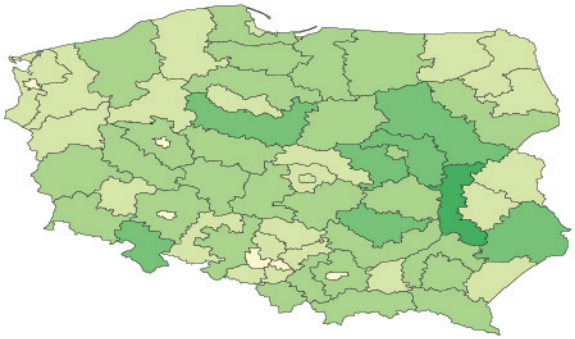
0 100 200 300 400 km

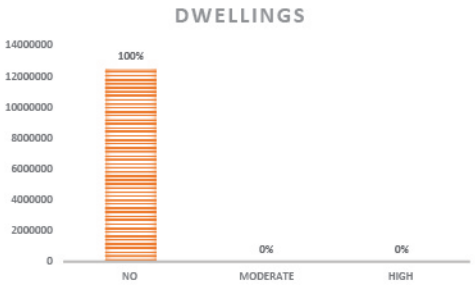
POPULATION		4896406
N° DWELLINGS		2414505
	Before 1919	224953
	1919-1945	179782
	1946-1960	325737
	1961-1970	291089
	1971-1980	380553
	1981-1990	330040
	1991-2000	230046
	2001-2006	138599
	After 2006	168727
	Not stated	144979
N° BUILDINGS		1380430

NORWAY

NUMBER OF BUILDINGS

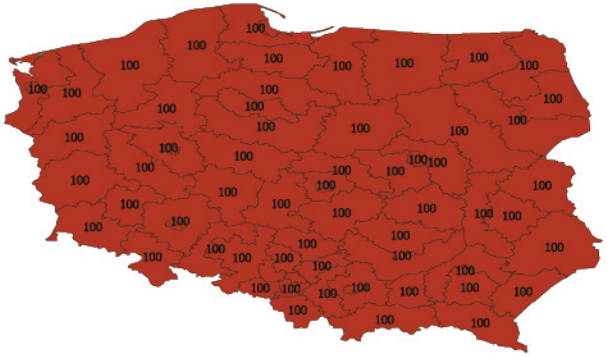
- 0 - 50000
- 50000 - 100000
- 100000 - 150000
- 150000 - 200000
- 200000 - 300000
- 300000 - 400000
- >4000000





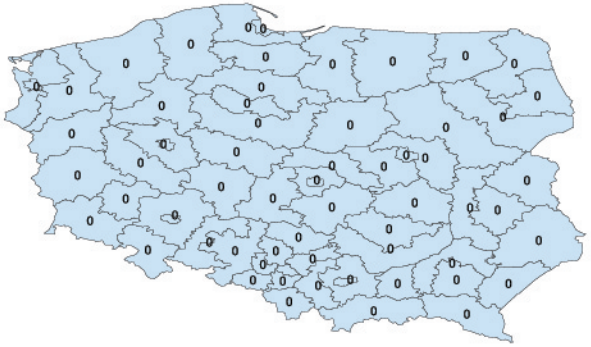
DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE

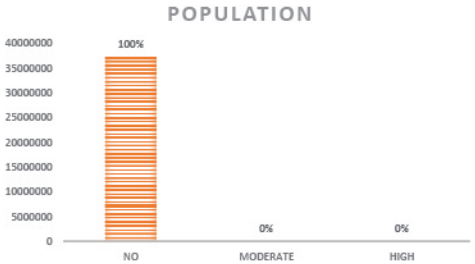
- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100



DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100





70 0 70 140 km

MOST FREQUENT CLASS OF DWELLINGS

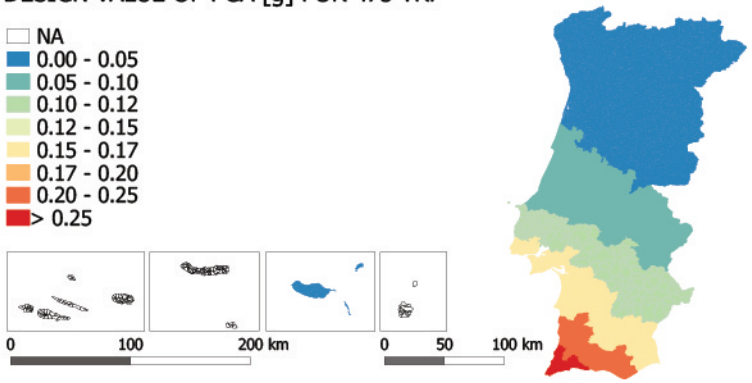
- H-HIGH LEVEL
- M-MODERATE LEVEL
- N-NO CODE

