ISSN 1831-9424

JRC SCIENCE FOR POLICY REPORT

# Identification of vulnerable EU regions considering asbestos presence and seismic risk

*Unlocking wider benefits of building deep renovation*

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2023

EUR 31550 EN

Joint Research Centre

**EU Science Hub**
https://joint-research-centre.ec.europa.eu

JRC133139

EUR 31550 EN

PDF ISBN 978-92-68-04254-0 ISSN 1831-9424 doi:10.2760/652785 KJ-NA-31-550-EN-N

Luxembourg: Publications Office of the European Union, 2023



How to cite this report: Kakoulaki, G., Maduta, C., Tsionis, G., Zangheri P., Bavetta, M., *Identification of vulnerable EU regions considering asbestos presence and seismic risk*, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/652785, JRC133139.

# Contents

## Abstract

The European Union's building stock is old, heterogeneous and with a gradually slow transformation as several aspects have to be considered. In addition, it is energy inefficient, and many existing buildings contain hazardous materials, such as asbestos, placing users' health in danger. As the building stock ages and deteriorates, the risk of asbestos exposure increases. Moreover, natural disasters, such as earthquakes, can trigger asbestos fibre release due to damage of the built environment. Building renovation has been singled out in the European Union policies as key initiative to drive energy efficiency in the sector but also to deliver additional benefits such as better indoor conditions and enhanced resilience and structural safety. The report identifies relevant characteristics to be considered for building stock deep renovation (such as number, age, energy saving potential, asbestos presence, and seismic risk) to unlock the quantification of wider benefits. For the first time, indications on the presence of asbestos in the residential building stock at EU regional NUTS3 level in high seismic risk areas are presented. The results will inform policy makers on prioritisation of regions in need of renovation that can benefit from deep renovation to ensure safe and healthy indoor environments besides reduced energy consumption. Moreover, it can be used as a tool and give insight to improve emergency response and post-disaster remediation guidelines.

## Acknowledgements

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## Executive summary

### *Policy context*

The reduction of energy demand is at the heart of the European Union initiatives to achieve the 2030 and 2050 energy and climate targets and improve the security of energy supply, in line with the clean, smart, and inclusive energy transition. In this context, buildings offer a significant potential for energy savings because they are currently responsible for about 45% of total EU energy consumption and about 36% of the $CO_2$ emissions. To achieve the target of 55% reduction in greenhouse gas emissions in the EU by 2030, the EU building stock should cut by 60% the emissions and reduce the final energy consumption by 14%. Building renovation has been singled out in the European Union policies as key initiative to drive energy efficiency in the sector but also to deliver additional benefits such as better indoor conditions, energy poverty alleviation, enhanced resilience and structural safety and many others. Significant renovation efforts are supported by the European Green Deal communication (European Commission, 2019) and the Renovation Wave strategy (European Commission, 2020), which aims to increase the building renovation rate and promotes deep energy renovation. The Energy Performance of Buildings Directive (EPBD) proposal acknowledges deep renovation as a prime opportunity to increase indoor environmental quality also through the removal of harmful substances such as asbestos and to increase building resilience, including seismic resilience (European Commission, 2021a). Building energy renovation creates opportunities for asbestos removal but may also increase asbestos exposure for both construction workers and occupants if unexpected asbestos-containing products are discovered during renovation works. This may also cause renovation delays endangering the renovation targets achievement. Against this background, actions to protect population from asbestos exposure and to safeguard energy efficiency upgrades are even more important and the recent EU policies reflect this aspect. The proposal for a revised Asbestos at Work Directive intends lowering the limit of asbestos exposure compared to current values from 0.1 fibres/$cm^3$ to 0.01 fibres/$cm^3$, promotes awareness-raising campaigns and provides guidance to EU employers (European Commission, 2022a). Moreover, the Directive asks for mandatory identification of asbestos products before demolition or maintenance works. Concomitantly, the communication on working towards an asbestos-free future announces a new legislative proposal on the screening and registration of asbestos in buildings (European Commission, 2022b)). Moreover, the actions put forward are part of the prevention pillar of Europe's Beating Cancer Plan (European Commission, 2021b) and will contribute to the objectives of the Zero Pollution Action Plan (European Commission, 2021c) and the European Pillar of Social Rights (European Commission, 2021d).

### *Main findings*

Across the European Union, the peak in raw asbestos consumption was registered in 1980 with approximately 1.2 million tonnes of raw asbestos consumed declining to less than 40 000 tonnes in 2000. Overall, in most Member States buildings constructed between 1960 and 1990 are at risk of having higher quantities of asbestos compared to buildings dating from different decades. However, in Croatia, Slovenia, Slovakia, and Romania newer buildings (1990-2000) are expected to contain large asbestos quantities while in Cyprus such risk characterises buildings constructed between 1920 and 1945.

The annual asbestos consumption between 1920 and 2003 in dwellings was normalised per capita and per dwelling for each Member States and at EU level. The results reveal that seven countries (Finland, Denmark, Slovakia, Estonia, Belgium, Luxembourg, and Cyprus) had values higher than 1.0 kg/capita/year, defined as high asbestos use level, while two countries showed values above 2.0 kg/capita/year (Lithuania and Latvia), defined as remarkably elevated level of asbestos use, considering the associated health impact. Moreover, these countries plus Czechia and Hungary revealed an average asbestos use in dwellings above 2.0 kg/dwelling/year with some states reaching values higher than 4.0 kg/dwelling/year (Latvia and Lithuania). The least critical cases are registered in Greece, The Netherlands, Portugal, Ireland, Croatia, Romania, and Slovenia, where the average asbestos use in dwellings is below 0.4 kg/capita/year and below 1.0 kg/dwelling/year. At the EU level, the average asbestos use in dwellings between 1920 and 2003 is approximately 0.67 kg/capita/year and 1.64 kg/dwelling/year. The disaggregated asbestos use in dwellings at regional level (NUTS3) disclose the regions with asbestos use exceeding 240 kg per dwelling from Belgium, Cyprus, Czechia, Denmark, Estonia, Latvia, Lithuania, Luxemburg, and Slovakia. Smaller quantities are noted in Bulgaria, Ireland, Greece, Sweden, The Netherlands, Spain, Portugal, Croatia, Slovenia, and Romania, with many regions of Romania, Croatia and Slovenia having less than 60 kg of asbestos per dwelling. The prioritisation highlights regions at higher risk of asbestos exposure in residential buildings indicating where asbestos registration should be prioritized before any renovation planning.

Moreover, the estimated asbestos quantity in dwellings was combined with the seismic risk to the residential building stock to reveal regions where seismic activity may trigger increased asbestos exposure due to damage of the built environment. The release of asbestos fibres can occur due to natural wear and tear process, erosion caused by environmental factors such as rain and dampness, or shrinkage and thermal expansion in high temperatures (industries). The concentration levels of asbestos fibres and their dynamics can vary depending on several factors, including the location of the ACMs inside or outside a building, the cohesion material (friable or non-friable), the size of the ACMs, and the extent of the damage (Obmiński, 2020).

Regions with high seismic risk and high asbestos use are in southern Europe, specifically in Italy and Cyprus. Fewer but highly affected regions under combined seismic risk and asbestos use are also observed in Austria, Bulgaria, France, Germany, Slovenia, and Hungary. Central and north Europe is less critical under this combination. The least affected regions are in Ireland, Netherlands, Poland and Sweden.

The findings indicate where asbestos screening and registration should be a priority at regional level and provide insight of the most vulnerable regions to asbestos exposure but also being under elevated seismic risk. The results can guide policy makers, local authorities, community members and emergency responders to prioritise areas potentially affected by an earthquake and quickly gather information about potential asbestos release if the residential building stock is damaged. Moreover, our work could advance and promote disaster resilience by providing insight of the most vulnerable regions but also support post-disaster asbestos remediation guidelines. In the future, similar studies could be carried out for other natural disasters such as floods. Finally, this study could support the creation of regulation on the safety and protection of workers from the harmful effects of asbestos.

Moreover, the asbestos quantity and seismic risk are combined in a composite indicator to give a potential prioritisation of EU regions that could benefit from deep renovation. We found top priority (30)-regions in Italy (23 regions), Belgium (1 regions) and Latvia (6 regions) where the composite indicator takes values between 0.64 and 1.0. Note here, that the high values in Latvia are due to high asbestos presence in the building stock but low seismic risk. High values (0.6-0.8) are also observed in Belgium (high asbestos use and low seismic risk) and some regions in Greece (low asbestos use and high seismic risk). Fostering deep building renovation in these regions could bring besides substantial energy and emission savings, reduction of seismic risk in Greece, Italy and asbestos exposure in Belgium, Italy, Latvia and Lithuania.

Last but not least, an overview of case studies of asbestos release during disasters is presented. For instance, the war in Ukraine is expected to increase asbestos exposure levels during and after the war clean-up, as historically, Ukraine was a major asbestos consumer until the recent asbestos ban (2021). It is estimated that the Ukrainian building stock has received enormous damages and with about 240 000 houses destroyed, around 5-10 tonnes of asbestos could have been released in the air during the war (World Bank et al., 2022).

***Related and future JRC work***

This work is a continuation of a block of previous studies elaborated in the frame of work programme (WP) 2021-22, with an extension for WP 23-24. It complements previous deliverables (Maduta et al., 2022; Zangheri et al., 2020) focused on a final objective of identifying EU regions at risk of low Indoor Environmental Quality (IEQ) based on contextual factors i.e., exposure to harmful materials and outdoor pollution. This work provides insights of EU regions that can have wider benefits from deep building renovations also through the removal of harmful materials and enhanced structural safety. Indicators of outdoor pollution will be added in further steps to finally identify EU priority-regions for deep energy renovation.

***Quick guide***

Chapter 1 presents the background on the importance of asbestos removal from existing buildings particularly in areas with high seismic risk since seismic activity may trigger fibre release and thus increased exposure to asbestos fibres. Chapter 2 identifies relevant characteristics for building stock deep renovation to unlock the quantification of wider benefits, such as number, age and energy saving potential of residential buildings as well as asbestos presence, and seismic risk. Chapter 3 prioritise EU regions (NUTS3 level) for deep renovation based on (i) asbestos presence in dwellings, (ii) combined asbestos presence and seismic risk and (iii) composite indicator covering asbestos presence, seismic risk and energy saving potential of the residential building stock. The analysis is carried out for all the EU Member States (except Malta as data on historically raw asbestos consumption is not available). Chapter 4 presents an overview of case studies of asbestos release during natural and anthropogenic disasters and finally Chapter 5 summarises main take away messages.

# 1 Introduction

Currently about 85% of the European Union's (EU) building stock dates before 2001 and almost 75% of it is energy inefficient according to current standards (European Commission, 2020; Filippidou and Jimenez Navaro, 2019). Moreover, many existing buildings form an unhealthy indoor environment for the occupants because they may contain hazardous materials (hazmat), such as asbestos-containing materials (ACM) which are carcinogens. Hazmat is defined as substances that can cause injury or death from exposure due to their characteristics (Purpura, 2019). Asbestos exposure causes between 30 000 and 90 000 deaths per year in the EU; with asbestos being the main cause of lung cancer (European Parliament, 2021). Moreover, 78% of occupational cancers are asbestos-related (European Commission, 2022b).

In the EU, restrictions on asbestos use started in early 1980s while the EU-wide asbestos ban took effect in 2005 (European Commission, 2022b). Before the ban, asbestos was widely used in the construction sector, and it can still be found in buildings thus posing a significant threat to human health.

Moreover, as the building stock is ageing there is an urgent need to remove this material before its deterioration or fibre release during a natural disaster. Natural disasters, such as earthquakes, floods, tornadoes, wildfires may be powerful and prominent mechanisms of direct and indirect hazardous material releases (Young et al., 2004). Unintentional hazmat release from technologic emergencies triggered by natural disasters and they are defined as natural-technologic (na-tech) events (Showalter and Myers, 1994). Previous studies showed that asbestos fibres may be released in the atmosphere during an earthquake and place the human health in danger (Nathan et al., 1992; Nukushina, 1995; Tierney, 1989). As such, in seismic-prone areas, asbestos fibre release may constitute a secondary disaster (Lindell and Perry, 1996).

During or after an earthquake large quantity of asbestos can be released without the affected communities to be able to foresee its release, removal, and clean-up (Canadian HAZ-MAT, 2016). Depending on the seismic hazard and the vulnerability of buildings, the EU neighbourhoods may be contaminated with hazardous materials as many existing buildings were constructed without modern seismic codes (Crowley et al., 2021; Gkatzogias et al., 2022) and when asbestos was extensively used as a construction material (Maduta et al., 2022).

Energy renovation of buildings creates opportunities for asbestos removal. But the European building stock is highly heterogeneous among the various Member States (MSs) as it represents their cultural diversity and history. Adding to this uniqueness, the annual energy renovation rate of the building stock is as low as 1%. Significant renovation efforts are supported by the European Green Deal communication (European Commission, 2019) and the following Renovation Wave strategy (European Commission, 2020), which aims to increase the building renovation rate and promote deep energy renovation. A recent JRC study estimated that renovation of residential buildings to cost-optimal level at an average yearly rate of 2.6% could save 1 517 TWh at EU level, reaching 66% of the technical energy saving potential of residential building stock (Zangheri et al., 2020). The Energy Performance of Buildings Directive (EPBD) proposal acknowledges deep renovation as a prime opportunity to increase indoor environmental quality also through the removal of harmful substances such as asbestos and to increase building resilience against disaster risks, including earthquakes (European Commission, 2021a). In this context, the European Parliament launched a pilot project[1] aimed at investigating technical solutions for integrated seismic strengthening and energy efficiency upgrades of existing buildings in the least invasive way. The pilot project provides evidence and guidelines based on the analysis of the current state of the building stock and socioeconomic vulnerability in Europe, scenarios for intervention, technologies for renovation and assessment methodologies. The project supports the development of action plans complementing existing EU policies on building renovation with the scope to protect life, economy, and the environment (Gkatzogias et al., 2023).

