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Towards energy efficient and asbestos-free dwellings through deep energy renovation

Identification of vulnerable EU regions

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Contents

Abstract

The European Green Deal aims at a greener and decarbonised society with less energy-consuming and healthier buildings. Existing buildings play a key role in achieving this long-term goal, as they are old, deemed as energy inefficient and the majority do not provide a healthy indoor environment. The building stock should undergo a renovation wave adopting the deep renovation concept.

The Energy Performance of Building Directive 2010/31/EU (EPBD) frames the concept of deep renovation going beyond energy upgrades and asks Member States to enhance the quality of the indoor climate also through the removal of harmful materials commonly used in buildings in the 20th century, such as asbestos. Indeed, as the building stock ages and deteriorates, the risk of asbestos exposure is increasing.

This study provides, for the first time, indications on the presence of asbestos in the residential building stock at EU regional level. It reveals the regions at risk of having high amounts of this dangerous substance in buildings thus indicating where asbestos screening prior to renovation, may be a priority. Adding indicators of the energy performance of buildings, the critical EU regions for deep energy renovation are subsequently mapped. The conclusions provide guidance to policy makers and authorities to tailor deep renovation programmes at regional level to address both energy efficiency and the quality of indoor life.

Acknowledgements

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Executive summary

Policy context

The building stock plays a key role in achieving the EU long-term energy and environmental goals and must undergo an ample transformation to be successful. The European Green Deal aims at a greener society with less energy-consuming and healthier buildings, also through a renovation wave of existing buildings. The Energy Performance of Buildings Directive 2010/31/EU (EPBD) lays down the requirements for building renovation going beyond energy efficiency by asking Member States (MSs) to enhance the quality of the indoor climate also through the removal of harmful materials and to ensure compliance with existing policies on exposure to asbestos and other pollutants. As an essential legislative tool to support the Renovation Wave strategy, the 2021 recast of the EPBD strengthens the requirement of the safe removal of asbestos from the building stock by merging it under the concept of deep renovation.

Main findings

In most EU countries, higher quantities of asbestos are expected in dwellings built between 1970 and 1990. However, in Cyprus, Belgium, Denmark, France, Luxembourg, The Netherlands, and Sweden it appears that dwellings dating before 1970 are at higher risk of having significant quantities of asbestos, while in Croatia, Slovenia, Slovakia and Romania, this risk is in newer residential buildings, built between 1990 and early 2000s.

Considering the average age of the residential building stock and the estimated quantities of asbestos, it seems that the most vulnerable NUTS2 regions[1] are located in central Europe (particularly in Germany and Belgium), including Italy and Denmark, dominated by old buildings (built before 1960) and high asbestos quantities. A particular case is represented by the northern and eastern regions (from Bulgaria, Finland, Estonia, Latvia, Lithuania, Slovakia, Poland, Romania) where high amounts of asbestos are expected to be incorporated in more recent dwellings (built after 1980).

The findings may indicate where scanning the asbestos before renovation should be a priority, since the identification of Asbestos Containing Materials (ACMs) during renovation works may cause delays. In the context of accelerated renovation of the building stock and given that most Member States have set renovation milestones in 2020 Long-Term Renovation Strategy, it is essential to anticipate possible delays. Particularly the late identification of the presence of asbestos, not only would delay renovation but it could also create a health hazard.

Considering also the energy saving potential, the criticality of the regions shifts from central Europe to eastern European regions that have potentially high energy saving potential and high quantities of asbestos.

Adding key economic aspects (the economic well-being, the employment multiplier and the renovation effectiveness), regions from southern Europe have high vulnerability while central Europe is less critical under this combination of parameters.

Considering all building, economic and climate related characteristics, both the most and the least vulnerable regions are scattered across Europe. It seems that the worst affected are some big urban areas (Wien, Berlin, Brussels region) but also most of the Italian regions. Many regions from Bulgaria, Poland, France and the Nordic countries also show high criticality.

Therefore, in the context of deep renovation, the indicator of the presence of is combined with relevant indicators of the energy performance of buildings and the EU priority-regions for the comprehensive renovation of the residential building stock are identified.

These findings can provide guidance to policy makers and national and regional authorities to design renovation programmes incentivising the removal of asbestos from the built environment in the regions identified as vulnerable thus addressing both energy efficiency and the quality of indoor climate.

Already several MSs are successfully coordinating the removal of asbestos with the energy renovation of buildings. Two common mechanisms are (1) offering additional top-ups on energy renovation subsidies if asbestos is identified and removed and (2) facilitating the installation of solar collectors and PV panels upon removal of asbestos roofing.

[1] Nomenclature of Territorial Units for Statistics level 2, a hierarchical system for diving up the EU territory for socio-economic analyses of the application of regional policies, among other purposes

Related and future JRC work

This study is developed under the frame of the JRC Self-cities project, work programme 2021-2022, task 8, aiming at identifying regions across the EU with buildings with low energy performance and low Indoor Environmental Quality (IEQ) based on contextual factors such as the presence of harmful materials and outdoor pollution. The report focuses on presence of asbestos in the residential building stock. Indicators of outdoor pollution and seismic vulnerability will be added to finally identify EU priority regions for deep energy renovation. It complements a recent study carried out under the same project which identifies the critical regions for the energy renovation of residential buildings (Zangheri et al., 2020).

Quick guide

Chapter 1 lays out the study in the current context and highlights the importance of addressing the removal of harmful materials from the building stock with the renovation wave in Europe. Chapter 2 describes the evolution of the asbestos consumption in the EU countries, highlighting the top consumers, the peak periods of asbestos use as well as the years when it was prohibited. Chapter 3 discusses the use of asbestos in buildings and provides estimations of asbestos quantities in EU dwellings, at national and regional level, highlighting the critical regions. Chapter 4 reports indicators of the energy performance of buildings and reveals the priority regions for deep energy renovation of the residential building stock. Chapter 5 gives an overview of good practices of asbestos removal from existing buildings across the EU and Chapter 6 draws the conclusions and recommendations.

1 Introduction

Within Europe, buildings account for about 40% of final energy consumption and 36% of associated CO_2 emissions (EC, 2019), thus the building stock is a crucial element in reaching the main milestone of decarbonising Europe by 2050. Our building stock is aged and heterogeneous, many of the existing buildings do not provide a healthy indoor environment for the occupants, and one of the main reasons is because they contain harmful substances, such as Asbestos-Containing Materials (ACMs).