0 100 200 300 400 km

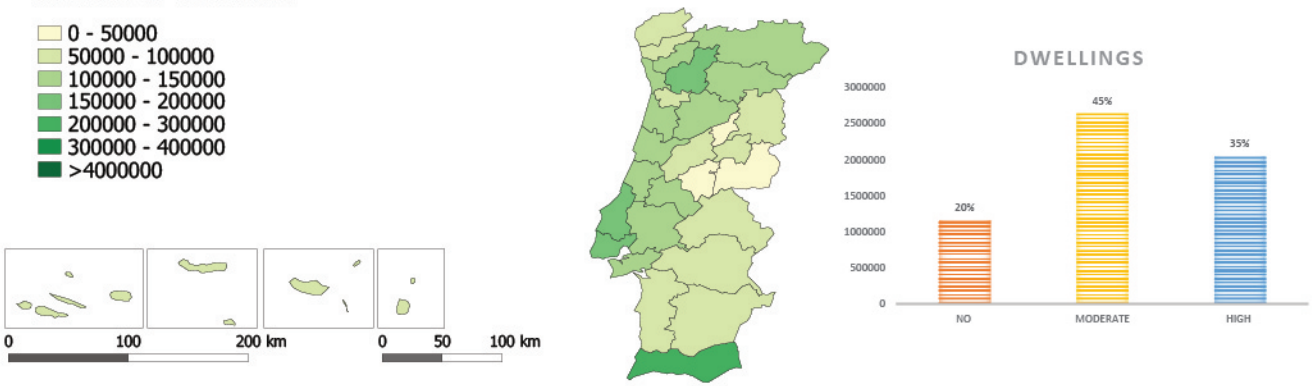
POPULATION	37362254
N° DWELLINGS	12965603
Before 1919	1037204
1919-1945	1439908
1946-1960	1123847
1961-1970	1802954
1971-1980	2646897
1981-1990	1781683
1991-2000	1161224
2001-2006	662856
After 2006	810027
Not Stated	499003
N° BUILDINGS	6908052

POLAND

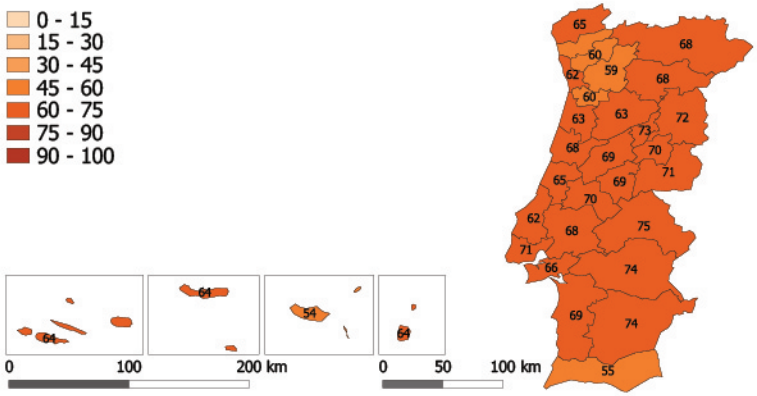
DESIGN VALUE OF PGA [g] FOR 475 YRP



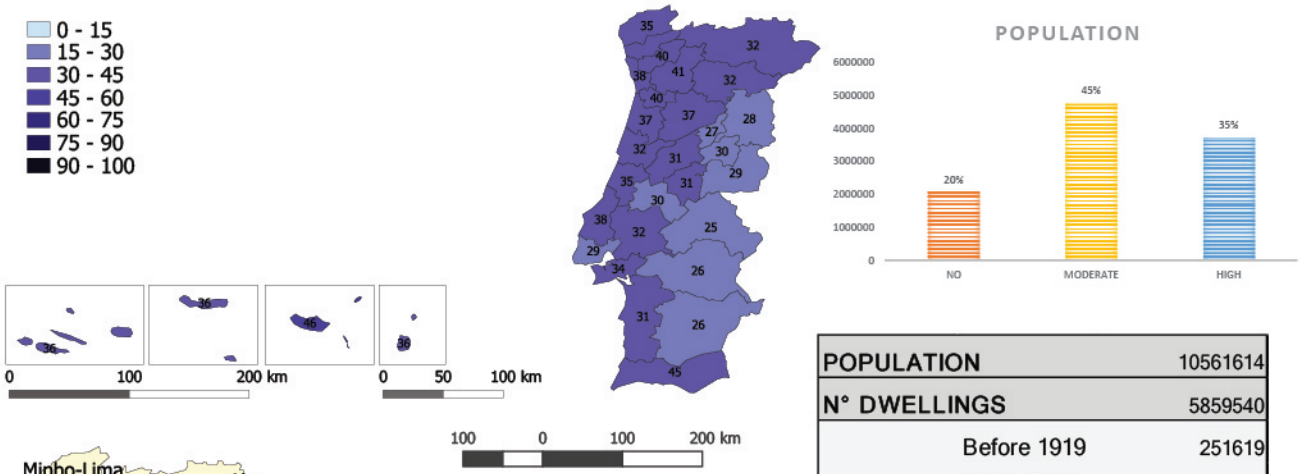
NUMBER OF BUILDINGS



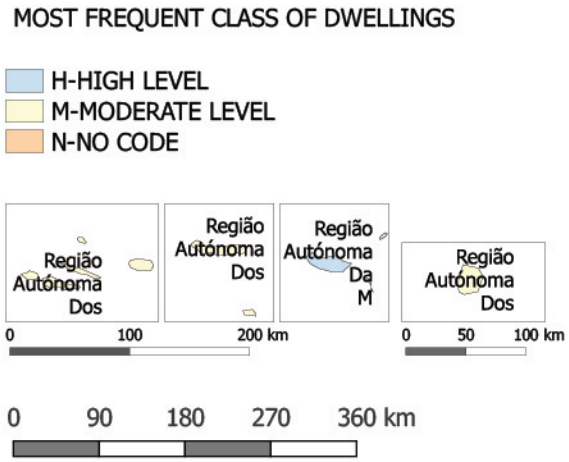
DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE



DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE



MOST FREQUENT CLASS OF DWELLINGS

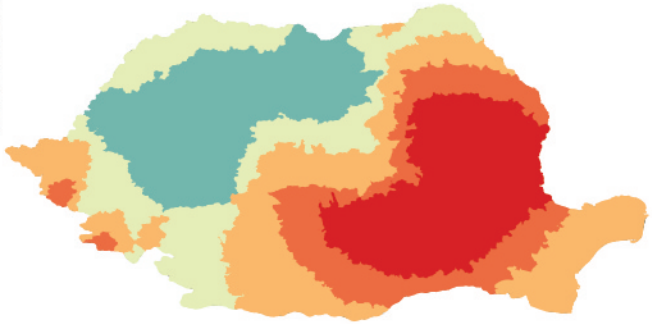


POPULATION	10561614
N° DWELLINGS	5859540
Before 1919	251619
1919-1945	373893
1946-1960	539060
1961-1970	648488
1971-1980	983645
1981-1990	1011960
1991-2000	1098329
2001-2006	581718
After 2006	370828
Not Stated	25636
N° BUILDINGS	2975440

PORTUGAL

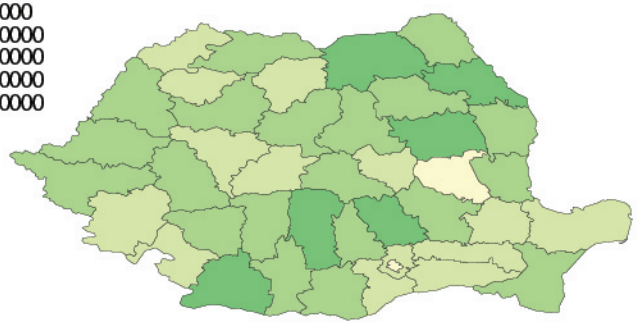
DESIGN VALUE OF PGA [g] FOR 100 YRP

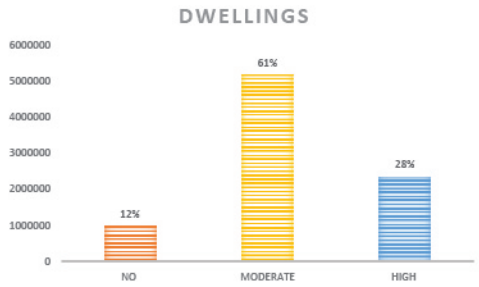
- 0.00 - 0.05
- 0.05 - 0.10
- 0.10 - 0.12
- 0.12 - 0.15
- 0.15 - 0.17
- 0.17 - 0.20
- 0.20 - 0.25
- > 0.25



NUMBER OF BUILDINGS

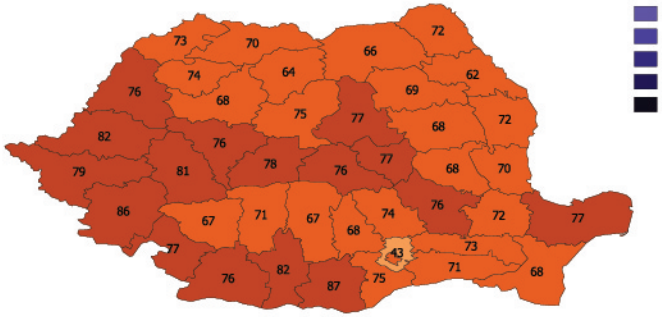
- 0 - 50000
- 50000 - 100000
- 100000 - 150000
- 150000 - 200000
- 200000 - 300000
- 300000 - 400000
- >4000000





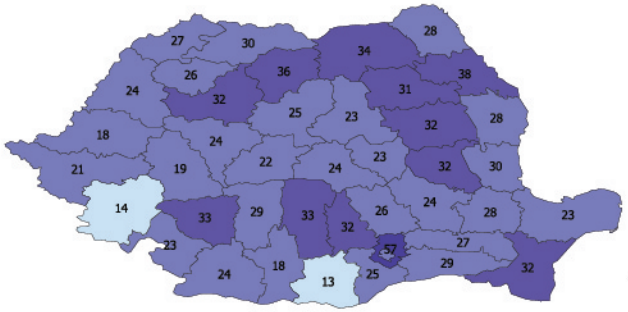
DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE

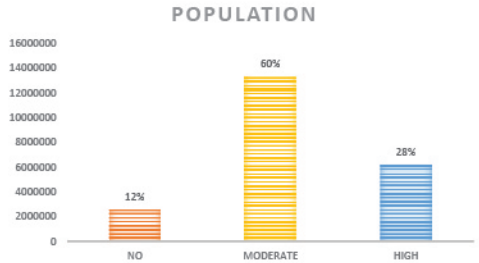
- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100



DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100





MOST FREQUENT CLASS OF DWELLINGS

- H-HIGH LEVEL
- M-MODERATE LEVEL
- N-NO CODE

0 80 160 240 320 km

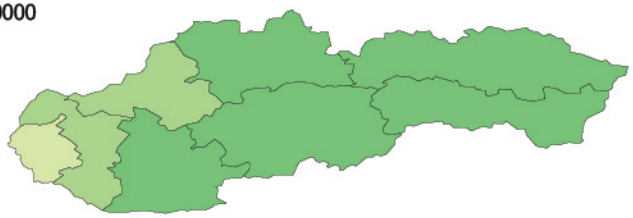
100 0 100 200 km

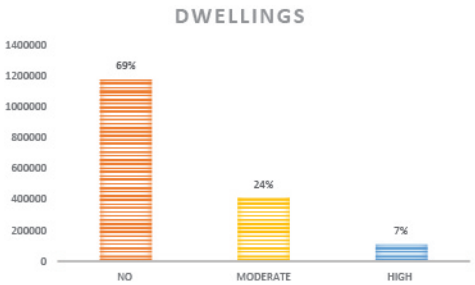
POPULATION	22241718
N° DWELLINGS	8722398
Before 1919	298142
1919-1945	680934
1946-1960	1371011
1961-1970	2054242
1971-1980	1730409
1981-1990	1186525
1991-2000	469868
2001-2006	249535
After 2006	447084
Not Stated	234648
N° BUILDINGS	4807017

ROMANIA

NUMBER OF BUILDINGS

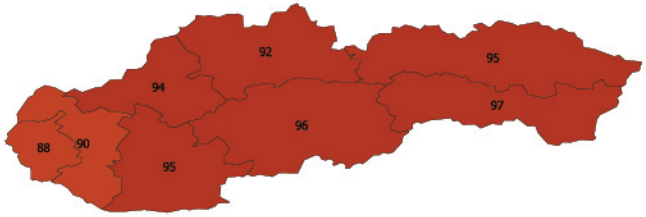
- 0 - 50000
- 50000 - 100000
- 100000 - 150000
- 150000 - 200000
- 200000 - 300000
- 300000 - 400000
- >4000000





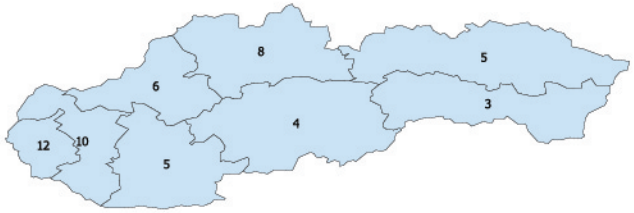
DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE

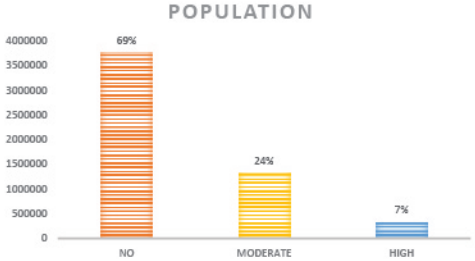
- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100



DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100





MOST FREQUENT CLASS OF DWELLINGS

- H-HIGH LEVEL
- M-MODERATE LEVEL
- N-NO CODE

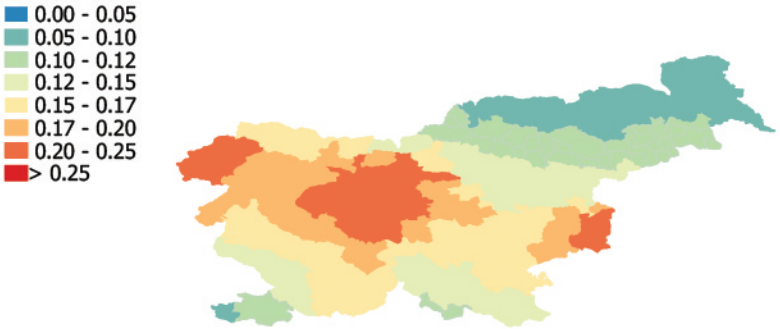
0 30 60 90 120 km

100 0 100 200 km

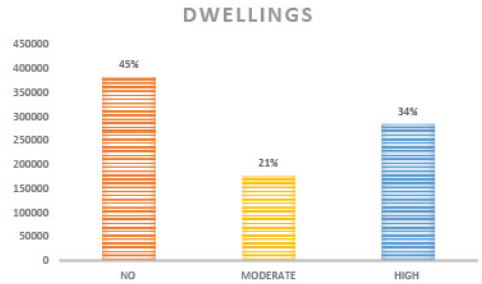
POPULATION	5426252
N° DWELLINGS	1941176
Before 1919	43015
1919-1945	117010
1946-1960	259667
1961-1970	331411
1971-1980	430301
1981-1990	322343
1991-2000	94976
2001-2006	50168
After 2006	62926
Not Stated	229359
N° BUILDINGS	1228597