The ambition to increase the renovation rate may increase asbestos exposure for both construction workers and occupants if products containing asbestos are discovered during renovation works. The unexpected asbestos presence not only could create a health hazard but may cause renovation delays endangering the achievement of renovation targets (Maduta et al., 2022). In this context, actions to protect population from asbestos' exposure and to safeguard energy efficiency upgrades are even more important and the recent EU policies reflect this aspect. The revision of the Asbestos at Work Directive proposes lowering by ten the limit of asbestos

[1] https://buildings-renovation-makerspace.jrc.ec.europa.eu

exposure compared to current values, promotes awareness campaigns, and provides guidance to EU employers (European Commission, 2022a). Moreover, the Directive requires mandatory identification of asbestos products before demolition or maintenance works, including renovation. At the same time, the European Commission announced a new legislative proposal on the screening and registration of asbestos in buildings and promote an asbestos-free future (European Commission, 2022b).

To enable the development of asbestos removal strategies, the asbestos presence in buildings must be first investigated. Currently, few EU countries have in place measures for asbestos presence identification and registration (Maduta et al., 2022). France initiated the mandatory identification of asbestos before certain works in buildings in 2017 and reinforced the requirement in 2019. The Flemish government introduced the asbestos certificate for buildings for sale as of 2022. Poland plans to remove all asbestos by 2032 and operates a national asbestos database publicly available. Moreover, the scientific publications on asbestos presence are limited with a few exceptions. For instance, (Kameda et al., 2014) estimated the average annual asbestos use in kg/capita/year from 1920–2012 by assessing asbestos data from the United States Geological Survey database (USGS) (R. Virta, 2006). Results revealed that during 1920–1970, 1971–2000 and 2001–2012, the World Health Organization (WHO) European countries used 31.2, 66.5 and 7.8 million metric tonnes of asbestos, respectively, accounting for 48%, 58% and 31% of the global use, respectively. (Alpert et al., 2020) estimated the apparent asbestos consumption per capita before widespread asbestos regulations in the EU and United States in 1980 and 2007, using reports from the USGS as well. The apparent asbestos consumption is calculated as sum of production and imports minus exports. (Krówczyńska and Wilk, 2019) used data on asbestos import derived from USGS and conducted surveys and literature review on asbestos use to estimate the environmental asbestos exposure in Poland. A more recent study (Maduta et al., 2022) presented for the first-time estimations and mapping of average asbestos quantities in dwellings at national and regional level across the EU. The potential quantity of asbestos in dwellings was estimated based on the apparent asbestos consumption in MSs between 1920 and 2003 (as reported by USGS), the fraction of raw asbestos used in building products, the age and number of EU dwellings and their share from the total number of building units built during the indicated periods assuming that asbestos products were equally used in both residential and non-residential buildings. Moreover, the authors identified priority regions for deep renovation considering estimated asbestos quantities, energy performance and economic indicators.

This report provides a first insight into EU regions where high quantity of asbestos fibres could be released in and from buildings during seismic activity. This study can support national authorities and EU policy makers to frame new guidelines to reduce asbestos exposure risk triggered by natural disasters, such as earthquakes, but also to prepare disaster waste management plans. Furthermore, the report identifies which regions can benefit from deep energy renovation ensuring safe and healthy indoor environments besides reduced energy consumption. The analyses are carried out at NUTS (Nomenclature of Territorial Units for Statistics) level 3.

This study is developed within the Energy Efficiency and Sustainable Buildings project, JRC's work programme 2023-2024, portfolio 7 Cities and buildings for better lives, and it is included in the 2023 European Commission work programme. It aims at enabling co-benefits of deep energy renovation, such as improved indoor environmental quality, also through the removal of harmful materials and enhanced structural safety.

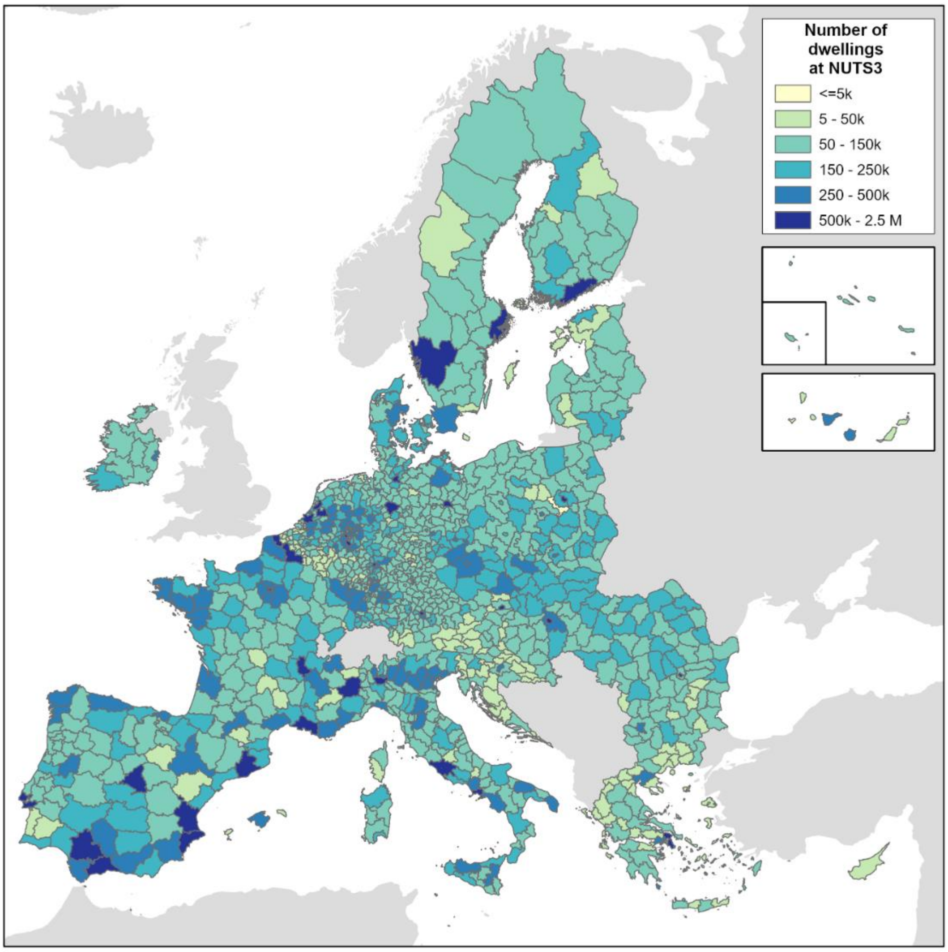
## 2 Characteristics to consider for deep renovation

The Energy Performance of Buildings Directive (EPBD), identified as the main legal tool to enhance energy efficiency of buildings, sets out how EU can decarbonise the building stock by 2050. It encourages Member States to carry out energy efficiency upgrades that address, inter alia, vulnerable categories of people, indoor climate conditions, fire safety, risk related to seismic activity, and accessibility. The proposal for a revised EPBD merges these recommendations under the concept of deep renovation, which is promoted by the Renovation Wave initiative (European Commission, 2021a). This section identifies relevant characteristics to be considered for building stock deep renovation (such as number, age, energy saving potential, asbestos presence, and seismic risk) to unlock the quantification of wider benefits.

### 2.1 EU building stock

The main scope of this study is to prioritize EU regions (NUTS3 level) for deep energy renovation by considering the energy performance, asbestos presence, and seismic risk information to the residential building stock. In this study, the number of dwellings (Figure 1) refers to conventional occupied dwellings located in residential buildings, at NUTS3 level, sourced from Eurostat census data[2]. As the census data is provided using NUTS3 version 2010, the number of dwellings were translated in the NUTS3 version 2021 using the population and area changes occurred during the years to reflect the most updated NUTS3 representation.

**Figure 1.** Number of dwellings in residential buildings in the EU-27, at NUTS3 level (version 2021)



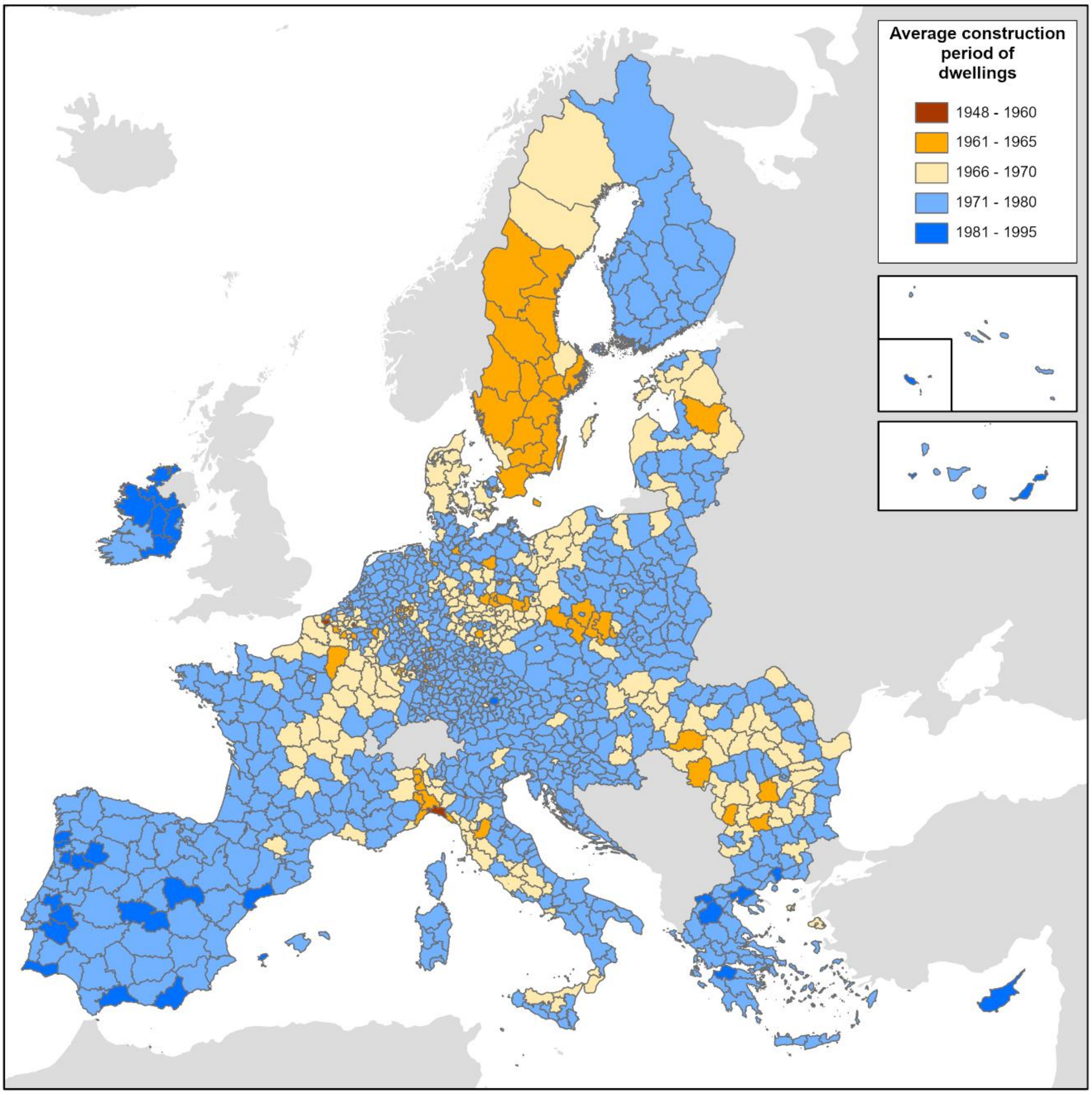

*Source:* JRC elaboration based on Eurostat census data, 2023

The average construction period of dwellings is a good indicator of building performance (Zangheri et al., 2020), not only from the energy performance point of view, but also for the indoor environmental conditions (i.e.,

[2] https://ec.europa.eu/CensusHub2/query.do?step=selectHyperCube&qhc=false

probability of asbestos presence) and safety conditions (i.e., seismic vulnerability). The EU has adopted energy policies promoting energy efficiency in buildings in late 1980s (Economidou et al., 2020). Moreover, most existing EU buildings have been designed without modern seismic requirements (Crowley et al., 2021; Gkatzogias et al., 2022), while buildings dating before 2005 (the year of EU-wide asbestos ban) have high probability of containing asbestos. In addition, old buildings (i.e., dating before 1920) might have retrofit limitations being part of historical heritage. Consequently, the analyses focus on the segment of buildings built between 1919 and 2005 (as asbestos general ban occurred in 2000 across the EU) and based on this time boundaries, Figure 2 shows the average construction period of the residential building stock at NUTS3 level across the EU. It can be observed that most dwellings are built between 1960 and 1980. In some regions in Bulgaria, Cyprus, Greece, Spain, and Ireland the presence of newer residential buildings (dating after 1980) is observed.