Asbestos, a natural silicate material, is found worldwide in construction materials. Exposure to asbestos fibres can cause fatal diseases, such as lung cancer, mesothelioma, asbestosis and pleural plaques (WHO, 2015). Although its use was banned in the EU approximately 20-30 years ago, asbestos can still be found in buildings, as it was widely used in the 20th century in the construction sector.

While the building stock ages and deteriorates, the risk of asbestos exposure is increasing for the occupants. Moreover, while buildings are being renovated or demolished, the health of construction workers is also at risk. In fact, asbestos exposure is the number one cause of work-related cancer in Europe (EECS, 2019).

The safe removal of asbestos from the European building stock is a long-term strategic target and it is addressed in several policy initiatives, some of which are mentioned below.

Regarding the protection of workers exposed to asbestos fibres, there is in place a comprehensive set of measures. The Framework Directive on Safety and Health at Work[2] sets general rules and principles of workers' protection. EU legal protection of workers from the specific risks of exposure to asbestos dates back to 1983[3]. It has since then been updated several times until the most recent instrument, the Asbestos at Work Directive[4] (AWD), which lays down strict obligations on employers in terms of protection, planning and training. In addition, since asbestos is a carcinogenic agent, Directive on the protection of workers from the risks related to exposure to carcinogens, or mutagens or reprotoxic substances at work[5] applies whenever it is more favourable to the health and safety of workers. The Commission is currently preparing a proposal to revise the Asbestos at Work Directive to further strengthen workers' protection with an expected adoption for after the summer of 2022.

However, the World Health Organization (WHO) states that 71% of WHO European Region countries who have banned asbestos before 2005 have policies on incentives for the removal and storage of asbestos while only 50% of WHO European countries who have banned asbestos after 2005 have implemented such policies (WHO, 2015).

The European Economic and Social Committee (EECS) stresses the need of creating clear synergies between energy renovation and the removal of asbestos to achieve healthy and energy efficient homes and states that MSs should prepare the long-term renovation strategy with a view to minimise the asbestos related health risk to workers, inhabitants and the general public (EECS, 2019).

The European Green Deal (EC, 2019) aims at a greener society with healthier and less energy-consuming buildings through a renovation wave of the existing buildings. The Renovation Wave (EC, 2020) is an action plan with the primary objective to at least double the annual energy renovation rate of buildings by 2030 across the EU and to foster deep renovation.

The second recast of the Energy Performance of Building Directive (EC, 2018) integrates the asbestos issue under the energy renovation of buildings It asks MSs to perform energy performance upgrades that improve the indoor environmental quality including the removal of asbestos and other harmful materials and at the same time to prevent the illegal removal of such materials (EC, 2018). In 2021, as an essential legislative tool to support the Renovation Wave strategy, the EPBD was revised again. The proposal takes over and strengthens the requirement of safe asbestos removal from the buildings stock by merging it under the concept of deep renovation (EC, 2021a).

Also in the frame of the 2018 EPBD, MSs were asked to prepare the national Long-Term Renovation Strategies (LTRSs). Some countries[6] have addressed the asbestos issues in the renovation plan but since no explicit reference is made to asbestos in article 2a, most countries have not taken any action. This may complicate the renovation roadmap if information on the presence of asbestos is not available and ACMs are detected during the renovation works.

[2] Directive 89/391/EEC
[3] Directive 83/477/EEC
[4] Directive 2009/148/EC
[5] Directive 2004/37/EC
[6] Flanders and Brussels-Capital regions (Belgium), France, Germany, Hungary and Poland

The first and probably the main problem in addressing the removal of asbestos from the building stock is the lack of inventories and open access databases indicating the quantities and the locations of ACMs. To the best of the authors knowledge there is no research available investigating the overall quantity of asbestos still present in the European building stock. Recent studies mapped the presence of ACMs in buildings through surveys (Campopiano et al., 2021) or by using machine learning techniques (Wilk et al., 2017; Wu et al., 2022). However, these studies cover limited geographical areas. To date, few MSs have inventoried, to some extent, the presence of asbestos in buildings. An exemplary case is Poland which has a comprehensive inventory of ACMs, publicly available.

Indeed, an ideal solution would be inventories of asbestos presence in buildings available through digital repositories (EC, 2021b) to anticipate possible hazards during renovation. Actually, the European Parliament resolution on asbestos called on the EU to screen and register the presence of asbestos in buildings and to make the information publicly available (EP, 2016).

However, screening the presence of asbestos in buildings is not straightforward as it is often impossible to detect asbestos by visual examination alone. The quantity of raw asbestos varies greatly in the many construction products, which could be hidden in the structure of buildings. Consequently, it would require product exposure followed by extraction and examination of samples, which could already be a hazard if specialized workers do not perform it under specific safe conditions.

This report provides an alternative solution for indicating the presence of asbestos in the European residential building stock. The potential quantity of asbestos in dwellings is estimated based on the apparent asbestos consumption in MSs between 1920 and 2003, the percentage of raw asbestos used in building materials, the age of dwellings and their share from the total number of building units built during the indicated periods.

It is noted that while the study estimates the potential quantity of asbestos present in the residential building stock, the scope is to identify the European regions with probable presence of excessive amounts of asbestos in buildings and not to account for the exact quantities. Consequently, our results may indicate where the asbestos screening prior to renovation should be a priority, based on the age of the building. Such information could be added in the renovation passport, whose main purpose is to provide a clear renovation roadmap helping owners and investors to plan the best timing for deep energy renovation. (EC, 2021a).

2 The evolution of asbestos use

Asbestos, a naturally occurring fibrous silicate material, has been widely used for centuries in various products due to its many advantages such as high resistance to fire and heat, high durability and low costs of mining and production (Roselli et al., 2014).

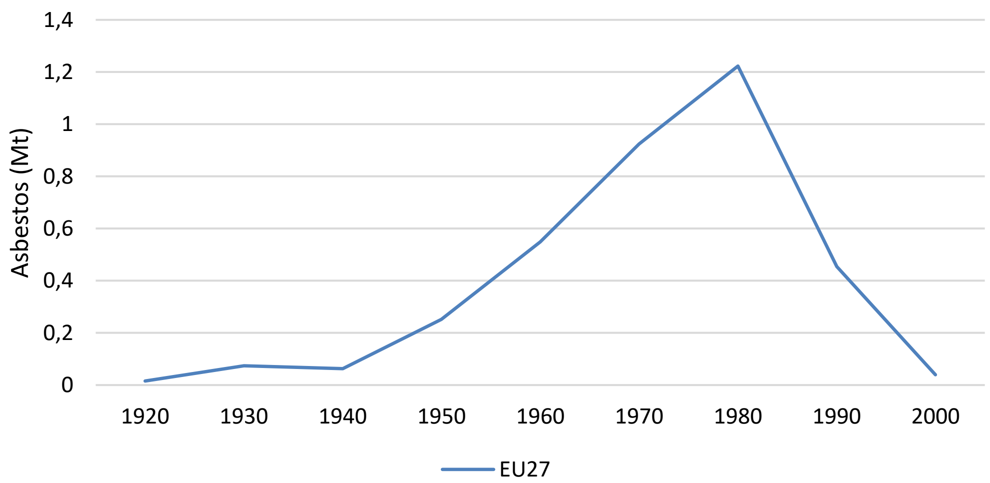
Although the use of asbestos started approximately 4 500 years ago, the modern asbestos industry began to flourish in the early 1800s, in Italy. In the early 1900s the possibility to produce asbestos cement panels as well as the development of the automotive industry led to an increase in asbestos demand. However, during World War I the production and use of asbestos products declined only to rise again at the end of the war simultaneously with the growth in the construction sector (R. Virta, 2006).