SLOVAKIA

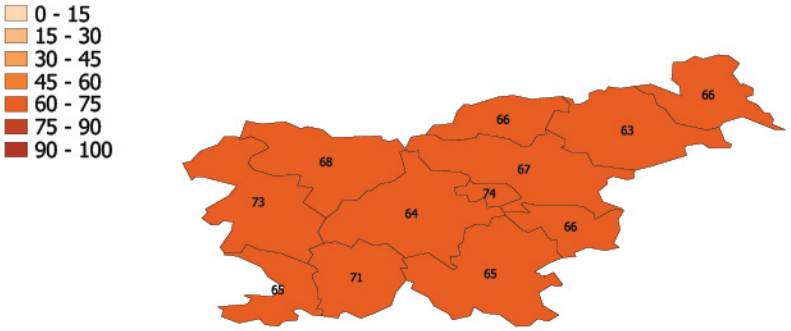
DESIGN VALUE OF PGA [g] FOR 475 YRP



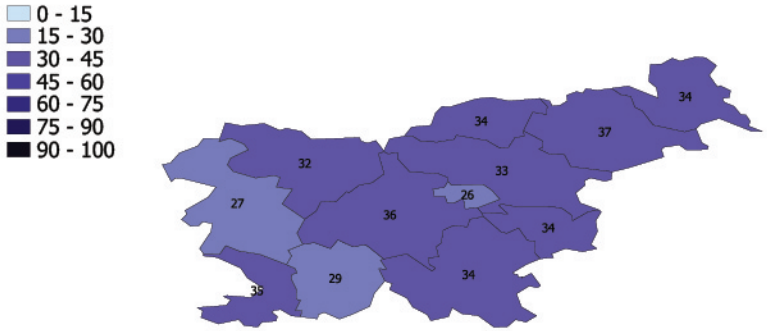
NUMBER OF BUILDINGS

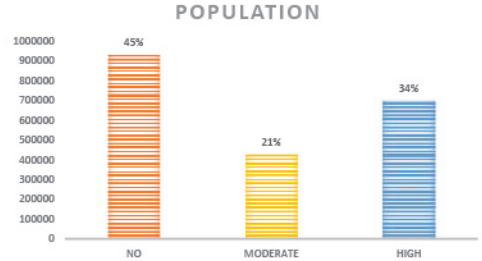


DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE



DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE



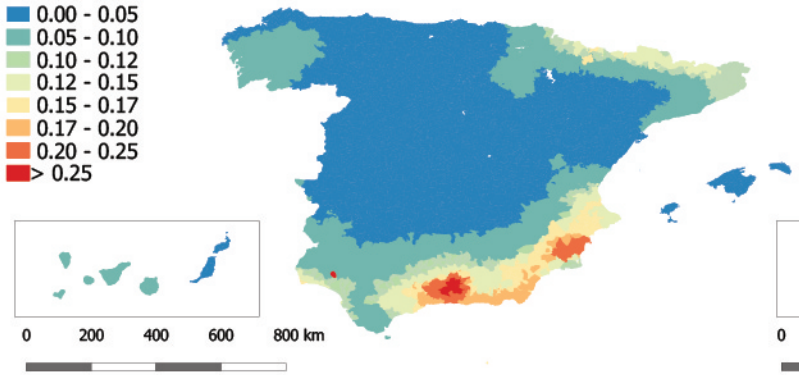


MOST FREQUENT CLASS OF DWELLINGS

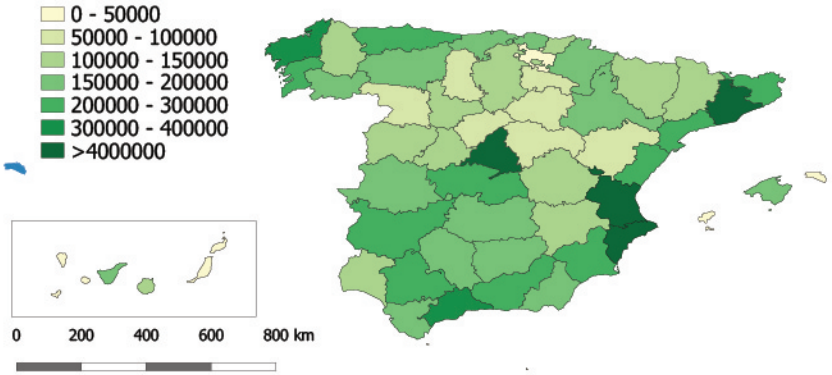
POPULATION	2060953
N° DWELLINGS	844656
Before 1919	121955
1919-1945	57973
1946-1960	80827
1961-1970	122353
1971-1980	176521
1981-1990	146825
1991-2000	64743
2001-2006	31500
After 2006	41959
N° BUILDINGS	556767