**Figure 2.** Average construction period of dwellings built between 1919 and 2005 in the EU, at NUTS3 level (version 2021)

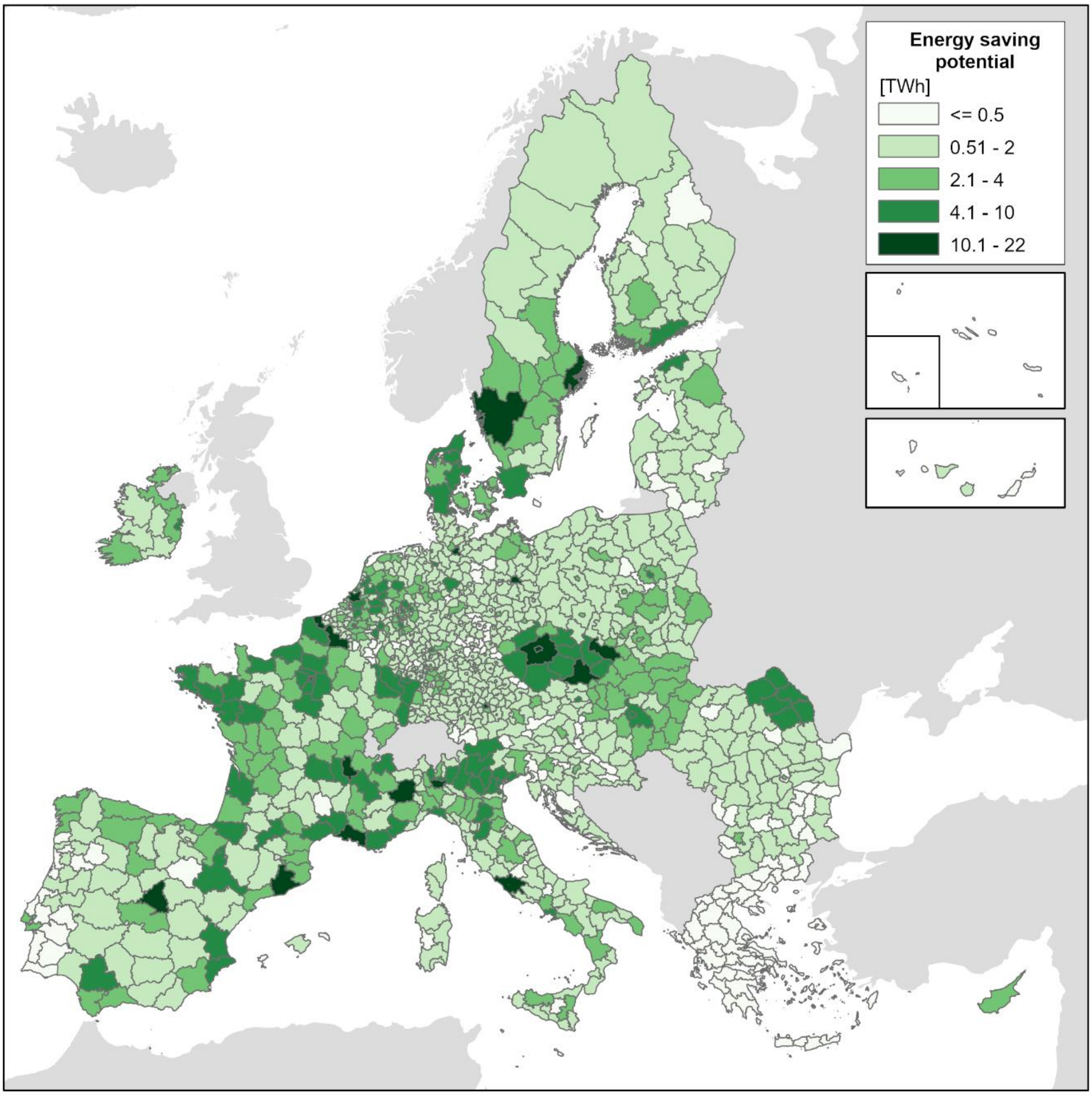



*Source:* JRC elaboration, 2023, based on ESTAT (European Statistics) Census data from 1919-2005.

Moreover, the absolute values of primary energy saving potential of residential buildings are presented in Figure 3, at NUTS3 level. The energy saving potential represents the technical potential of primary energy savings following the renovation of residential buildings as estimated by (Zangheri et al., 2020).

The renovation ambition (primary energy saving targets) reflects the lower energy level between the cost-optimal and the Nearly-Zero Energy Buildings (NZEB) levels, as defined by each MS[3].

**Figure 3.** Absolute values of primary energy saving potential (TWh) in the residential building stock, at NUTS3 level, version 2021




*Source:* JRC elaboration, 2023

The energy saving potential at building level depends on several factors, including the reference building,[4] location (climate conditions), energy renovation target, while the absolute values of energy saving potential at regional level are also strongly related to the absolute number of dwellings. Consequently, metropolitan areas such as Berlin, Milan, Torino, Groo-Rijnmond (Netherlands), Madrid (Spain) and Nord (France) show the highest primary energy saving potential, ranging from 15 to 22 TWh, with Berlin on the top of the list with 22 TWh. In addition, several regions in Czechia, France, Italy, and Sweden shows high energy saving potential. The lowest

[3] The cost-optimal level was considered for Austria, Bulgaria, Cyprus, Finland, Greece, Malta, Portugal, Slovakia and Spain, while the NZEB level was considered for Belgium, Croatia, Czechia, Denmark, Estonia, France, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Poland, Romania, Slovenia and Sweden.

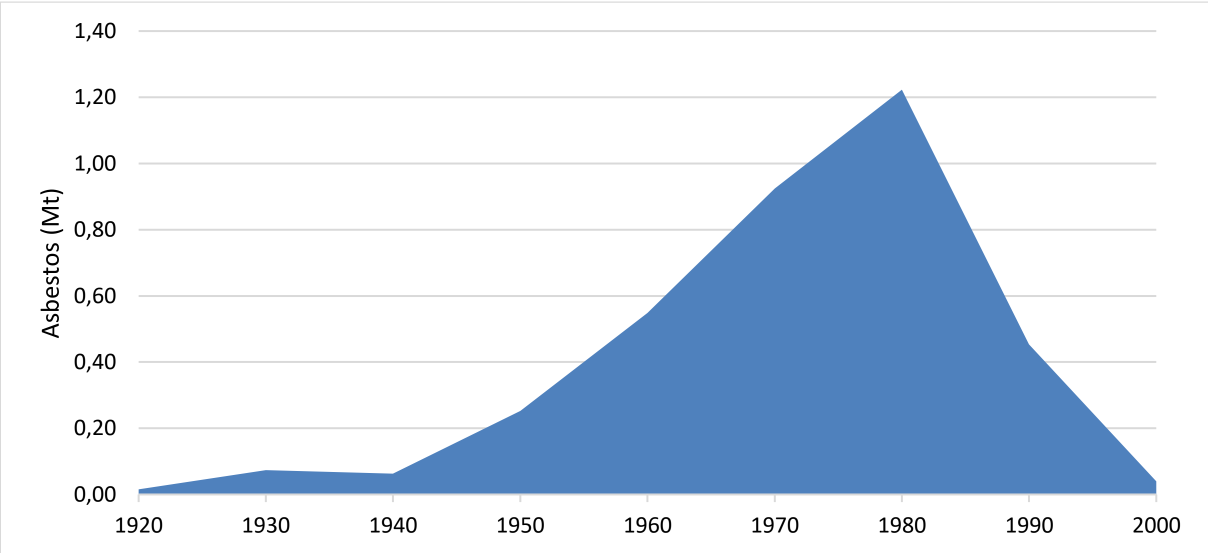
[4] The reference building approach implies using a building representative for a category to perform energy calculation (European Commission, 2012). For the residential sector, Member States set reference buildings for two main categories, single family and multi-family buildings, respectively. The reference building is usually a real example representing the most typical building in its category or a virtual building that includes the most common features identified in its category.

values of energy saving potential (below 0.5 TWh) are observed in all Greek regions, Malta as well as in many regions in Austria, Bulgaria, Croatia, Germany, Portugal.

## 2.2 Asbestos use

Globally, between 1900 and the 1940s, asbestos production rose by 2000% (Kazan-Allen, 2006). Triggered by post-war reconstruction, asbestos production and consumption reached 4.8 million tonnes in 1977 worldwide and remained at over 4 million tonnes annually until 1991 (Allen et al., 2017). In the EU, the largest quantities of asbestos were used between 1960 and 1980 (Virta, 2006). The apparent asbestos consumption[5] reached 920 000 tonnes in 1970. The peak was registered in 1980 with approximately 1.2 million tonnes of asbestos consumed, declining to less than 40 000 tonnes in 2000 (Figure 4). Some EU countries started banning asbestos in late 1970s. The EU-wide ban on the use of asbestos took effect in 2005 (European Commission, 2022b). Despite the ban, we are left with major environmental and public health problems resulting from decades of widespread and uncontrolled asbestos use. Some policies as the EPBD that supports energy performance upgrades of existing buildings and the removal of hazardous substances like asbestos. Furthermore, national programmes adopted asbestos removal strategies. Although, data on the quantity of asbestos removed are publically unavailable with the exception of Poland[6]. Users of buildings and construction workers continue to be exposed to asbestos. In the EU, 78% of occupational cancers are asbestos-related (European Commission, 2022b).

**Figure 4.** Evolution of apparent asbestos consumption in the EU through the years




*Source*: JRC elaboration, 2023

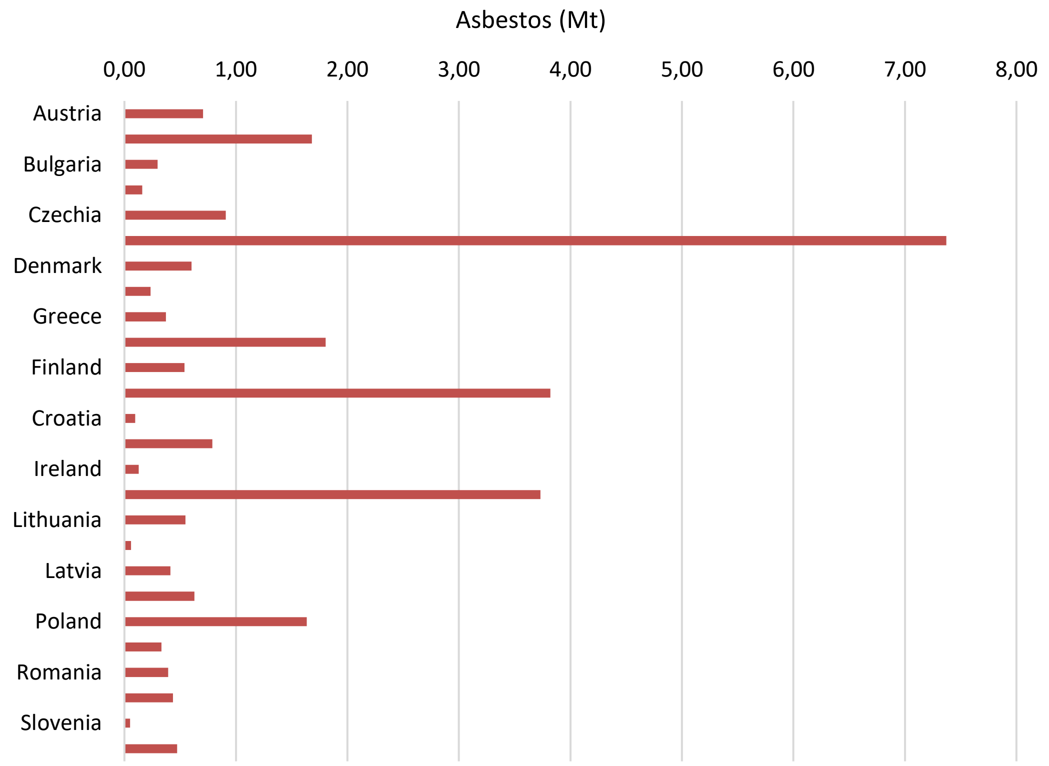
Recently, (Maduta et al., 2022) estimated the potential asbestos consumption in the EU building stock[7] at national and regional level using the United States Geological Survey database (Virta, 2006). The apparent asbestos consumption data in the EU countries is available in 10-year interval from 1920 to 1970, 5-year interval from 1970 to 1995 and yearly thereafter up to 2003. The whole apparent asbestos consumption from 1920 to 2003 is estimated considering a linear interpolation between those years. For this study, the data was disaggregated at regional level for conventional dwellings based on current area extent and past population records, to depict the asbestos quantities in the MSs (using the NUTS3 version 2021). The most uncertain disaggregation is the one of Baltic nations, which are divided from the extremely large territory of the Soviet Union. The age bands are the same as the one provided by Eurostat[8] on reporting number of buildings.

[5] The apparent asbestos consumption is defined as the production plus imports minus exports.
[6] https://bazaazbestowa.gov.pl/en/
[7] Except for Malta, as data on the historically raw asbestos consumption is not available in the reference database
[8] https://ec.europa.eu/CensusHub2/query.do?step=selectHyperCube&qhc=false

Around 70% to 90% of raw asbestos was employed in asbestos cement products (WHO, 2014). Among these, asbestos cement roofs are the most common source of exposure to asbestos fibres in existing buildings (Lee and Kim, 2021).

Figure 5 shows the absolute values of asbestos consumption for building products (in million tonnes), such as roofing shingles, ceiling and floor tiles, separation panels, sewage pipes, rainwater goods, fire and sounds proofing spayed material, and others per country between 1920 and 2003. As expected, among the top asbestos consumers are the largest EU countries such as Germany, Italy, and France. In fact, The Federal Institute for Occupational Safety and Health of Germany estimates that between 1950 and 1990, 4.3 million tonnes of raw asbestos were used to produce asbestos cement products in Germany (BAuA, 2014).