The most common asbestos products were asbestos cement panels, thermal insulation for heating pipes and boilers, roofing and flooring elements, automotive clutches, fillers and reinforcement for plasters, heat resistant gaskets, fire retardant spray coating for steel elements, brake pads and linings for automobiles and fireproof suits and accessories (R. Virta, 2006). Production declined once World War II started. Soon after the war ended the production and consumption of asbestos products started increasing again because of post-war reconstruction, reaching a peak around the late 1970s with an average of 4.8 million tonnes of raw asbestos consumed per year worldwide. Thereafter, the consumption started to decrease to a level of around 2 million tonnes per year in 2000 (Allen et al., 2017; R. Virta, 2006).

The main reason behind the decline in asbestos use is health problems related to its use. Early in the 20th century, a link between certain respiratory problems and the exposure to asbestos was reported in several medical studies. Between 1940 and 1960 the link between lung cancer and asbestos exposure was confirmed by scientists (Bartrip, 2004; Merlo et al., 2018; Pira et al., 2018). However, it took several decades before the controversial material was phased-out and eventually banned in Europe (Schindler, 2016; Virta, 2006).

The evolution of the apparent asbestos consumption[7] in the EU27 from 1920 to 2000 is shown in Figure 1 (R. Virta, 2006). In 1970 more than 920 000 tonnes were consumed in the EU27 reaching a peak of 1 200 000 tonnes in 1980 and declining to less than 40 000 tonnes in 2000.

Figure 1. Asbestos consumption in the EU27

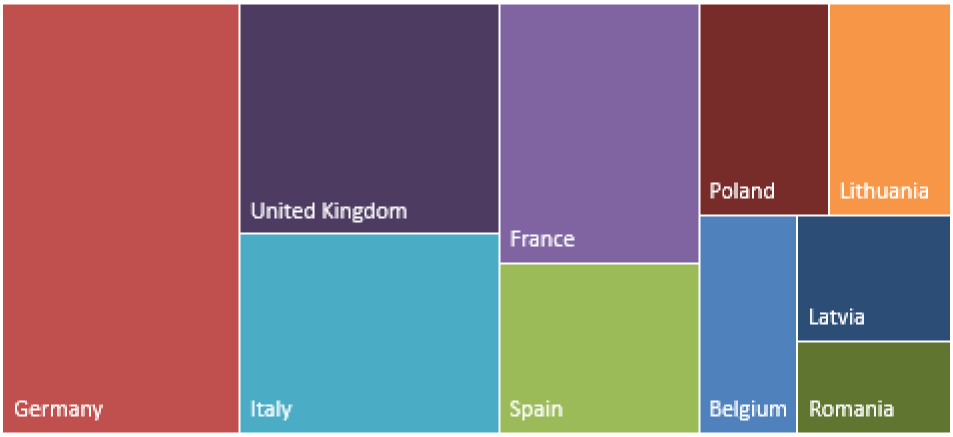


Source: JRC, 2022

Figure 2 illustrates the top ten asbestos consuming countries in the EU27+UK ranked by the total quantity of apparent asbestos consumed between 1920 and 2003. Among these, Germany was the main consumer reaching a peak of more than 440 000 tonnes of asbestos consumed in 1980 as may be observed in Figure 3. United Kingdom (UK), Italy and France also stand out as large asbestos consumers (BAuA, 2014; Kazan-Allen, 2020, 2018a, 2018b).

[7] The apparent asbestos consumption is defined as the production plus imports minus exports.

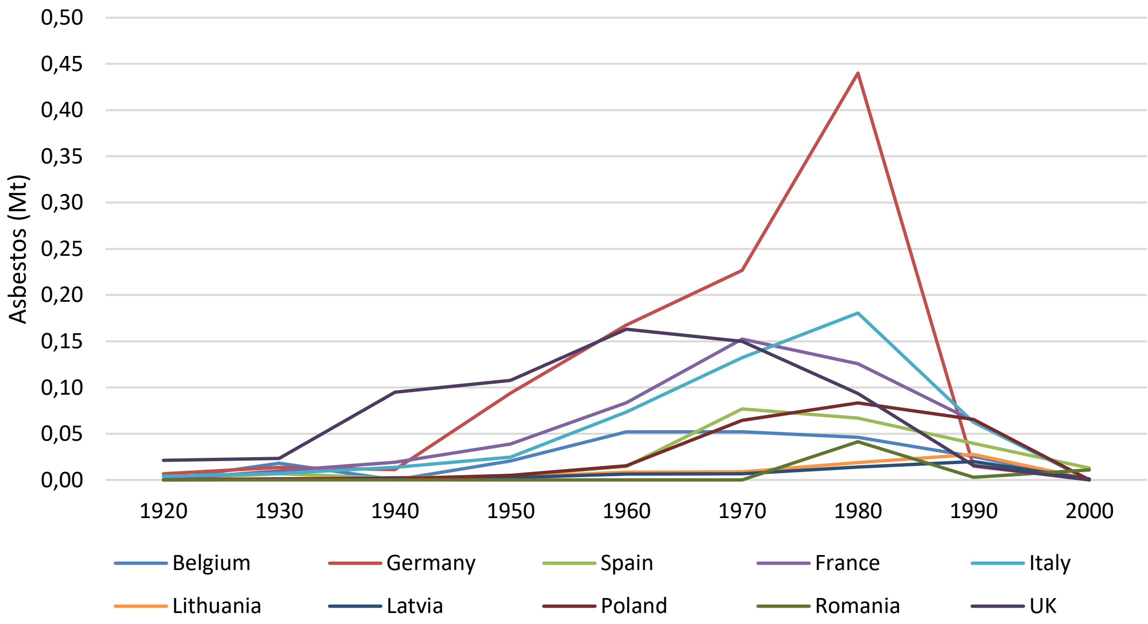
Figure 2. Top ten asbestos consuming countries in the EU27+UK



Source: JRC, 2022

It appears that in most countries the asbestos consumption peaked around 1970 – 1980 (Figure 3). However, in Romania, Latvia and Lithuania the peak was registered later, during 1980-1990, while in the UK and Belgium the asbestos consumption seems to have been slowly decreasing after 1960.