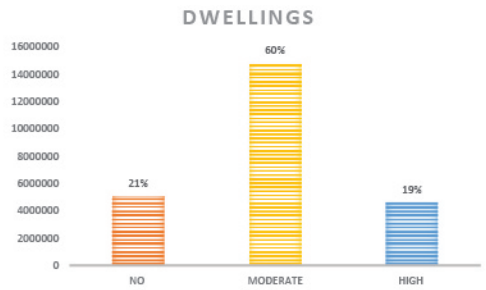
SLOVENIA

DESIGN VALUE OF PGA [g] FOR 475 YRP

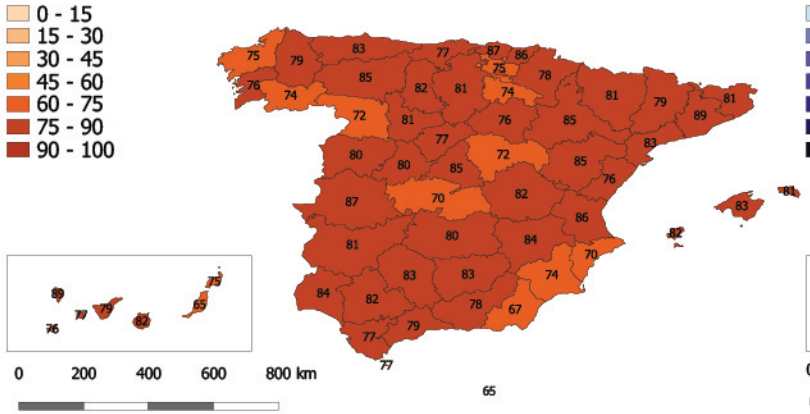


NUMBER OF BUILDINGS

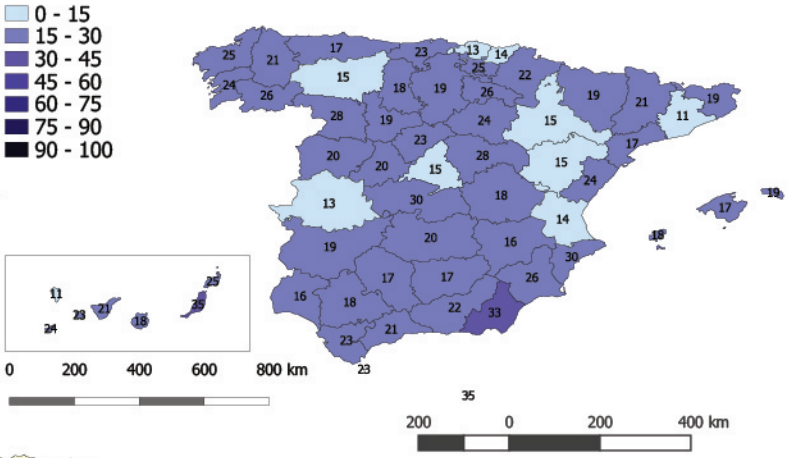


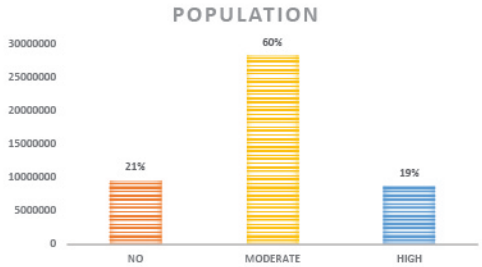


DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE

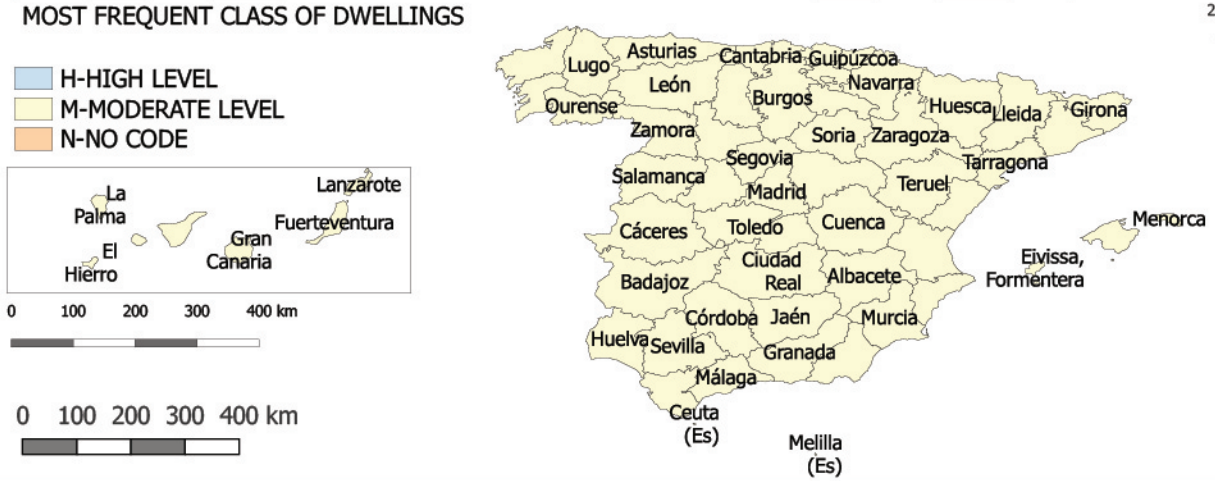


DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE





MOST FREQUENT CLASS OF DWELLINGS



POPULATION	46812745
N° DWELLINGS	25206530
Before 1919	1575405
1919-1945	1230440
1946-1960	2246510
1961-1970	3573215
1971-1980	5011350
1981-1990	3137205
1991-2000	3084015
2001-2006	2217815
After 2006	2443790
Not Stated	686785
N° BUILDINGS	10055707

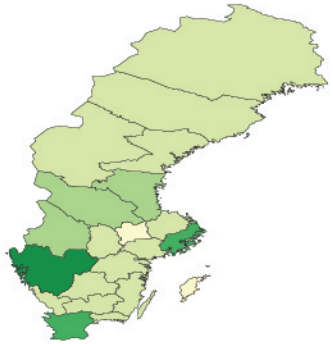
SPAIN

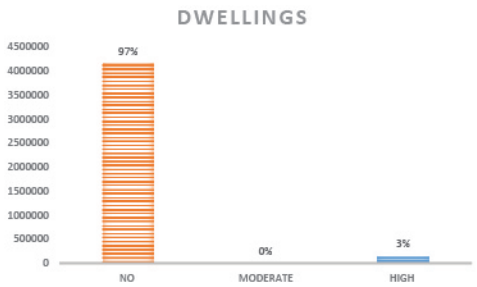
DESIGN VALUE OF PGA [g] FOR 475 YRP

- 0.00 - 0.05
- 0.05 - 0.10
- 0.10 - 0.12
- 0.12 - 0.15
- 0.15 - 0.17
- 0.17 - 0.20
- 0.20 - 0.25
- > 0.25