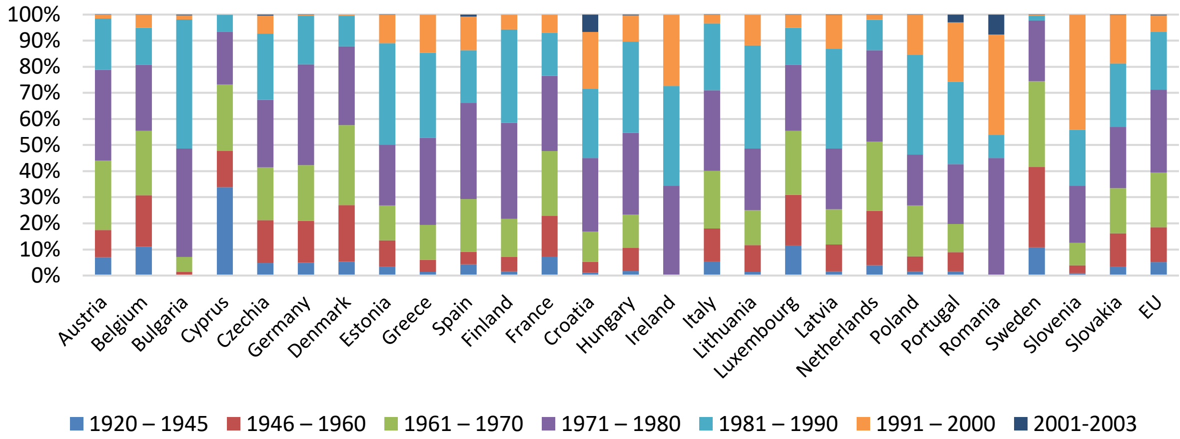
**Figure 5.** Estimated asbestos use in building products between 1920 and 2003 in the EU countries. No data for Malta is available




*Source*: JRC elaboration, 2023 (adapted from (Maduta et al., 2022))

Moreover, the asbestos consumption was disaggregated per main periods of building construction (age bands) and illustrated in Figure 6 that shows the fraction of asbestos consumption in buildings in each construction period. In most countries, the larger share of asbestos was used in buildings between 1970 and 1990. It appears that in Belgium (55%) Cyprus (75%), Denmark (60%), Luxembourg (55%), The Netherlands (50%), and Sweden (75%) the main quantity of asbestos was used before the 1970s, while in Croatia (30%), Ireland (30%), Romania (50%), Slovenia (55%), and Slovakia (20%) significant quantities of asbestos were registered after 1990.

**Figure 6.** Share of asbestos use in building products per construction period in the EU countries and at EU level

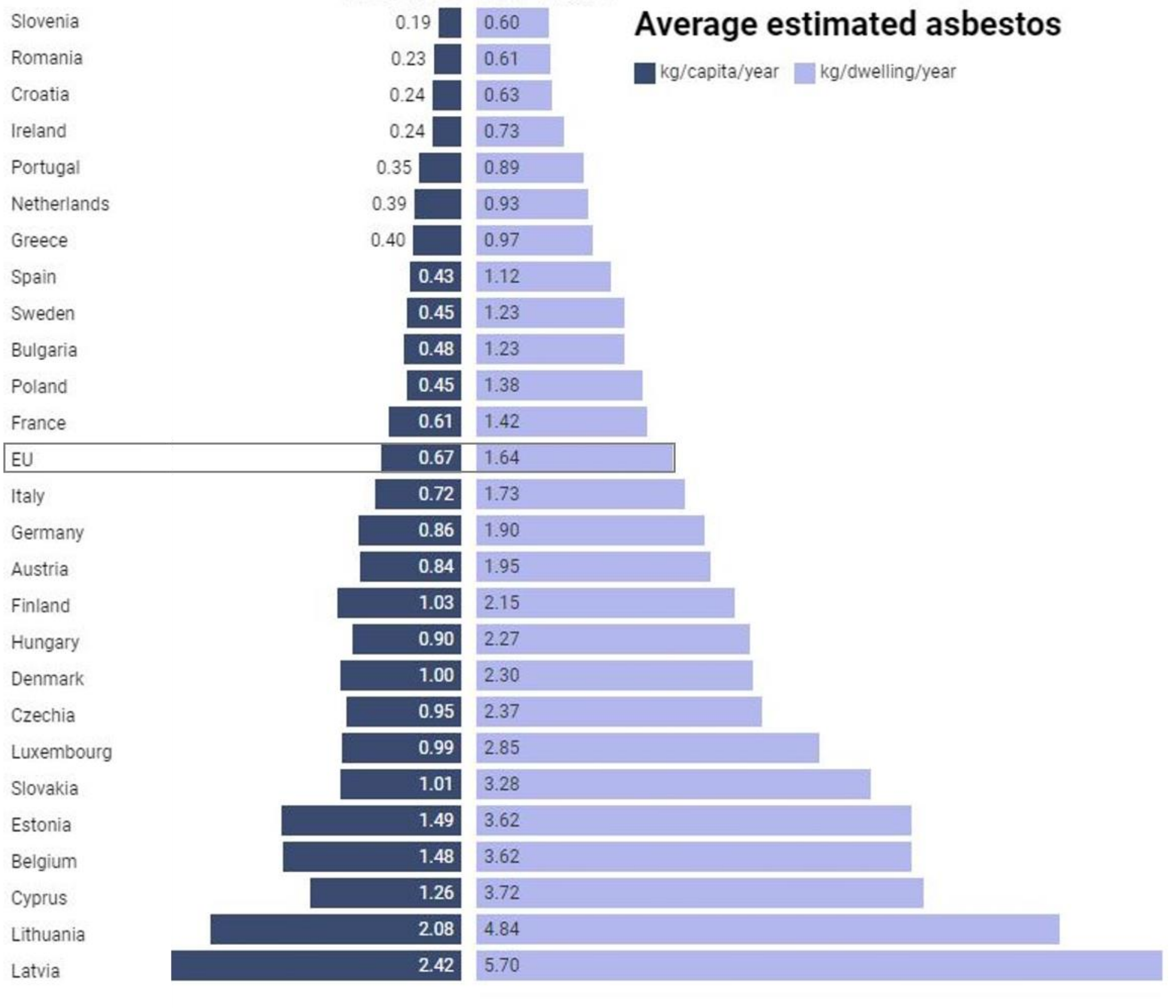



*Source*: JRC elaboration, 2023 (adapted from (Maduta et al., 2022))

Furthermore, the asbestos use in dwellings was estimated by disaggregating the asbestos use in building products based on the share of residential and non-residential buildings for each age band (Pezzutto et al., 2018). Figure 7 illustrates the average annual asbestos use in residential buildings between 1920 and 2003, in each EU country and at EU level, per capita and per dwelling. The figure employs the number of dwellings built between 1920 and 2005 as explained in 2.1 and the EU population in the year 2022[9] to reflect current asbestos exposure assuming that the estimated quantities of asbestos are still present in existing buildings.

[9] https://ec.europa.eu/eurostat/databrowser/view/TPS00001/default/table

**Figure 7.** Estimated asbestos use in residential buildings between 1920 and 2003, in the EU countries and at EU level (in kg/capita/year and kg/dwelling/year)




*Source*: JRC elaboration, 2023

Previous research on asbestos impact on human health associated historical asbestos consumption and asbestos-related diseases and found 1.0 kg/capita/year as high level and 2.0 kg/capita/year as extremely elevated level of asbestos use (Kameda et al., 2014). Following this approach, Figure 7 shows that seven countries have elevated level of asbestos use per capita (Finland, Denmark, Slovakia, Estonia, Belgium, Luxembourg, and Cyprus), while two countries have remarkably high level of asbestos use (Lithuania and Latvia). At the same time, all these countries (plus Czechia and Hungary) show an average asbestos use in dwellings above 2.0 kg/dwelling/year between 1920 and 2003. The least critical cases are registered in Greece, The Netherlands, Portugal, Ireland, Croatia, Romania and Slovenia, where the average asbestos use in dwellings per capita appears below 0.4 kg/year and per dwelling below 1.0 kg/year. At the EU level, the average asbestos use in dwellings between 1920 and 2003 is approximately 0.67 kg/capita/year and 1.64 kg/dwelling/year.

## 2.3 Seismic risk

Natural disasters such as earthquakes can harm and devastate communities in several ways with cascading effects. During and after an earthquake, obsolete buildings with asbestos-containing materials may be damaged (depending on the earthquake intensity and building fragility) and asbestos fibres can be released in the atmosphere becoming a long-term health hazard (Kazan-Allen, 2006). The release of asbestos from buildings that are damaged by an earthquake can have a broad range of impacts varying from socioeconomic to health-related issues. In fact, (Kim et al., 2020) showed through measurements that asbestos fibres above the acceptable limit were generated where asbestos-containing buildings were damaged during the Great Hanshin earthquake.

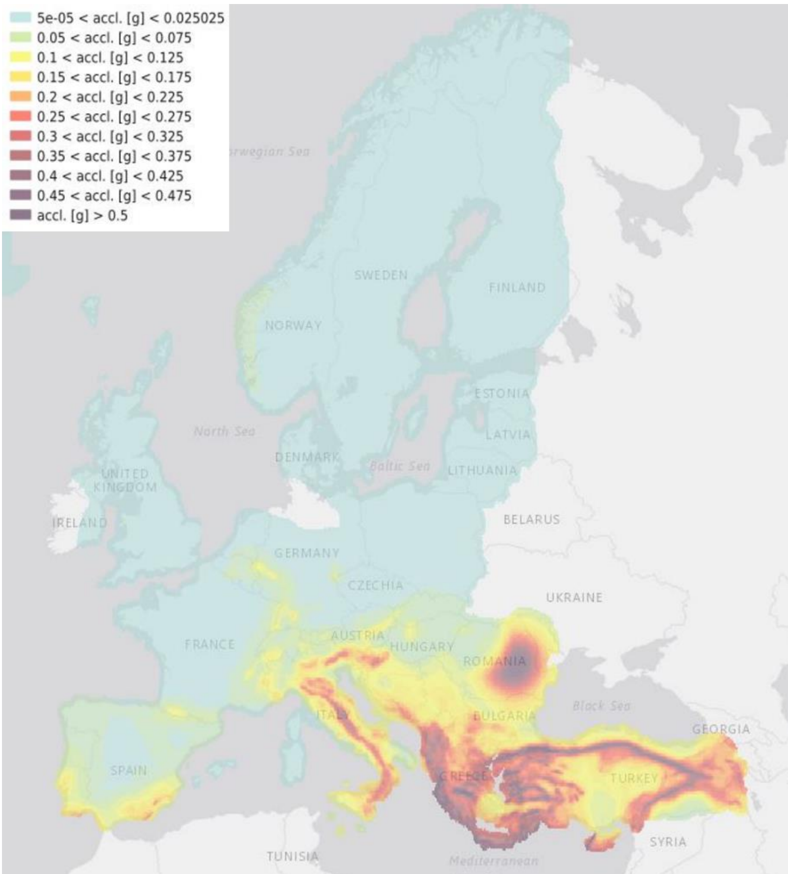
Furthermore, the aftermath of an earthquake (related to asbestos) is quantities of asbestos waste. To dispose, reuse and recycle post-earthquake building waste, the asbestos waste must be separated from demolition waste. However, such operation can be challenging as asbestos waste is easily mixed with other wastes and often is not visible (Trotta et al., 2022). Consequently, improper demolition or improper clean-up of sites after an earthquake (or burnt asbestos material) can increase the local level of asbestos exposure. Asbestos is also a threat for the health of workers and occupants during the repair of damaged buildings.

To estimate the probability and magnitude of undesirable consequences resulting from potential future earthquakes, the seismic risk must be assessed (Gkatzogias et al., 2022). To determine seismic risk, information on the spatial distribution of buildings and people (i.e. exposure), the physical vulnerability of the built environment as well as the earthquake hazard are needed.

The seismic hazard describes the expected level of ground motion intensity due to earthquakes, and it is considered as the first step in assessing seismic risk. According to the European Seismic Hazard Model 2020 (Danciu et al., 2021), Balkan and Mediterranean countries (such as Bulgaria, Cyprus, Greece, Romania, Croatia, Slovenia, Italy, Spain, Portugal) present the highest seismic hazard among the EU countries (Figure 8).

As mentioned above, besides seismic hazard, the vulnerability of the built environment is necessary to estimate the seismic risk. In the EU, most buildings were designed and constructed without prescriptions for earthquake resistance thus forming a vulnerable built environment to earthquakes (Palermo et al., 2018).