Figure 3. Asbestos consumption in top ten asbestos consuming countries, EU27+UK



Source: JRC, 2022

Across the EU countries, the year of asbestos ban varies between 1986 and 2007. Sweden and Denmark banned all asbestos products in the 1980s, after banning asbestos spray in the 1970s. In the 1990s, nine EU states prohibited asbestos. However, most EU countries banned asbestos in the 2000s. Some countries prohibited the use of crocidolite and amosite before the final asbestos ban. However, these two forms of asbestos represent only 4% of the total asbestos available in the market between 1920 and 2003, while chrysotile represent 96% (WHO, 2011). The ban year of all form of asbestos in EU countries is presented in Table 1.

Table 1. Year of asbestos ban in the EU27+UK[8]

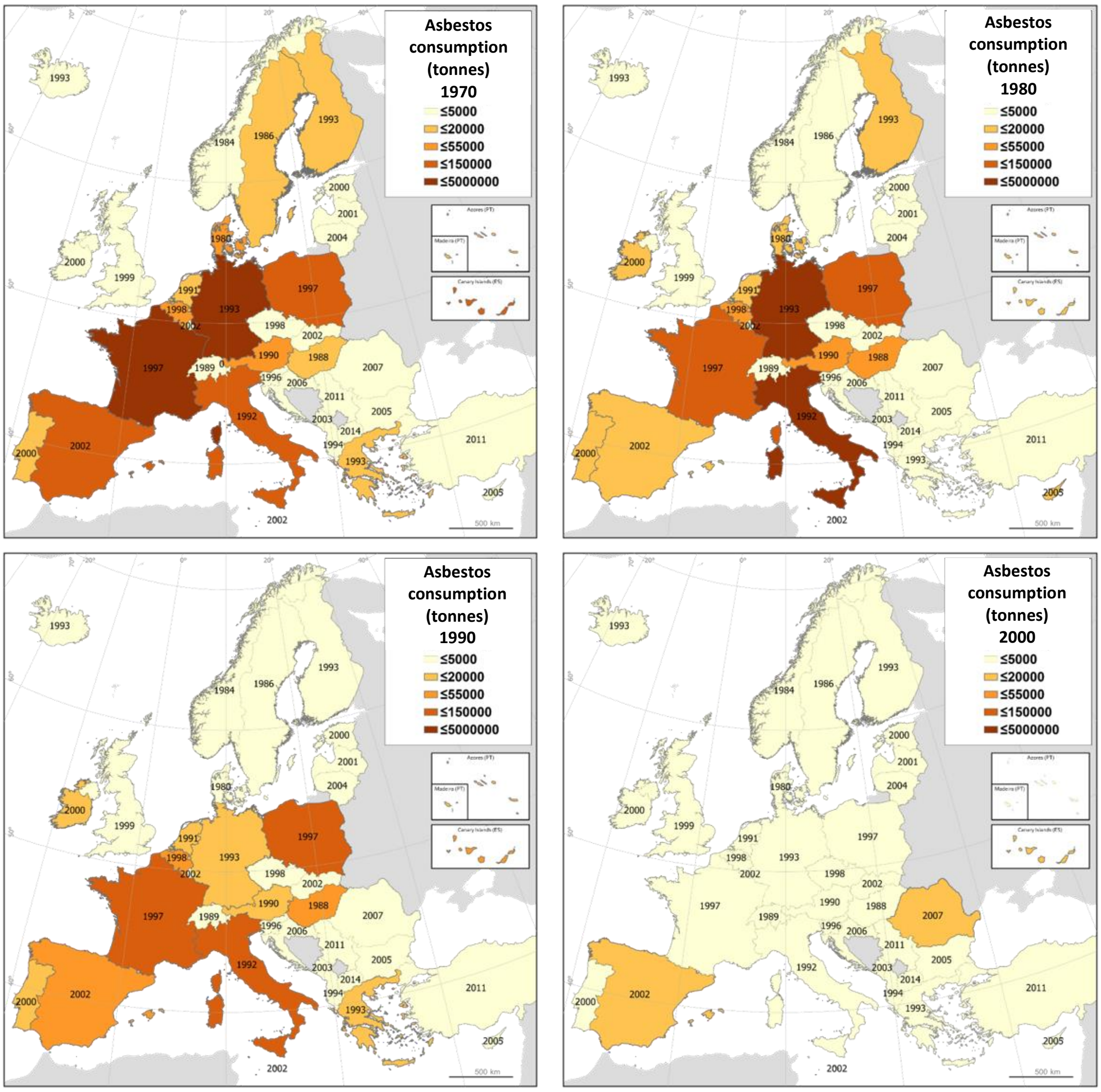
Member States	Year of ban	Notes
Austria	1990	
Belgium	1998	
Bulgaria	2005	
Croatia	2006	crocidolite and amosite were banned in 1993
Cyprus	2005	
Czechia	2005	the use of asbestos products in buildings were prohibited in 1997
Denmark	1988	the use of asbestos thermal and acoustic insulation and waterproofing was banned in 1972
Estonia	2005	
Finland	1994	various forms of asbestos were banned between 1988 and 1994
France	1996	
Germany	1993	asbestos spray was banned in 1979
Greece	2005	
Hungary	2005	asbestos cement products are banned in 2003
Ireland	2004	phasing out asbestos started in 1994
Italy	1992	
Latvia	2001	
Lithuania	2005	
Luxemburg	2002	
Malta	2005	
Netherlands	1991	
Poland	1997	
Portugal	2005	
Romania	2007	industrial exposure is controlled since 1990s
Slovakia	2005	
Slovenia	1996	
Spain	2002	
Sweden	1986	asbestos spray was banned in 1973
United Kingdom	1999	crocidolite and amosite were banned in 1986

Source: JRC, 2022

Figure 4 illustrates the apparent asbestos consumption in the EU27+UK in 1970, 1980, 1990 and 2000 (R. Virta, 2006) together with the year in which asbestos was banned. The declining trend can be observed in almost all countries.