NUMBER OF BUILDINGS

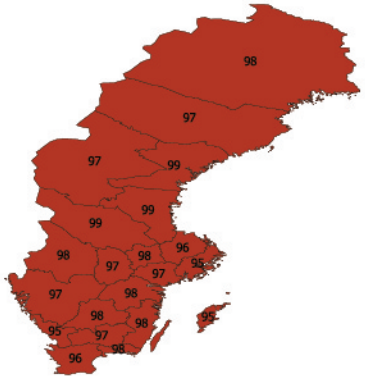
- 0 - 50000
- 50000 - 100000
- 100000 - 150000
- 150000 - 200000
- 200000 - 300000
- 300000 - 400000
- >4000000





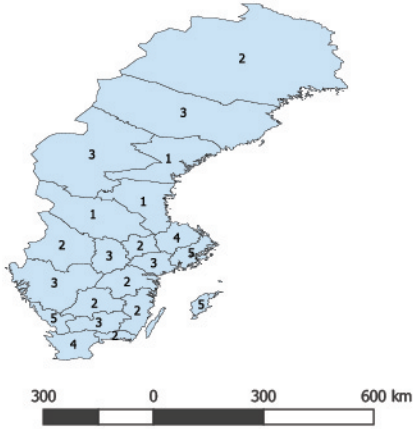
DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE

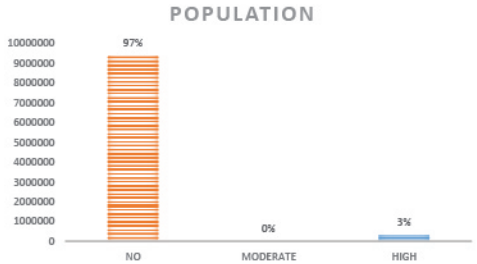
- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100



DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100





MOST FREQUENT CLASS OF DWELLINGS

- H-HIGH LEVEL
- M-MODERATE LEVEL
- N-NO CODE

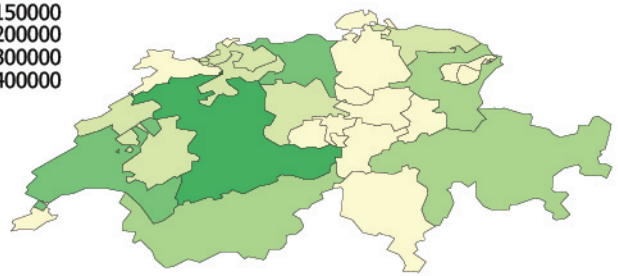
0 100 200 300 400 km

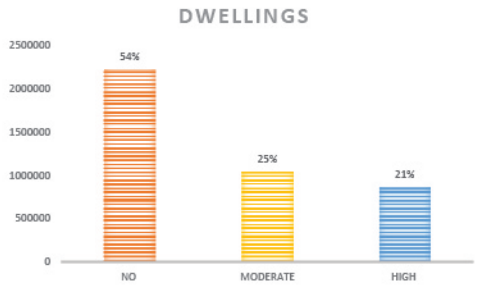
POPULATION	9737559
N° DWELLINGS	4824227
Before 1919	365836
1919-1945	805780
1946-1960	772274
1961-1970	816988
1971-1980	713354
1981-1990	386117
1991-2000	205649
2001-2006	85567
After 2006	138417
Not Stated	534245
N° BUILDINGS	2272850

SWEDEN

NUMBER OF BUILDINGS

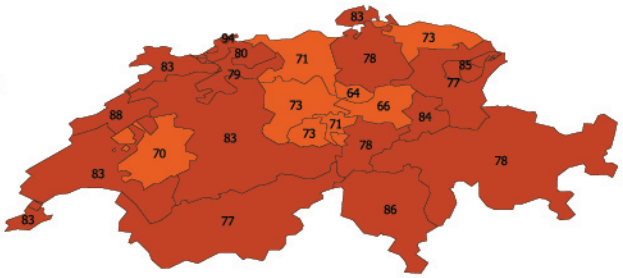
- 0 - 50000
- 50000 - 100000
- 100000 - 150000
- 150000 - 200000
- 200000 - 300000
- 300000 - 400000
- >4000000





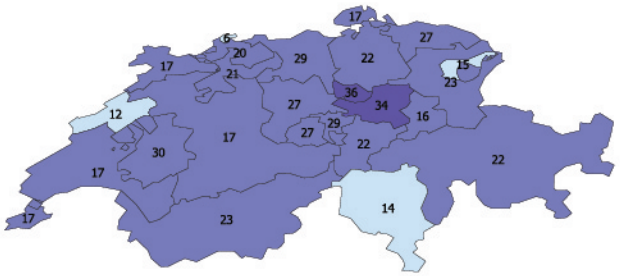
DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE

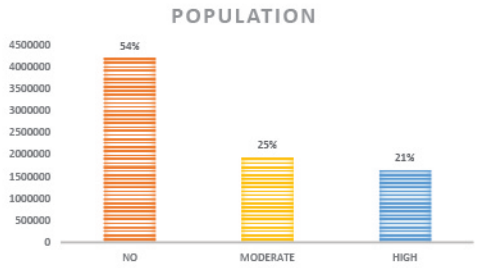
- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100



DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100





70 0 70 140 km

MOST FREQUENT CLASS OF DWELLINGS

- H-HIGH LEVEL
- M-MODERATE LEVEL
- N-NO CODE

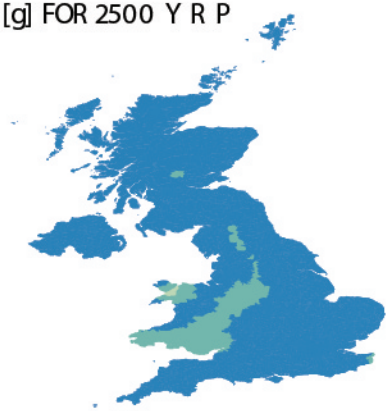
0 40 80 120 160 km

POPULATION	7786672
N° DWELLINGS	4131342
Before 1919	675016
1919-1945	423664
1946-1960	511143
1961-1970	613617
1971-1980	574153
1981-1990	468251
1991-2000	418916
2001-2006	169912
After 2006	276670
N° BUILDINGS	1692980

SWITZERLAND

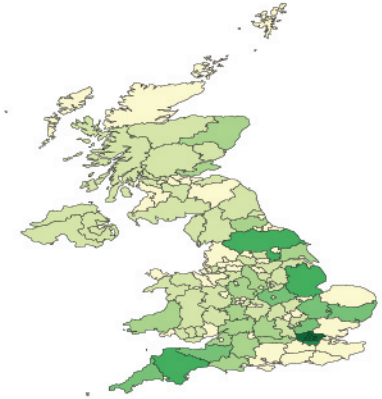
DESIGN VALUE OF PGA [g] FOR 2500 Y R P

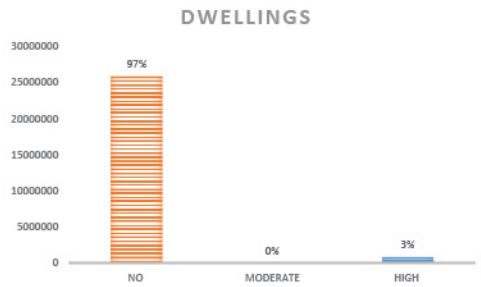
- 0.00 - 0.05
- 0.05 - 0.10
- 0.10 - 0.12
- 0.12 - 0.15
- 0.15 - 0.17
- 0.17 - 0.20
- 0.20 - 0.25
- > 0.25



NUMBER OF BUILDINGS

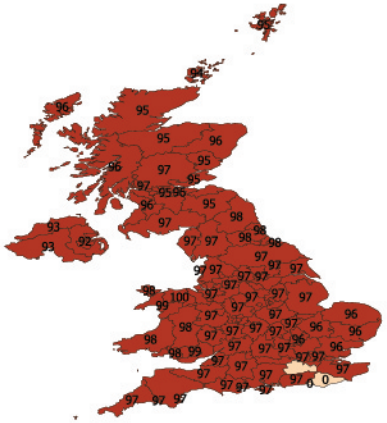
- 0 - 50000
- 50000 - 100000
- 100000 - 150000
- 150000 - 200000
- 200000 - 300000
- 300000 - 400000
- >4000000





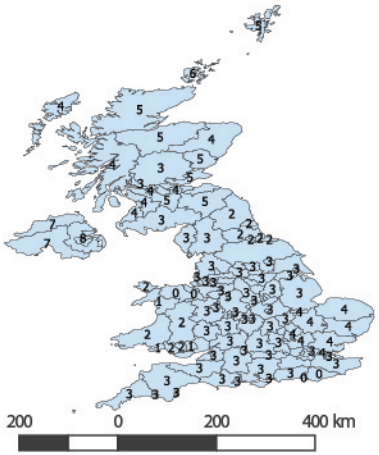
DWELLINGS [%] IN BUILDINGS DESIGNED WITH NO CODE AND MODERATE LEVEL CODE

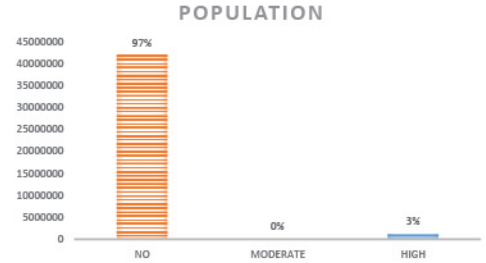
- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100



DWELLINGS [%] IN BUILDINGS DESIGNED_WITH HIGH-LEVEL CODE

- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 100





MOST FREQUENT CLASS OF DWELLINGS

- H-HIGH LEVEL
- M-MODERATE LEVEL
- N-NO CODE

0 100 200 300 400 km

POPULATION	44159618
N° DWELLINGS	27469425
Before 1919	5771870
1919-1945	4610900
1946-1960	4194100
1961-1970	3836220
1971-1980	2871780
1981-1990	2341690
1991-2000	1936280
2001-2006	1021875
After 2006	884710
N° BUILDINGS	10005718

UNITED KINGDOM

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