**Figure 8.** European seismic hazard map (mean values of PGA on reference rock with a return period of 475 years)

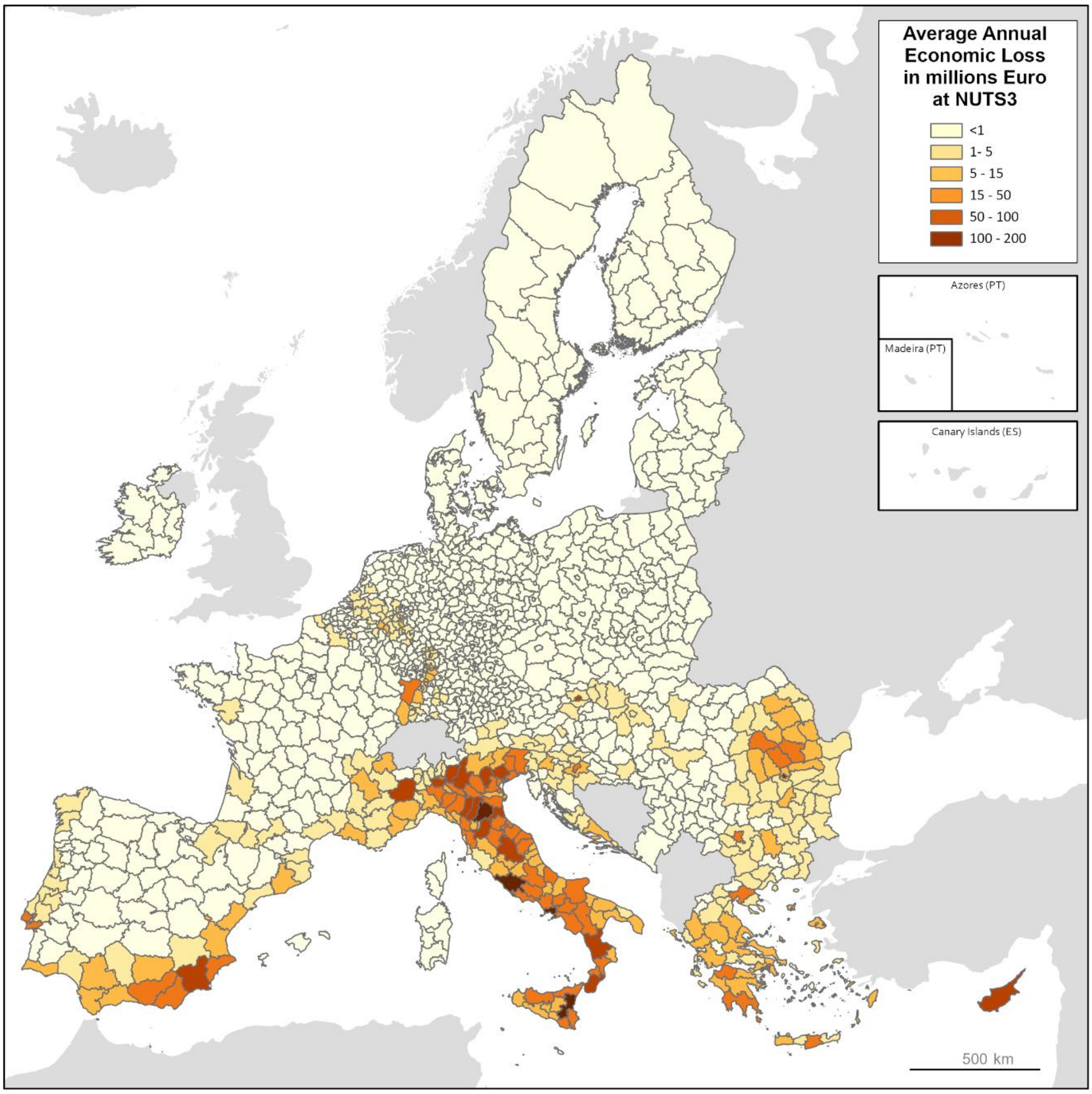



*Source*: (Danciu et al., 2021)

Seismic risk is presented in Figure 9 in terms of average annual economic loss (AAEL) at the regional level, as obtained from Gkatzogias et al. (2022). AAEL represents the average quantity of money that would be spent yearly to repair all buildings within a region assuming that building loss occurs like clockwork, once a year, with the same amplitude. Overall, the distribution of average annual economic loss clearly follows the pattern of seismic hazard (Figure 8). However, apart from hazard, AAEL is affected by the vulnerability of the building stock. As AAEL is an aggregated metric, it further depends on the number and the value of buildings within regions. The top 100 priority regions include regions from Austria, Bulgaria, Cyprus, Germany, Greece, Spain, France, Croatia, Italy, Portugal, Romania, and Slovenia with aggregated AAEL more than 3.5 billion euro

(Gkatzogias et al., 2022). Note here that for some regions, as Canary Islands, Madeira, Azores, seismic risk results are unavailable.

**Figure 9.** Seismic risk expressed in millions of euros, AAEL (Average Annual Economic Loss (Gkatzogias et al., 2022)) in residential EU building stock, NUTS3 level (version 2021)




*Source*: JRC elaboration

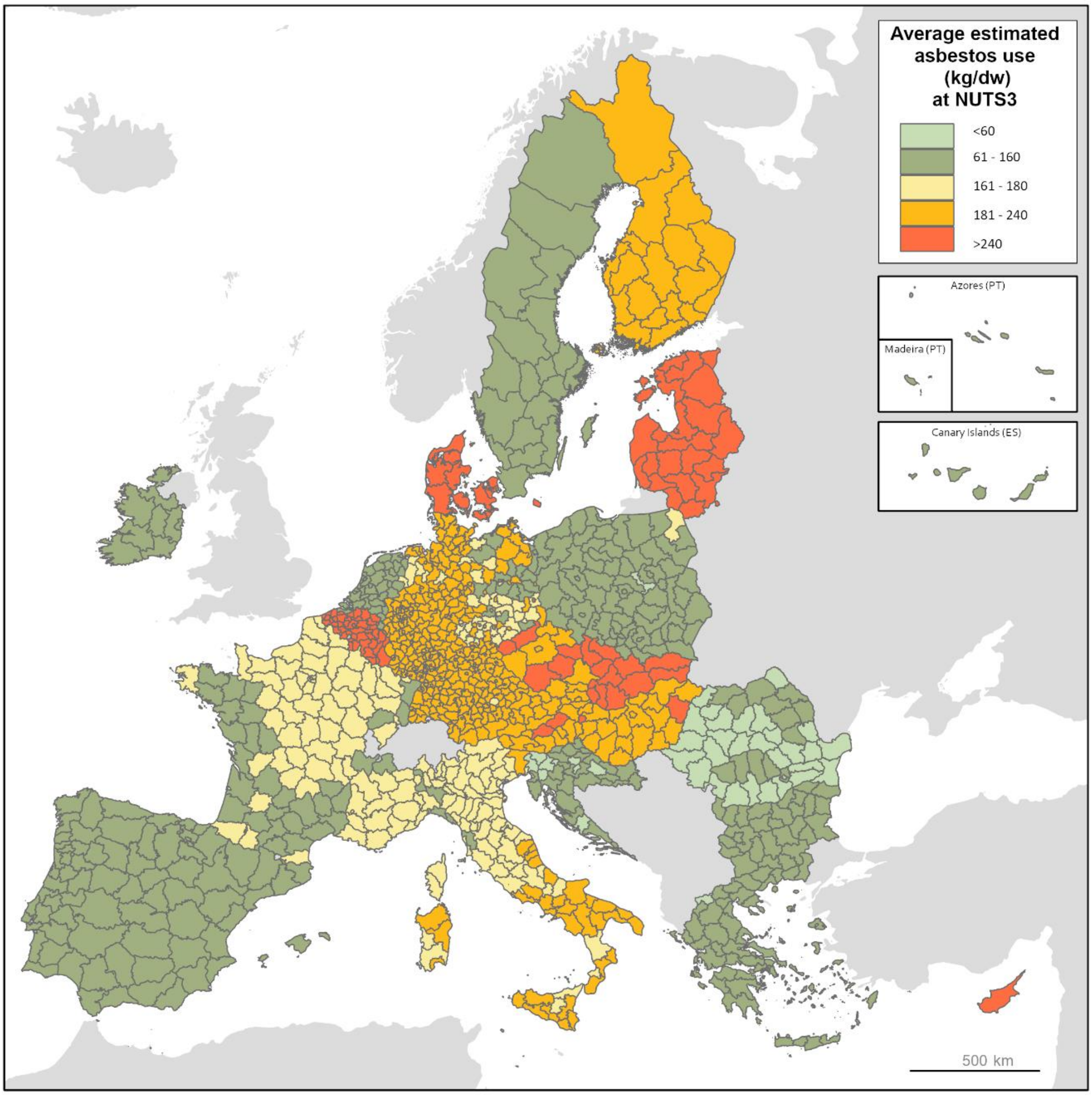
# 3 Priority regions for deep renovation

In the following sections the methodology for the identification of regions that can be prioritized in energy renovation plans at NUTS3 level is described. The prioritisation is made based on (i) asbestos presence in dwellings, (ii) combined asbestos presence and seismic risk and (iii) composite indicator covering asbestos presence, seismic risk and energy saving potential of the residential building stock.

## 3.1 Asbestos presence in dwellings

The asbestos quantities in residential buildings were estimated following the method introduced in (Maduta et al., 2022) and explained in Section 2.2. The asbestos use was first estimated at country level and disaggregated at regional level employing the national quantities of asbestos use in dwellings and the number of dwellings at regional level, per period of construction. Figure 10 shows the estimated average quantity of asbestos per dwelling at NUTS3 across the EU.

**Figure 10.** Estimated average quantity of asbestos in the EU dwellings, NUTS3 level (version 2021)




*Source*: JRC elaboration, 2023

Regions with higher asbestos quantities are observed in Belgium, Cyprus, Czechia, Denmark, Estonia, Latvia, Lithuania, Luxemburg, and Slovakia, exceeding 240 kg per dwelling. High asbestos quantities are also observed in most regions of central Europe, ranging from 160 to 240 kg per dwelling. Smaller quantities are noted in

Bulgaria, Ireland, Greece, Sweden, The Netherlands, Spain, Portugal, Croatia, and Romania, with many regions of Romania, Croatia and Slovenia having less than 60 kg of asbestos per dwelling. As such, Figure 10 reveals regions at risk of higher asbestos exposure in residential buildings indicating where asbestos registration and removal should be prioritized before any renovation planning.

## 3.2 Asbestos presence and seismic risk

The estimated asbestos use in dwellings is combined with seismic risk to give a prioritisation of EU regions where earthquakes may trigger asbestos release due to damage of buildings. Here, seismic risk is presented in terms of average annual economic loss (AAEL) at the regional level and represents the average quantity of money that would be spent yearly to repair all buildings within a region assuming that building loss occurs like clockwork, once a year, with the same amplitude, (Gkatzogias et al., 2022).

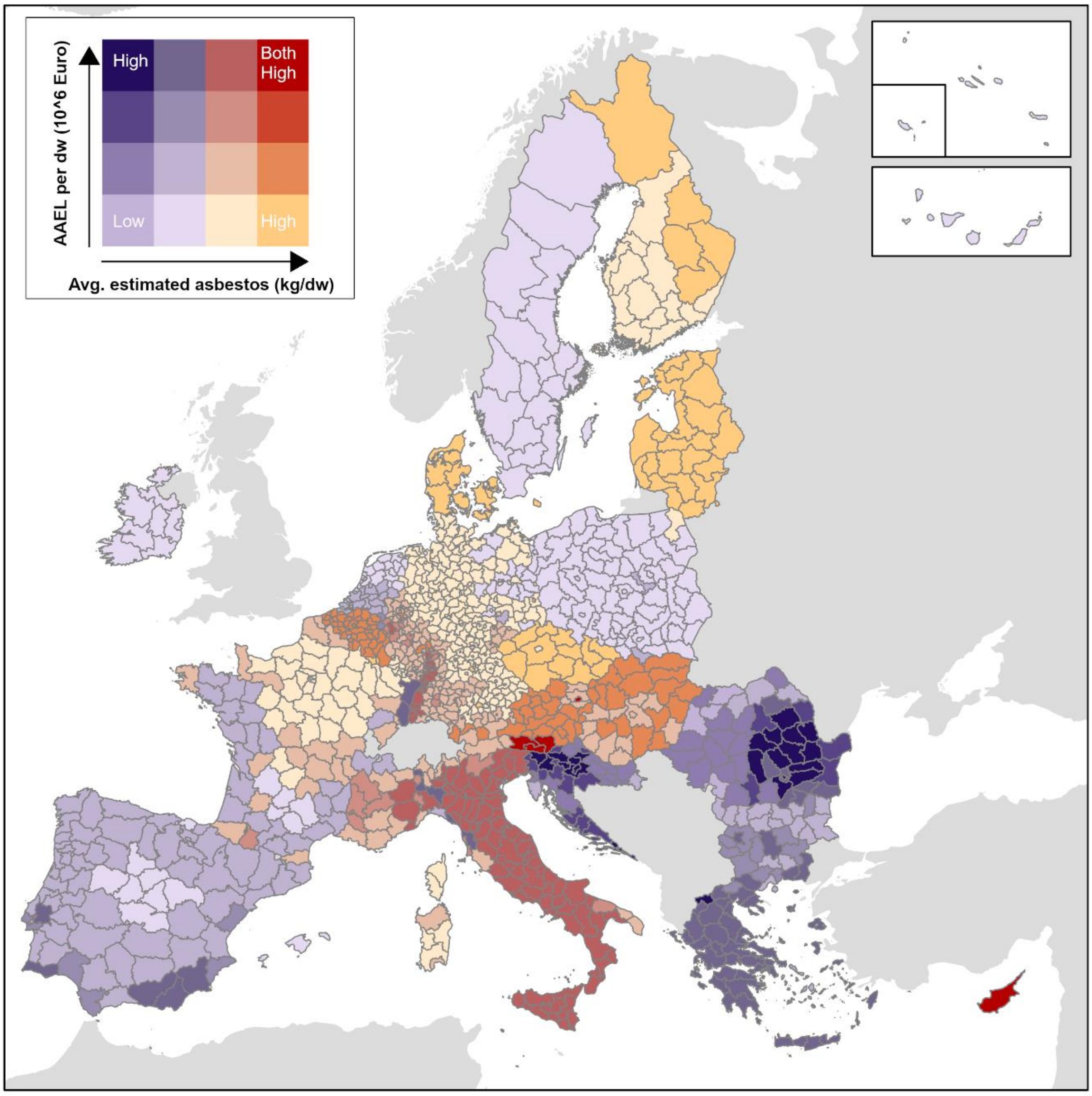
The dwellings' data source used in AAEL calculation and asbestos estimation were different. Hence, an average AAEL per dwelling was estimated at NUTS3 level using the number of dwellings used in the AAEL calculations. Figure 11 shows a bivariate map[10] of the new estimated AAEL per dwelling (in million euros) and the average estimated asbestos quantity per dwelling (kg/dwelling) at NUTS3 level. Note here that for some regions, as Canary Islands, Madeira, Azores, seismic risk results are unavailable.