[8] Data mainly from http://www.ibasecretariat.org/chron_ban_list.php cross-checked with WHO and national communications, where available

Figure 4. Asbestos consumption in 1970, 1980, 1990 and 2000 and the year of ban, EU27+UK



Source: JRC, 2022

However, banning all forms of asbestos does not solve entirely the health-related issues, especially for construction workers and for people living or carrying out activities in buildings constructed in the 'golden decades' of asbestos as many of them continue to be exposed to the dangerous fibres. Asbestos continues to be on the top of the list of occupational cancer sources in the EU (EECS, 2019).

It is estimated that by 2030, 500 000 people will die of asbestos caused cancer in Europe. This is possible because although asbestos was banned several years ago in all EU MSs, the latency period from the moment of exposure is long (Roselli et al., 2014).

The World Health Organization (WHO) asks its member countries to review and update their national programmes according to the latest guidelines. As matter of fact only 32% of the WHO European Regions[9] have provisions related to asbestos exposure for the general population (WHO, 2015).

[9] Only 31 out of 53 countries from the WHO European Region responded to the survey that assesses the Member States progress in implementing the goals of the Parma declaration. EU Member States included in the survey: Austria, Belgium, Denmark, Germany, Ireland, Italy, Latvia, Poland, Slovakia, Slovenia, Spain, Sweden, Portugal, Croatia, Czechia, Estonia, Hungary, Lithuania and Malta.

3 Asbestos use in buildings

Asbestos is found worldwide in Asbestos-Containing Materials (ACMs) incorporated in the existing building stock. So far, there is no evidence for a threshold for the carcinogenic effect of asbestos. Since health problems have been observed even in low levels of exposure (ECHA, 2021; Loomis et al., 2009; Pira et al., 2009; Visonà et al., 2018), WHO suggest that the most appropriate way to avoid asbestos-related diseases is to stop using all types of asbestos (WHO, 2014).

Studies showed that most of the raw asbestos, 70-90%, was used to produce asbestos cement products (Allen et al., 2017; BAuA, 2014; Campopiano et al., 2004; WHO, 2014; Wilk et al., 2017; Zhang et al., 2021). Generally, in existing buildings, asbestos cement roofs are the most common source of exposure to asbestos. Such roofs contain between 10% and 20% raw asbestos (Lee and Kim, 2021).

Other common asbestos cement products are wall sheets, sewage pipes, rainwater goods, hot water pipe insulation, drinking water tanks, separation panels and ventilation ducts. The raw asbestos content is approximately 15% in such products (Gualtieri, 2012).

Asbestos cement products were not considered a health hazard because the fibres were bound by cement. However, studies showed that the aging of the products eventually lead to fibre detachments and release in the air (Angelini and Silvestri, 2022). A study on a 60-year-old asbestos cement roof of a dwelling concluded that weathering of the roof resulted in a layer of loosely bound fibres that could be easily released in the air (Ervik et al., 2021). Another study (Pastuszka, 2009) links the susceptibility of asbestos cement slabs to emit fibres in the air to the quality of the slabs rather than with the aging of the slabs concluding that the mechanical destruction has a higher influence than the atmospheric corrosion. A study on the distribution of asbestos naturally discharged fibres concluded that when used indoors, asbestos containing products do not cause serious problems while when used outdoors, fibres are dispersed into the atmosphere due to aging and vibration over time (Zhang et al., 2016). Naturally, in case of dismantling or maintenance activities involving asbestos containing products, whether indoor or outdoor, the risk of fibres dispersion is high.

Another use of asbestos in existing buildings is sprayed asbestos materials generally used for sound and fireproofing. The content of asbestos in such materials varies from 5% up to 95% (Dumortier and De Vuyst, 2011). Asbestos fabrics used as fireproof sealing materials and vinyl asbestos for flooring are also frequently identified in existing buildings (Allen et al., 2017; Zichella et al., 2021).

Following a data search on asbestos consumption in Europe, the most comprehensive data on asbestos production, imports and exports were found in the US Geological Survey Circular on worldwide asbestos supply and consumption trends from 1900 through 2003 (Virta, 2006). The apparent consumption of raw asbestos is defined as production plus imports minus exports and considering changes in government and industry.

However, for the European countries the apparent asbestos consumption data is provided in 10-year interval from 1920 to 1970, in 5-year intervals from 1970 to 1995 and yearly thereafter up to 2003 (Virta, 2006). Based on these data the whole apparent asbestos consumption from 1920 to 2003 is estimated considering a linear interpolation between those years.