The regions showing high seismic risk and high asbestos presence are in southern Europe, specifically in Italy (within Campania, Puglia, Basilicata and Sicily) and Cyprus. Moreover, highly affected regions under combined seismic risk and asbestos use are also observed in Austria, France, Germany, Slovenia. In Bulgaria, the capital region is the most vulnerable one. Within these countries, such regions may be prioritised for deep renovation to address high seismic risk and asbestos presence, avoiding cascading disasters.

Many regions in Croatia, Greece, Spain, and Romania are subject to high seismic risk, but the quantities of asbestos are lower (Figure 11) while most regions in Czechia, Denmark, Finland, Poland, Slovakia, and the Baltic countries are the least affected by seismic activity but the presence of asbestos is moderate to high.

[10] Bivariate choropleth map combines two datasets into a single map allowing to show relatively how much of variable 1 and variable 2 exist in each enumeration unit.

**Figure 11.** Bivariate map representing average asbestos presence in dwellings (kg/dwelling) and seismic risk (AAEL per dwelling in million EUR) in the EU residential building stock, NUTS3 level (version 2021)




*Source*: JRC elaboration, 2023

## 3.3 Energy saving potential, asbestos presence and seismic risk

To capture the multi-dimensional aspects that can be addressed with deep renovation of existing buildings, we designed a composite indicator by compiling into a single index the following individual indicators: (1) seismic risk, and (2) asbestos quantity.

Composite indicators are recognized as useful tools for policy analysis. Normalization methods, weighting and aggregation highly influence the final form of composite indicators (OECD, 2008). The weight of each variable depends on the emphasis that the designer wants to give to different components. In this study, we applied the same weight for the components, meaning that, in this case, the two variables are equally important. Specifically:

- Asbestos use (quantity) in kg/dwelling: 50%;
- Seismic risk (AAEL) in $10^6$ EUR/dwelling: 50%.

In order to provide a useful tool for prioritising the deep renovation in EU, the weighted components were aggregated (by normalising them on a homogeneous scale) and the resulted composite indicator at NUTS3 level was combined with the primary energy saving potential (TWh/dwelling) obtained from a previous study (Zangheri et Al., 2020) in a bivariate map, Figure 12. Concretely, the composite indicator describes the overall regional criticality from low (0.0-0.2) to high (0.8-1.0) at NUTS3 level considering the asbestos presence and seismic risk for the residential building stock.

A detailed table, Table 1, with the first 30 regions sorted based on the composite indicator (higher to lower) and the corresponding values for asbestos, AAEL and dwellings are presented. The majority of the first 30 regions, are located in Italy, 23 out of 30, followed by some regions in Latvia, 6 out of 30, and one region in Belgium, with the composite indicator's values between 0.65 to 1.0. The countries following after the first 30 regions are Belgium and Lithuania with the composite indicator's values ranging from 0.64 to 0.5. In the first 100 regions a couple of Greek regions have values equal to 0.54 (high seismic risk and low asbestos use). The Italian regions continue to be present even after the first 100 regions. These regions could benefit from deep building renovation, which will help the reduction of seismic risk in Greece, Italy, and asbestos exposure in Belgium, Italy, Latvia and Lithuania.

**Table 1.** Summary table sorted based on the composite indicator from higher to lower values. The first 30 regions are presented with the corresponding values of number of dwellings, AAEL total, the AAEL per dwelling, the total asbestos, the average asbestos per dwelling, the primary energy saving potential, the primary energy saving potential per dwelling and the composite indicator.

| NUTS3 | NUTS3 NAME | Number of dwellings | AAEL ($10^6$. EUR) | AAEL per dwelling (kEUR/dw) | Asbestos use (tonnes) | Asbestos use (kg/dw) | Primary energy saving (TWh) | Primary energy saving per dwelling (MWh/dw) | Composite Indicator |
|---|---|---|---|---|---|---|---|---|---|
| **ITH54** | Modena | 231894 | 59.5 | 256.8 | 40.0 | 172.4 | 3.6 | 15.6 | 1 |
| **ITH57** | Ravenna | 140294 | 35.7 | 254.5 | 23.0 | 164.1 | 2.2 | 15.6 | 0.98 |
| **ITF65** | Reggio di Calabria | 194927 | 47.1 | 241.5 | 35.3 | 181.3 | 1.9 | 9.8 | 0.96 |
| **ITI21** | Perugia | 203724 | 49.4 | 242.4 | 36.1 | 177.1 | 2.7 | 13.3 | 0.96 |
| **ITH56** | Ferrara | 130349 | 31.3 | 240.1 | 21.9 | 167.6 | 2.0 | 15.6 | 0.94 |
| **ITF63** | Catanzaro | 123290 | 28.4 | 230.5 | 23.0 | 186.7 | 1.2 | 9.8 | 0.94 |
| **ITH53** | Reggio nell'Emilia | 167771 | 39.1 | 233.1 | 27.7 | 165.4 | 2.6 | 15.6 | 0.92 |
| **ITF11** | L'Aquila | 90745 | 19.9 | 218.9 | 15.7 | 173.0 | 1.3 | 14.6 | 0.88 |
| **ITF61** | Cosenza | 237761 | 47.8 | 201.0 | 42.8 | 180.0 | 2.3 | 9.8 | 0.84 |
| **ITH58** | Forlì-Cesena | 134077 | 26.8 | 200.2 | 23.4 | 174.3 | 2.1 | 15.6 | 0.82 |
| **ITH52** | Parma | 149395 | 30.4 | 203.2 | 25.0 | 167.2 | 2.3 | 15.6 | 0.82 |
| **ITH55** | Bologna | 364470 | 73.4 | 201.3 | 59.4 | 162.8 | 5.7 | 15.6 | 0.81 |
| **ITG17** | Catania | 372653 | 71.1 | 190.9 | 68.8 | 184.7 | 2.9 | 7.8 | 0.81 |
| **ITF64** | Vibo Valentia | 53261 | 10.0 | 187.8 | 9.4 | 176.8 | 0.5 | 9.8 | 0.79 |
| **LV007** | Pierīga | 103998 | 0.02 | 0.2 | 58.4 | 561.5 | 1.1 | 10.4 | 0.75 |
| **LV005** | Latgale | 114501 | 0.01 | 0.1 | 64.2 | 561.1 | 1.2 | 10.4 | 0.75 |
| **LV006** | Rīga | 217480 | 0.02 | 0.2 | 121.1 | 556.8 | 2.3 | 10.4 | 0.75 |
| **ITF21** | Isernia | 26149 | 4.6 | 175.1 | 4.5 | 172.0 | 0.4 | 16.2 | 0.74 |
| **LV009** | Zemgale | 86452 | 0.02 | 0.2 | 47.2 | 546.1 | 0.9 | 10.4 | 0.73 |
| **LV003** | Kurzeme | 91929 | 0.01 | 0.1 | 50.1 | 544.8 | 1.0 | 10.4 | 0.73 |
| **ITF62** | Crotone | 57997 | 9.3 | 160.5 | 11.0 | 190.1 | 0.6 | 9.8 | 0.72 |

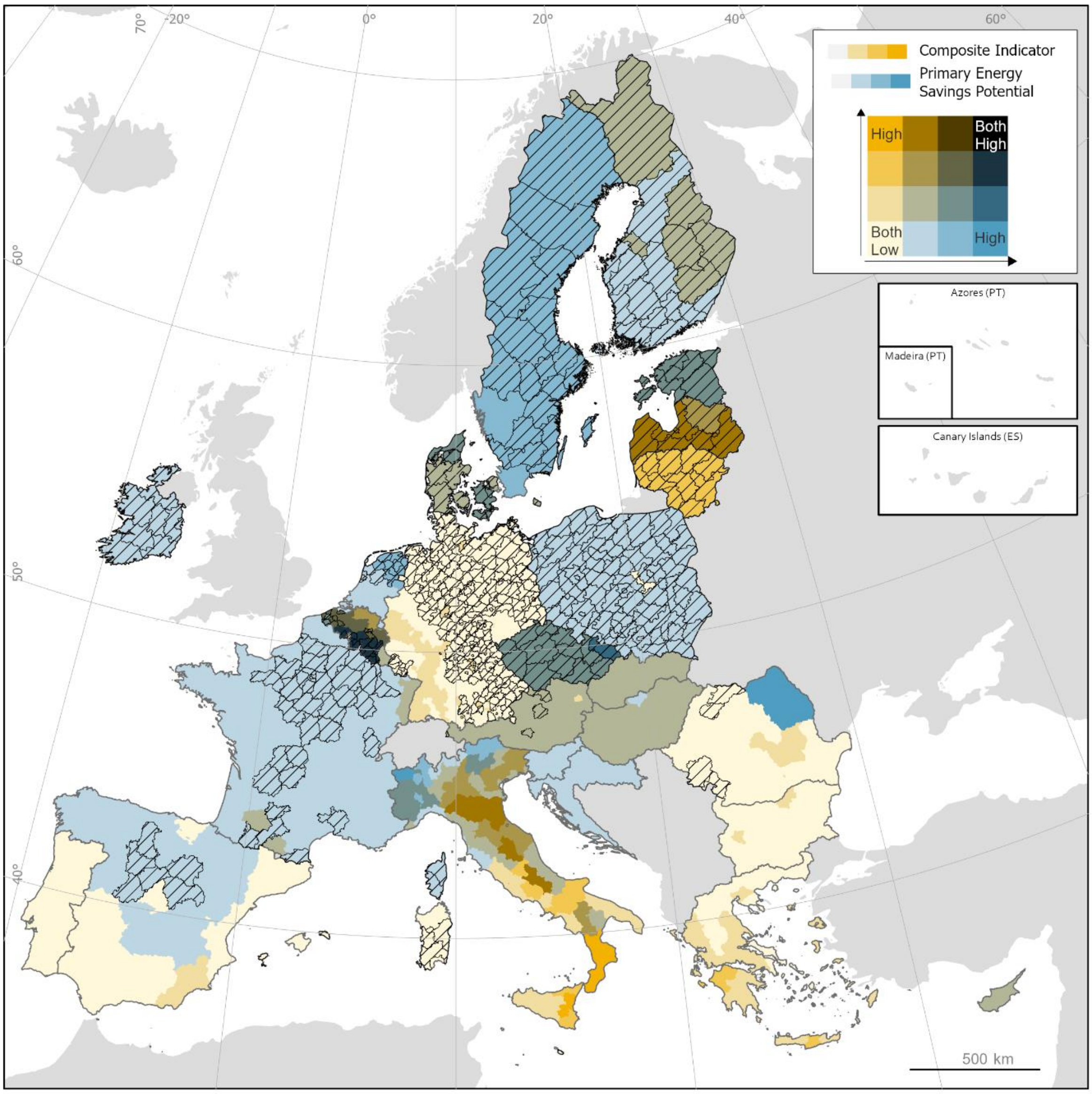
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **ITH34** | Treviso | 280056 | 43.6 | 155.7 | 46.3 | 165.4 | 5.2 | 18.4 | 0.67 |
| **LV008** | Vidzeme | 68518 | 0.01 | 0.1 | 34.3 | 500.1 | 0.7 | 10.4 | 0.66 |
| **ITG19** | Siracusa | 142982 | 20.2 | 141.3 | 27.2 | 190.0 | 1.1 | 7.8 | 0.66 |
| **ITC4B** | Mantova | 125290 | 19.2 | 153.4 | 20.5 | 163.3 | 2.2 | 17.7 | 0.66 |
| **ITH41** | Pordenone | 103023 | 15.2 | 147.2 | 17.7 | 171.6 | 1.8 | 18.0 | 0.65 |
| **ITH59** | Rimini | 113719 | 16.4 | 144.3 | 20.1 | 176.7 | 1.8 | 15.6 | 0.65 |
| **ITH42** | Udine | 189490 | 26.9 | 142.0 | 34.4 | 181.5 | 3.4 | 18.0 | 0.65 |
| **BE225** | Arr. Maaseik | 78397 | 1.0 | 12.6 | 36.2 | 461.3 | 1.4 | 18.4 | 0.65 |
| **ITF32** | Benevento | 92276 | 12.7 | 138.06 | 17 | 184.1 | 0.86 | 9.3 | 0.64 |

As final result we obtained the bivariate map shown in Figure 12. The combination of the composite indicator and the primary energy saving potential in a bivariate map is expected to identify EU regions where building renovation would bring not only substantial energy savings and thus emissions curtailment, but also additional benefits, such as reduction of seismic risk and potential asbestos exposure if deep renovation is pursued.

It is confirmed from the map that the most vulnerable regions based on the composite indicator are located in Italy with values in range between 0.8-1.0 (Modena, Ravenna, Reggio di Calabria are the top three regions). In these regions, both the presence of asbestos and seismic risk is high. Latvia, Belgium, Lithuania and some regions in Greece follow with values between 0.7- 0.5. Asbestos use is high in Belgium, Latvia, and Lithuania, medium to high in Italy and low in Greece. Seismic risk is null in Latvia and Lithuania, low in Belgium and high in Greece and Italy.