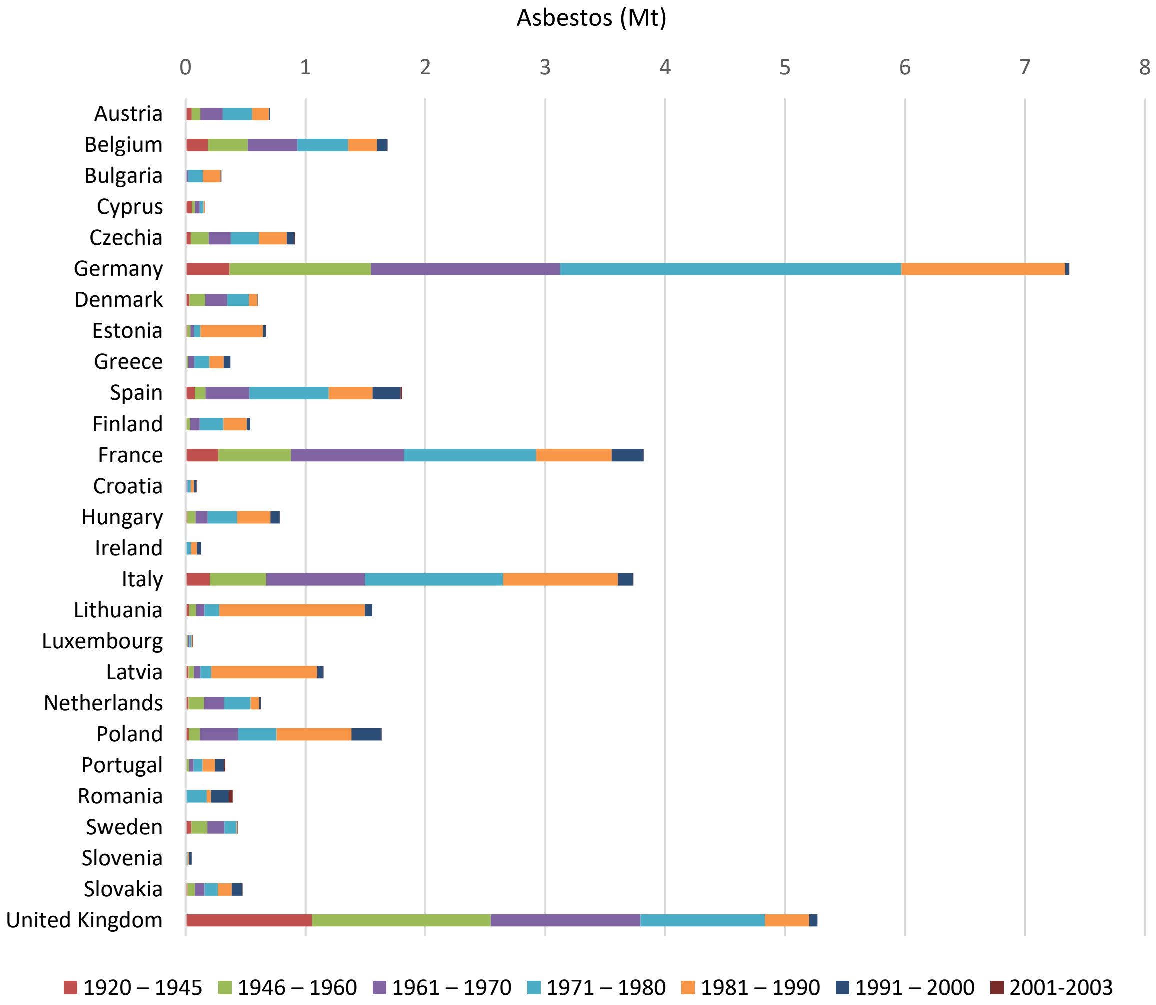
The data reflects the political situation in Europe between 1920 and 2003, thus data processing was needed to depict the asbestos situation in the EU countries as we know them today, as many were part of unions. The disaggregation is made based on current and past population records, considering the apparent asbestos consumption in a specific year proportional with the population of the state in that year. Particularly this was the case for Czechia and Slovakia known as Czechoslovakia (1920-1990), for Latvia, Lithuania, and Estonia which were part of the Soviet Union (1920-1990) and for Croatia and Slovenia which were part of Yugoslavia (1930-1990). The same approach is used to disaggregate data for Belgium and Luxembourg which was provided combined while data for West and East Germany was combined under Germany (1950-1985). Among all, the most uncertain disaggregation is the one of the Baltic nations, which was divided from the extremely large territory of the Soviet Union.

Furthermore, the amount of asbestos used in building is estimated. As presented above, the literature reports that about 70% to 90% of raw asbestos was used in the production of building materials, particularly in asbestos cement products, while the remaining share is attributed to friction products, gaskets, textiles, paper products, insulation for industrial machineries, and other uses. Consequently, in this study the apparent consumption reported in the Circular on worldwide asbestos trends (Virta, 2006) is reduced by 20% to reflect on average, the quantity of raw asbestos used in building materials.

To identify the European regions at higher risk of having buildings with asbestos incorporated in the elements, the apparent asbestos consumption is grouped over the same periods of years used by Eurostat[10] to report the total number of buildings.

Figure 5 shows the apparent asbestos consumption in buildings (EU27+UK) estimated following the methodology described above.

Figure 5. Estimated asbestos consumption in buildings, EU27+UK



Source: JRC, 2022

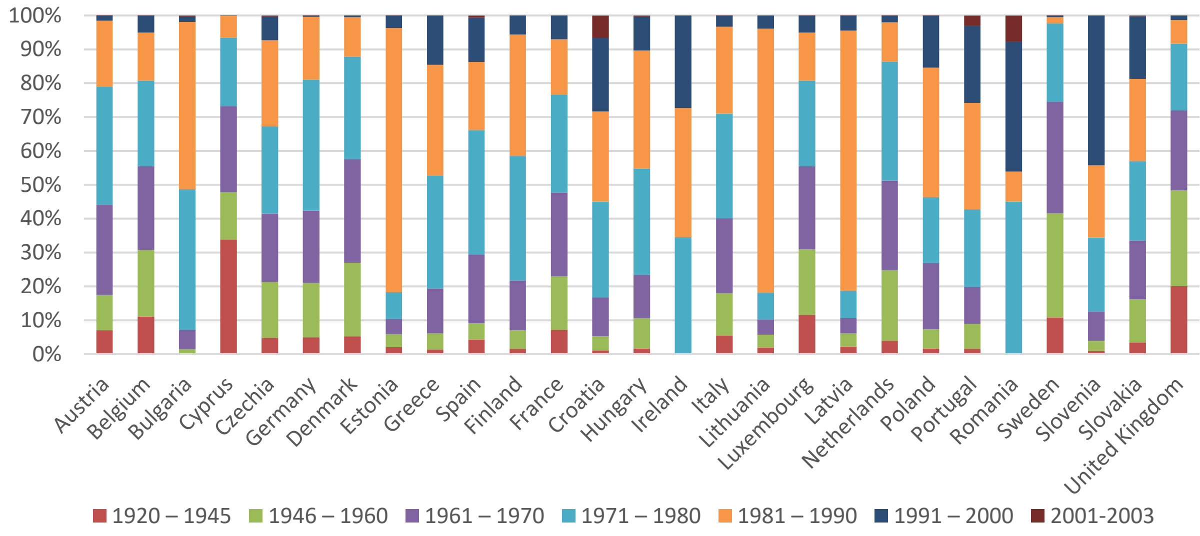
To validate the methodology, the estimations were crosschecked with data on asbestos consumption reported by other studies. The Federal Institute for Occupational Safety and Health from Germany estimates that between 1950 and 1990, 4.3 million tonnes of raw asbestos was used only for the production of asbestos cement products in Germany (BAuA, 2014). In Poland, using the national asbestos database, it was estimated that about 1.3 million tonnes of raw asbestos is incorporated in asbestos cement panels (considering a share of 15% of raw asbestos in the product). In Flanders region it is estimated that 1.9 million tonnes of ACMs are in buildings (OVAM, 2016). Thus, the reported results appear to be aligned with data reported by other studies considering that these estimations cover the asbestos quantity in all ACMs used in buildings (including asbestos spray insulation and asbestos cement pipes and ducts).

Figure 6 illustrates the share of apparent asbestos consumption in buildings per age band. In Cyprus, Belgium, Denmark, Luxembourg, The Netherlands and Sweden the main quantities were consumed before the 1970s while Croatia, Ireland, Romania, Slovenia, and Slovakia registered high asbestos consumption in the 1990s and

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

early 2000s. Therefore, it is expected that buildings constructed in those periods have a higher probability of containing asbestos.

Figure 6. Share of asbestos consumption in buildings per construction age band, EU27+UK



Source: JRC, 2022

However, so far, accurate data on the number of buildings per period of construction is given only for residential buildings, specifically for dwellings (Eurostat, 2011). In this study, the estimated number of dwellings per age band is based on 2011 Census data by Eurostat adjusted by downscaling the national construction after 2011 (Eurostat, 2011; Zangheri et al., 2020).

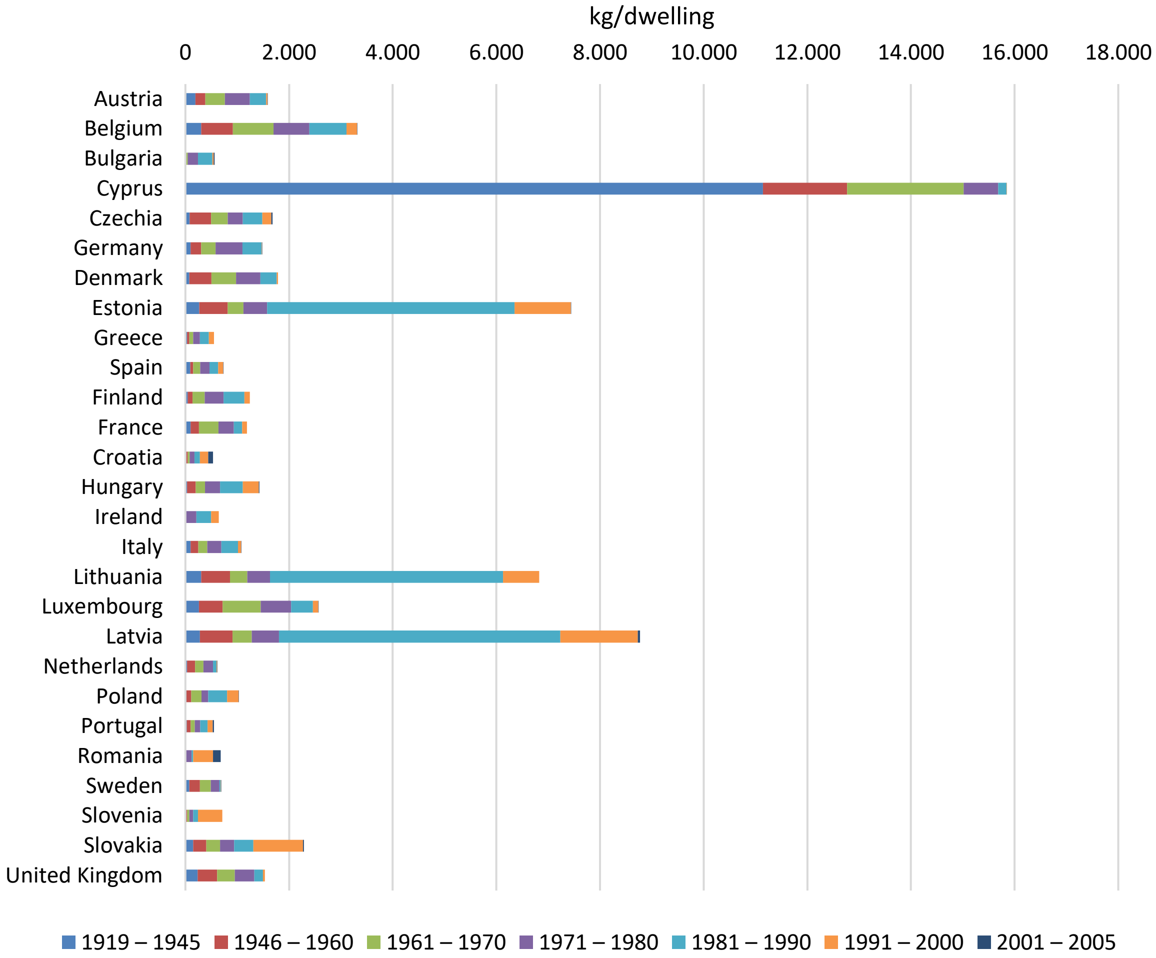
To evaluate asbestos consumption in dwellings, the estimated quantity of asbestos in buildings is disaggregated based on the share of residential and non-residential building units reported for each age band (Pezzutto et al., 2018) assuming that, on average, the same quantity of raw asbestos was used in both type of buildings in all periods. Then, using the share for residential building units, the asbestos consumption in kilograms per unit of dwelling is calculated.

Figure 7 illustrates an estimation of the apparent asbestos consumption (kg) per dwelling.

From this perspective, the most critical cases are Cyprus, Latvia, Lithuania, Estonia, and Belgium. Indeed, Cyprus is seen as one of the oldest asbestos sources and one of the largest chrysotile asbestos producer in Europe (Leonidou Associates and Institute of Cancer Research UK, 2005). Belgium has one of the highest mesotheliomas (asbestos triggered disease) mortality rates in the world (Van den Borre and Deboosere, 2014). The results are also aligned with the situation in countries of the former Soviet Union, which are reporting high consumption of asbestos when the construction sector flourished in the second half of the 20th century[11].

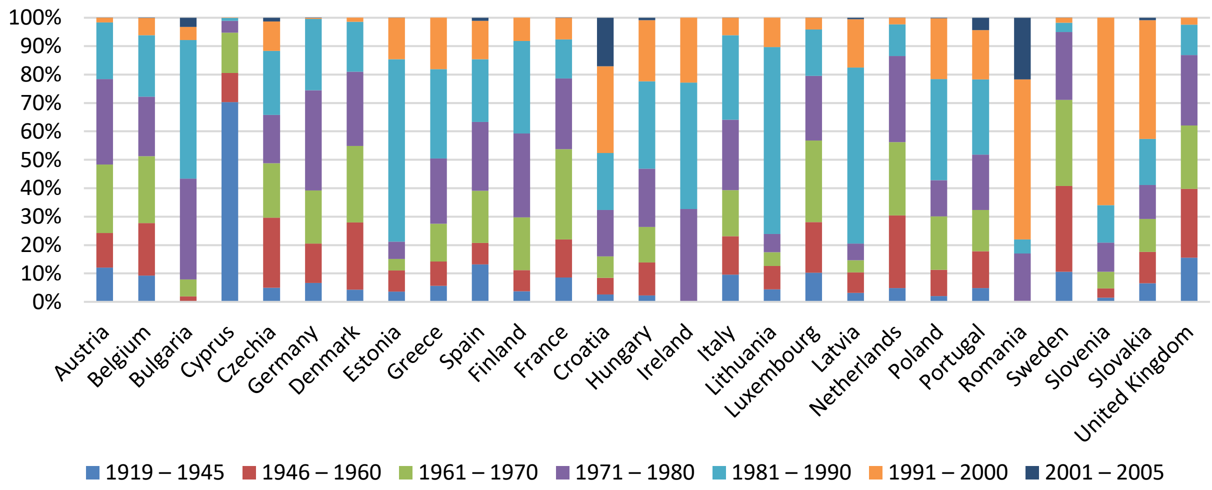
[11] Latvia: https://azbests.lv/vesture/; Lithuania: https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/5b8201000f0111e7b6c9f69dc4ecf19f?jfwid=, Estonia: https://kodus.ee/artikkel/mida-jalgida-ohtliku-asbesti-lammutamisel