To help readers comprehend better the results and distinguish if regions with high values of composite indicator is due to high asbestos use or seismic risk, we used a diagonal hatch pattern when AAEL values are less than 0.1 million EUR as it is the smallest value observed and a conventional limit to describe low seismic risk, Figure 12. Hence, the regions with hatch pattern coloured in dark yellow have high asbestos use values and low or no seismic risk. Furthermore, the bivariate map's light yellow colours indicate low values of primary energy saving potential and composite indicator. For the composite indicator this means that both the asbestos use and AAEL have low values in these regions. The dark blue colour indicates regions with high values of asbestos or AAEL and energy saving potential. These regions should be prioritized during a renovation plan. The regions in dark yellow represent high values of the composite indicator. Furthermore, the light darker blue colour shades (right low corner of the cube legend of the bivariate map) indicate regions with high potential of energy savings. As it observed from the bivariate map, regions in Belgium such as Arr. Dinant could benefit from deep building renovation and could be prioritized. Several regions in Italy could also benefit.

**Figure 12.** Composite indicator covering asbestos use and seismic risk of the residential building stock combined with the primary energy savings potential in a bivariate map, NUTS 3 level (version 2021). The regions with diagonal hatch pattern indicate low AAEl values (<0.1 $10^6$ EUR)




*Source*: JRC elaboration, 2023

# 4 Case studies of man-made disasters and asbestos release

The EU takes measures to better protect people from asbestos exposure. The revision of the Asbestos at Work Directive and the EC Communication on working towards an asbestos-free future creates a strong and coordinated framework to protect people (both workers and occupants) from asbestos exposure during planned and organised activities, such as building renovation (European Commission, 2022a, 2022b). However, during natural or anthropogenic disasters which involve damage of the built environment, exposure to asbestos may increase in an uncontrolled way, generating secondary disasters. The following sections present case studies of asbestos release as a secondary disaster after natural disasters (e.g., earthquakes) and human-induced disasters (e.g., wars). In this context, the EC initiative on mandatory screening and registration of asbestos in buildings followed by national asbestos removal strategies could mitigate the risk of secondary disasters.

**The war in Ukraine**

One of the short-term consequence of a war is the destruction and deterioration of physical infrastructure (building destruction) similar to an earthquake. The recent war in Ukraine has caused the loss of life of many civilians but also damaged a huge portion of the Ukrainian infrastructure and residential building stock leaving millions of people homeless (Kazan-Allen, 2022).

Historically, Ukraine consumed enormous quantities of asbestos and during the Soviet Union era it was also a major asbestos producer (Nielsen and Hodgkin, 2022). However, consistent data on asbestos production and consumption for Ukraine is available only after the dissolution of the Soviet Union (i.e., for 1998-2003 in (Virta, 2006)). To estimate the apparent asbestos use in Ukraine between 1920 and 1991, the asbestos use in the Soviet Union was disaggregated based on the past population records of the union and its member states (Maduta et al., 2022). In 2005, Ukraine reported an asbestos use of 183 000 tonnes. Based on Ukraine's population (43.79 million) in 2021 and the reported asbestos use in 2005, the per capita kilogram of asbestos corresponds to 4 kg/capita. Between 2009 and 2015, Ukraine imported an average of 42 200 tonnes of raw asbestos annually (Kraja, 2017). Between 2018 and 2020, the average annual consumption of asbestos in Ukraine was over 10 000 tonnes. Moreover, in 2020, Ukraine imported 4.33 million USD in asbestos, becoming the 11th largest importer of asbestos in the world (OEC, 2020). Based on these data, .

The first efforts to phase-out asbestos in Ukraine started in 2011. In 2017, the attempt to completely ban asbestos failed, facing opposition from asbestos stakeholders from Russia and Kazakhstan (biggest producers of global asbestos 65%) but also from Ukrainian companies working with asbestos (Asbestos Justice, 2017; Kraja, 2017). Only the Ukrainian asbestos market employs more than 4000 people. In late 2022 Ukraine's Ministry of Health has banned the use of all types of asbestos (Kazan-Allen, 2022).

It is estimated that more than 1 billion square meters of asbestos-cement slate roofs were installed across Ukraine, representing around 60% of the country's roofing (Kryvoruchkina, 2022).

It is expected that asbestos exposure levels will increase during the war clean-up (UNEP, 2022). In the rush to respond to damages, rescue services (fire fighters or emergency or military personnel) are exposed to asbestos, while the remaining destroyed buildings are levelled to provide space for emergency shelter and housing, leaving people living amongst millions of tonnes of asbestos-contaminated waste.

The Rapid Damage and Needs Assessment report estimated that with about 240 000 houses destroyed, about 5-10 tonnes of asbestos could have been released in the air during the war (World Bank et al., 2022). Around 817,000 residential units were impacted by the war, 38 % of them destroyed beyond repair (as of July 2022). The urban areas are the ones most impacted and especially the apartment buildings. The age of residential building stock in big cities in Ukraine varies with the majority to date before 1980 (28.1 %) (Oppelt et al., 2020).

**Figure 13** shows the estimated asbestos consumption in Ukraine in a 5-year interval, between 1920 and 2020. The percentage of asbestos used in the Ukrainian buildings is unknown. The highest values of asbestos consumption were observed in the periods from 1985 to 1990 with a decrease during the last few years.

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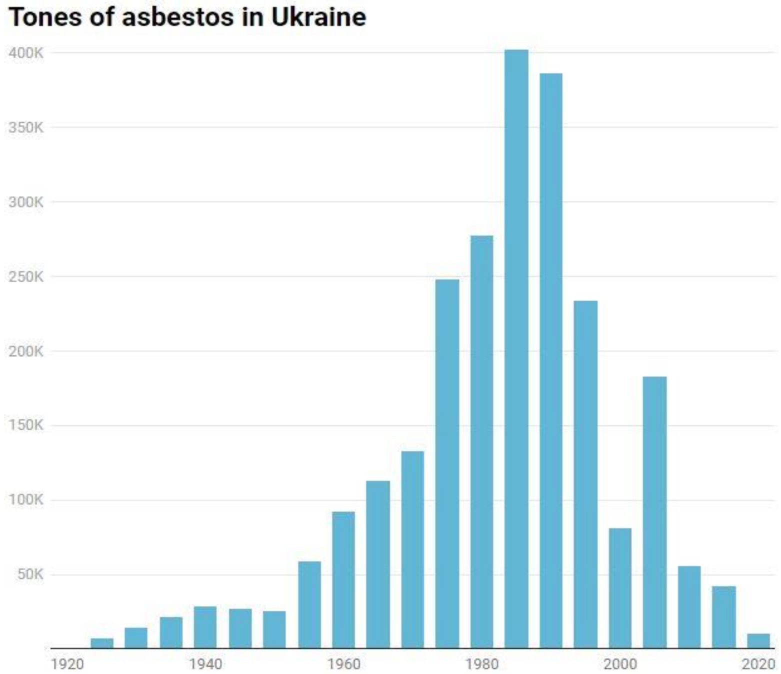
**Figure 13**. Asbestos consumption in Ukraine since 1920




*Source*: JRC elaboration, 2023

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**World Trade Centre attack**

Another man-made disaster with cascading impacts including asbestos exposure was the World Trade Center's (WTC) collapse in 2001. The WTC was constructed in the late 1960s and early 1970s, when United States reported high asbestos consumption (Virta, 2006). Spray-on asbestos was used to fireproof part of the north tower's steel structure. However, many other asbestos-containing products were incorporated in both towers. It is estimated that 2 000 tonnes of asbestos fibres were released into the air during the collapse and about 500 000 people were exposed to it, including 90 000 workers (Whitmer, 2023). Higher levels (than the accepted values of United States standards at that time) of asbestos concentration were observed in the air in the first days after the collapse but decreased within the accepted values after first few days (Landrigan et al., 2004). Samples of dust contained between 0.8% to 3.0% asbestos fibres (chrysotile) and indoor concentration (in nearby apartments) was found at higher levels than in the outdoor environment (Lioy et al., 2002). Scientific evidence shows considerable risk of asbestos-related disease (i.e., mesothelioma) among the first responders in contact with the cloud of dust, workers at ground zero and workers employed to clean asbestos waste from contaminated buildings (Landrigan et al., 2004). Moreover, almost 4 500 persons exposed to collapse dust reported symptoms associated with mesothelioma (Whitmer, 2023).

**Great Hanshin earthquake**

An example of asbestos release after an earthquake is the Great Hanshin-Awaji earthquake 1995, in Japan. Atmospheric monitoring by the Environmental Agency (Japan) after the earthquake showed an increase of asbestos concentration in the air by at least 1.5 times in the affected area (Kim et al., 2020). The estimated quantity of asbestos prior to the earthquake was 3740 tonnes of sprayed-on asbestos in the affected buildings and about 26.4 kg were released into the environment during the earthquake (Kazan-Allen, 2006). This led to an increased number of pneumonia patients (Kim et al., 2020). Moreover, (Kim et al., 2020) measured the asbestos concentrations (in fibres per cubic centimetre) after an earthquake at 0.162 f/cc (at 0 h) and 0.119 f/cc (after 36 h), respectively by assuming a post-disaster situation (controlled experiments). The results showed that asbestos fibres above the acceptable limit are generated where damaged asbestos-containing materials exist. Even after 36 hours, the concentration is still higher than the acceptable limit of 0.01 f/cc (according to the Korean air quality standard (Kim et al., 2015)), representing a health hazard for workers and residents.

# 5 Conclusions

Asbestos was banned approximately 20 years ago in the EU but it is still present in the existing residential and non-residential buildings. About 85% of the EU building stock dates before 2001 when asbestos was widely used in the construction industry. Moreover, 85-95% of existing buildings will still be standing in 2050 making the risk of asbestos exposure higher for its occupants and workers.

In the EU, the peak in raw asbestos consumption was registered in 1980 with approximately 1.2 million tonnes of raw asbestos. Overall, in most Member States buildings constructed between 1960 and 1990 are at risk of having higher quantities of asbestos compared to buildings dating from different decades. Around 70% to 90% of raw asbestos was used in asbestos cement products and among these products, asbestos cement roofs are the most common source of exposure to asbestos fibres in existing buildings. However, in Croatia, Slovenia, Slovakia, and Romania newer buildings (1990-2000) are expected to contain larger asbestos quantities while in Cyprus such risk characterises buildings constructed between 1920 and 1945.

The annual asbestos consumption between 1920 and 2003 in dwellings was normalised per capita and per dwelling for each Member States and at EU level. The results reveal that seven countries (Finland, Denmark, Slovakia, Estonia, Luxembourg, Belgium, and Cyprus) have values above 1.0 kg/capita/year defined as elevated level of asbestos use and two countries show values above 2.0 kg/capita/year (Lithuania and Latvia) defined as extremely high asbestos use considering the associated health impact. Moreover, these countries plus Hungary and Czechia show an average asbestos use in dwellings above 2.0 kg/dwelling/year. The least critical cases are registered in Greece, The Netherlands, Portugal, Ireland, Croatia, Romania, and Slovenia, where the average asbestos use is below 0.4 kg/capita/year and below 1.0 kg/dwelling/year. At the EU level, the average asbestos use in dwellings between 1920 and 2003 is approximately 0.67 kg/capita/year and 1.64 kg/dwelling/year.

The disaggregated asbestos use in dwellings at regional level (NUTS3) disclose the regions with asbestos use exceeding 240 kg per dwelling from Belgium, Cyprus, Czechia, Denmark, Estonia, Latvia, Lithuania, Luxemburg, and Slovakia. Smaller quantities are noted in Bulgaria, Ireland, Greece, Sweden, The Netherlands, Spain, Portugal, Croatia, Slovenia, and Romania, with many regions of Romania, Croatia and Slovenia having less than 60 kg of asbestos per dwelling. The prioritisation highlights regions at higher risk of asbestos exposure in residential buildings indicating where asbestos registration should be prioritized before any renovation planning.

Moreover, the estimated asbestos quantity in dwellings was combined with seismic risk in the residential building stock to reveal regions where seismic activity may trigger increased asbestos exposure due to damage of the built environment. Regions with high seismic risk and high asbestos use are in southern Europe, specifically in Italy and Cyprus. Fewer, but highly affected regions under concurrent high seismic risk and asbestos use are also observed in Austria, Bulgaria, France, Germany, Slovenia. Central and north Europe is less critical under this combination. Few regions in Romania, Greece, Spain, and Portugal have high seismic risk (expected repair cost of 14 million of euros), but with lower quantities of asbestos compared to Italy and Cyprus. The least affected regions are in Ireland, Netherlands, Poland, and Sweden.

These findings indicate where asbestos screening and registration should be a priority at regional level and provide insight of the most vulnerable regions to asbestos exposure but also being under elevated seismic risk. The identification of regions where asbestos material is present could help in assessment plan and inform and prepare emergency staff included in the clean-up of asbestos for the potential risk that could be exposed but also how to inform and help the affected citizens. Furthermore, the local authorities could better manage and inform citizens and create public awareness on how to handle debris as during the clean-up operations accumulation of asbestos debris will occur. Moreover, our work could advance and promote disaster resilience by providing insight of the most vulnerable regions but also support post-disaster asbestos remediation guidelines. In the future, similar studies could be carried out for other natural disasters such as asbestos release due to floods.

Finally, the asbestos quantity and seismic risk were combined in a composite indicator to give a potential prioritisation of EU regions that could benefit from deep renovation. We found top priority-regions in Italy (22 regions with high asbestos use and high seismic risk) and Latvia (high asbestos use and no seismic risk) and Belgium (high asbestos use and low seismic risk) where the composite indicator takes values between 0.8 and 1.0. High values (0.6-0.8) continue to be present in Belgium, Italy and Lithuania (high asbestos use and no seismic risk). Furthermore, more, a couple of regions in Greece were observed with values ranging from 0.4-0.5 (low asbestos use and high seismic risk). Cyprus, Estonia, and north-west Romania belong in the same range of composite indicator values.

The results indicate that fostering deep building renovation in these regions could bring besides substantial energy and emission savings, reduction of seismic risk in Greece, Italy and asbestos exposure in Belgium, Italy, Latvia and Lithuania.

## References


Allen, L.P., Baez, J., C. Stern, M.E., George, F., 2017. Asbestos - Economic Assessment of Bans and Declining Production and Consumption 48.

Asbestos Justice, 2017. Asbestos Justice. Ukraine has finally banned asbestos! available at: https://www.asbestosjustice.co.uk/ukraine-finally-banned-asbestos/.

BAuA (Ed.), 2014. National asbestos profile for Germany. Federal Institute for Occupational Safety and Health, Dortmund Berlin Dresden.

Canadian HAZ-MAT, 2016. Reducing Risk Level of Asbestos Exposure after an Earthquake – Victoria BC Canada; available at: https://www.haz-mat.ca/2016/07/04/lowering-risk-level-asbestos-exposure-earthquake-victoria-bc-canada/.

Crowley, H., Despotaki, V., Silva, V., Dabbeek, J., Romão, X., Pereira, N., Castro, J.M., Daniell, J., Veliu, E., Bilgin, H., Adam, C., Deyanova, M., Ademović, N., Atalic, J., Riga, E., Karatzetzou, A., Bessason, B., Shendova, V., Tiganescu, A., Toma-Danila, D., Zugic, Z., Akkar, S., Hancilar, U., 2021. Model of seismic design lateral force levels for the existing reinforced concrete European building stock. Bull Earthquake Eng 19, 2839–2865. https://doi.org/10.1007/s10518-021-01083-3

Danciu, L., Nandan, S., Reyes, C., Basili, R., Weatherill, G., Beauval, C., Rovida, A., Vilanova, S., Sesetyan, K., Bard, P.-Y., Cotton, F., Wiemer, S., Giardini, D., 2021. The 2020 update of the European Seismic Hazard Model: Model Overview. EFEHR Technical Report 001, v1.0.0, https://doi.org/10.12686/a15.

Economidou, M., Todeschi, V., Bertoldi, P., D'Agostino, D., Zangheri, P., Castellazzi, L., 2020. Review of 50 years of EU energy efficiency policies for buildings. Energy and Buildings 225, 110322. https://doi.org/10.1016/j.enbuild.2020.110322

European Commission, 2022a. Proposal for a Directive of the European Parliament and of the Council ameding Directive 2009/148/EC on the protection of workers from the risks related to exposure to asbestos at work. COM(2022) 489 final.

European Commission, 2022b. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the regions on working towards an asbestos-free future: an European approach to addressing the health risks of asbestos. COM(2022) 488 final.

European Commission, 2021a. Proposal for a Directive of the European Parliament and of the Council on the energy performance of buildings (recast) (2021/0426 (COD) No. COM(2021) 802). Brussels.

European Commission, 2021b. Europe's Beating Cancer Plan: A new EU approach to prevention, treatment and care, Press release available at: https://ec.europa.eu/commission/presscorner/detail/en/ip_21_342.

European Commission, 2021c. Zero pollution action plan. Towards zero pollution for air, water and soil, available at: https://environment.ec.europa.eu/strategy/zero-pollution-action-plan_en.

European Commission, 2021d. The European Pillar of Social Rights Action Plan, available at: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/economy-works-people/jobs-growth-and-investment/european-pillar-social-rights/european-pillar-social-rights-action-plan_en.

European Commission, 2020. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the regions: Renovation Wave for Europe - greening our buildings, creating jobs, improving lives (No. COM(2020) 662). Brussels.

European Commission, 2019. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: The European Green Deal (No. COM(2019) 640). Brussels.

European Commission, 2012. Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements 19.

European Parliament, 2021. European Parliament resolution of 20 October 2021 with recommendations to the Commission on protecting workers from asbestos.

Filippidou, F., Jimenez Navaro, J.P., 2019. Achieving the cost-effective energy transformation of Europe's buildings, EUR 29906 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-12394-1, doi:10.2760/278207, JRC117739.

Gkatzogias, K., Crowley, H., Veljkovic, A., Pohoryles, D., Norlen, H., Tsionis, G., Bournas, D., 2022. Prioritising EU regions for building renovation: seismic risk, energy efficiency, socioeconomic vulnerability, Gkatzogias, K. and Tsionis, G. editor(s), EUR 31149 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-55022-8, doi:10.2760/263803, JRC128988.

Kameda, T., Takahashi, K., Kim, R., Jiang, Y., Movahed, M., Park, E.-K., Rantanen, J., 2014. Asbestos: use, bans and disease burden in Europe. Bull. World Health Organ. 92, 790–797. https://doi.org/10.2471/BLT.13.132118

Kazan-Allen, L., 2022. Asbestos update: Ukraine 2022. International Ban Asbestos Secretariat, available at: http://www.ibasecretariat.org/lka-asbestos-update-ukraine-2022.php.

Kazan-Allen, L., 2006. Global impact of asbestos: the environment. Presented at international conference: Health, The Environment and Justice. Vence, Italy.

Kim, Y.-C., Hong, W.-H., Zhang, Y.-L., 2015. Development of a model to calculate asbestos fiber from damaged asbestos slates depending on the degree of damage. Journal of Cleaner Production 86, 88–97. https://doi.org/10.1016/j.jclepro.2014.08.092

Kim, Y.-C., Zhang, Y.-L., Park, W.-J., Cha, G.-W., Hong, W.-H., 2020. Quantifying asbestos fibers in post-disaster situations: Preventive strategies for damage control. International Journal of Disaster Risk Reduction 48, 101563. https://doi.org/10.1016/j.ijdrr.2020.101563

Kraja, E., 2017. Milestone achievement: asbestos banned in Ukraine. WECF Internationl; available at: https://www.wecf.org/milestone-achievement-asbestos-banned-in-ukraine/.

Krówczyńska, M., Wilk, E., 2019. Environmental and Occupational Exposure to Asbestos as a Result of Consumption and Use in Poland. IJERPH 16, 2611. https://doi.org/10.3390/ijerph16142611

Kryvoruchkina, O., 2022. The Asbestos Time Bomb: War and the Soviet Construction Legacy, available at: https://blog.liga.net/user/koryvoruchkina/article/44864.

Landrigan, P.J., Lioy, P.J., Thurston, G., Berkowitz, G., Chen, L.C., Chillrud, S.N., Gavett, S.H., Georgopoulos, P.G., Geyh, A.S., Levin, S., Perera, F., Rappaport, S.M., Small, C., NIEHS World Trade Center Working Group, 2004. Health and environmental consequences of the world trade center disaster. Environ Health Perspect 112, 731–739. https://doi.org/10.1289/ehp.6702

Lee, E.-S., Kim, Y.-K., 2021. Asbestos Exposure Level and the Carcinogenic Risk Due to Corrugated Asbestos-Cement Slate Roofs in Korea. IJERPH 18, 6925. https://doi.org/10.3390/ijerph18136925

Lindell, M.K., Perry, R.W., 1996. Addressing gaps in environmental emergency planning: Hazardous materials releases during earthquakes1. Journal of Environmental Planning and Management 39, 529–544. https://doi.org/10.1080/09640569612363

Lioy, P.J., Weisel, C.P., Millette, J.R., Eisenreich, S., Vallero, D., Offenberg, J., Buckley, B., Turpin, B., Zhong, M., Cohen, M.D., Prophete, C., Yang, I., Stiles, R., Chee, G., Johnson, W., Porcja, R., Alimokhtari, S., Hale, R.C., Weschler, C., Chen, L.C., 2002. Characterization of the dust/smoke aerosol that settled east of the World Trade Center (WTC) in lower Manhattan after the collapse of the WTC 11 September 2001. Environmental Health Perspectives 110, 703–714. https://doi.org/10.1289/ehp.02110703

Maduta, C., Kakoulaki, G., Zangheri, P., Bavetta, M., 2022. Towards energy efficient and asbestos-free dwellings through deep energy renovation, EUR 31086 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-52961-3, doi:10.2760/00828, JRC129218.

Nathan, A.R., Olson, K.R., Everson, G.W., Kearney, T.E., Blanc, P.D., 1992. Effects of a major earthquake on calls to regional poison control centers. Western Journal of Medicine 156, 278–280.

Nielsen, A., Hodgkin, D., 2022. Rebuilding Ukraine: the imminent risks from asbestos. PreventionWeb; available at: https://www.preventionweb.net/blog/rebuilding-ukraine-imminent-risks-asbestos.

Nukushina, J., 1995. Japanese earthquake victims are being exposed to high density of asbestos. We need protective masks desperately. Epidemiologia e prevenzione 19, 226–227.

Obmiński, A., 2020. Asbestos in building and its destruction. Construction and Building Materials 249, 118685. https://doi.org/10.1016/j.conbuildmat.2020.118685

OEC, 2020. Asbestos in Ukraine. The Observatory of Economic Complexity (OEC); available at: https://oec.world/en/profile/bilateral-product/asbestos/reporter/ukr.

OECD, 2008. Organisation for Economic Co-operation and Development: Handbook on constructing composite indicators. Methodology and user guide.

Oppelt, D., Banja, M., Anashkin, S., Ukraine, P.R., Khomenko, O., 2020. Market study on mitigation potential for heat pump and commercial refrigeration equipment in Ukraine.

OVAM, 2016. States of the art: asbestos - possible treatment methods in Flanders: Constraints and opportunities 144.

Palermo, V., Tsionis, G., Sousa, M., 2018. Building stock inventory to assess seismic vulnerability across Europe, EUR 29257 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-86707-1, doi:10.2760/530683, PUBSY No 112031.

Pezzutto, S., Zambotti, S., Croce, S., Zambelli, P., Garegnani, G., Scaramuzzino, C., Pascual Pascuas, R., Zubaryeva, A., Haas, F., Exner, D., Muller, A., Hartner, M., Fleiter, T., Klingler, A.-L., Kühnbach, M., Manz, P., Marwitz, S., Rehfeldt, M., Steinbach, E., Popovski, E., 2018. Hotmaps Project, D2.3 WP2 Report – Open Data Set for the EU28.

Purpura, P., 2019. Security and Loss Prevention: An Introduction, 7th edition. ed. Butterworth-Heinemann.

Showalter, P.S., Myers, M.F., 1994. Natural Disasters in the United States as Release Agents of Oil, Chemicals, or Radiological Materials Between 1980-1989: Analysis and Recommendations. Risk Analysis 14, 169–182. https://doi.org/10.1111/j.1539-6924.1994.tb00042.x

Tierney, K.J., 1989. Secondary hazards resulting from earthquakes: hazardous materials emergencies and high-rise fires. Urban Resources 5, 33–36.

Trotta, O., Bonifazi, G., Capobianco, G., Serranti, S., 2022. DETECTION OF ASBESTOS CONTAINING MATERIAL IN POST-EARTHQUAKE BUILDING WASTE THROUGH HYPERSPECTRAL IMAGING AND MICRO-X-RAY FLUORESCENCE. Detritus 27–34. https://doi.org/10.31025/2611-4135/2022.17233

UNEP, 2022. United Nations Environment Programme (UNEP). UN warns of toxic environmental legacy for Ukraine, available at: https://www.unep.org/news-and-stories/press-release/un-warns-toxic-environmental-legacy-ukraine-region.

Virta, 2006. Worldwide Asbestos Supply and Consumption Trends from 1900 through 2003 (Circular).

Virta, R., 2006. Worldwide Asbestos Supply and Consumption Trends from 1900 through 2003 (Circular 1298). US Geological Survey.

Whitmer, M., 2023. Asbestos, 9/11 and the World Trade Center, available at: https://www.asbestos.com/world-trade-center/.

WHO (Ed.), 2014. Chrysotile asbestos. World Health Organization, Geneva.

World Bank, Government of Ukraine, European Commission, 2022. Ukraine - Rapid damage and needs assessment.

Young, S., Balluz, L., Malilay, J., 2004. Natural and technologic hazardous material releases during and after natural disasters: a review. Science of The Total Environment 322, 3–20. https://doi.org/10.1016/S0048-9697(03)00446-7

Zangheri, P., Armani, R., Kakoulaki, G., Bavetta, M., Martirano, G., Pignatelli, F., Baranzelli, C., 2020. Building energy renovation for decarbonisation and Covid-19 recovery, EUR 30433 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-24766-1, doi:10.2760/08629, JRC122143.

## List of abbreviations and definitions

| | |
|---|---|
| $AAEL_{eq}$ | Average Annual Economic Losses |
| ACM | Asbestos-Containing Material |
| EPBD | Energy Performance of Buildings Directive |
| EU | European Union |
| Hazmat | hazardous material |
| IEQ | Indoor Environmental Quality |
| MS | Member State |
| na-tech | natural-technologic events |
| NUTS | Nomenclature of Territorial Units for Statistics |
| PGA | Peak Ground Acceleration |
| USGS | United States Geological Survey |
| WHO | World Health Organization |
| WTC | World Trade Centre |

## List of figures

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