Figure 7. Estimated asbestos consumption per dwelling, EU27+UK



Source: JRC, 2022

Figure 8. Share of asbestos consumption per dwelling and age band, EU27+UK



Source: JRC, 2022

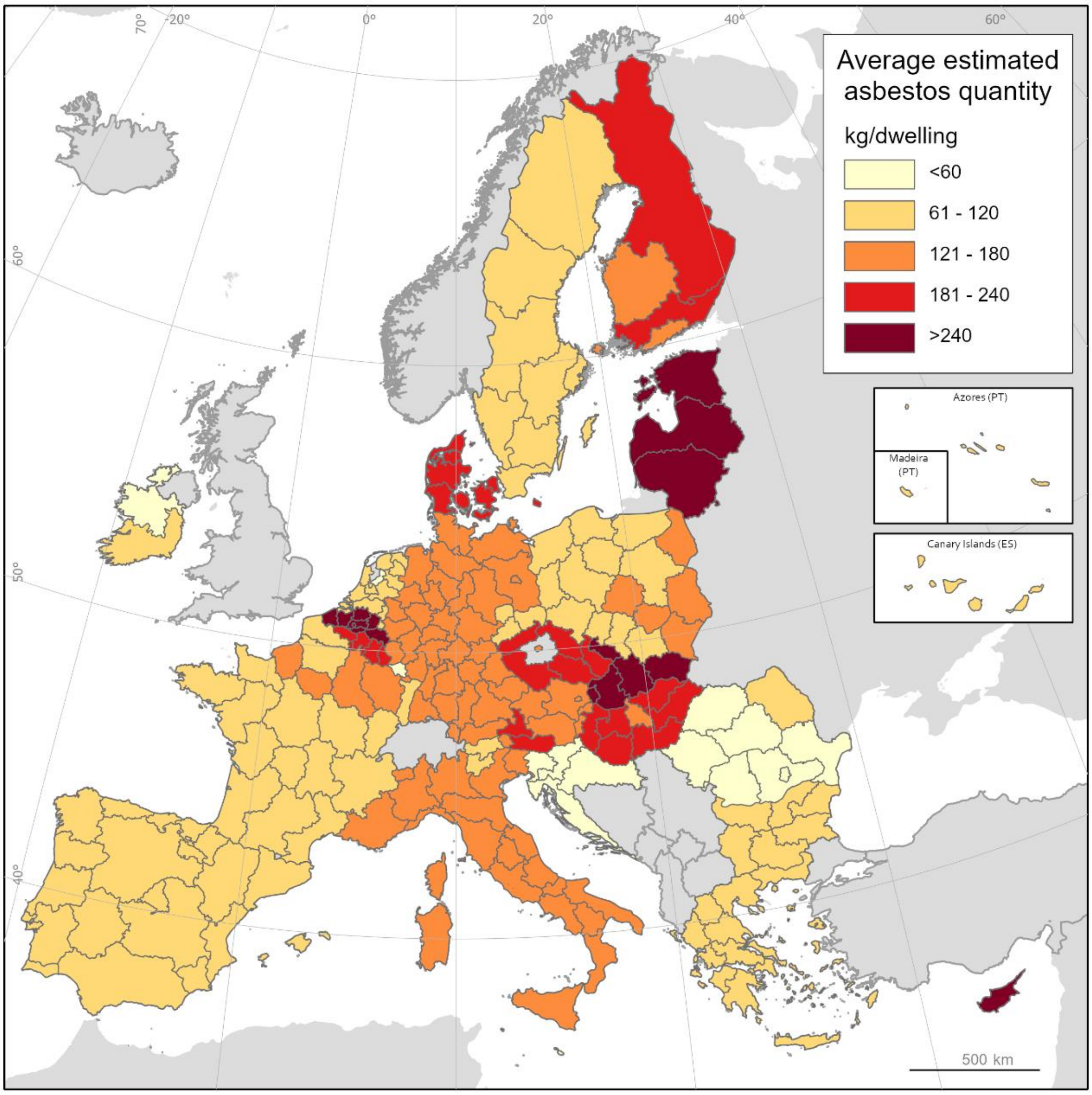
Figure 8 shows the estimated share of asbestos in dwellings per age band.

In most EU countries, dwellings built between 1970 and 1990 probably have higher quantities of asbestos. However, in Cyprus, Belgium, Denmark, France, Luxembourg, The Netherlands, and Sweden it appears that such dwellings date before 1970. In Croatia, Slovenia, Slovakia and Romania newer residential buildings, built between 1990 and early 2000s are at higher risk of having significant quantities of asbestos. In Bulgaria, Estonia, Ireland, Lithuania, Latvia, and Poland dwellings built in the 1980s stand out from this perspective.

Furthermore, the asbestos quantity in buildings at regional level (NUTS2) is estimated. The data is disaggregated based on the quantities of asbestos per dwelling at national level and the number of dwellings at regional level per period of construction. The estimation of the numbers of dwellings at regional level per period of construction is based on EUROSTAT data[12] and adjusted as explained in (Zangheri et al., 2020).

Figure 9 illustrates the estimated average quantity of asbestos across the age bands (average kg/dwelling).

Figure 9. Estimated average quantity of asbestos in the residential building stock, EU27



Source: JRC, 2022

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

It appears that most regions in central Europe have an average of over 120 kg of asbestos per dwelling. Belgium, Denmark, Finland, Czechia, Cyprus, Slovakia, Hungary as well as the Baltic countries shown high criticality with several regions (from Belgium, Slovakia, Cyprus, and the Baltic countries) having an average above 240 kg of asbestos per dwelling. Less vulnerable are most regions from Romania, Croatia and Ireland with an average below 60 kg of asbestos per dwelling.

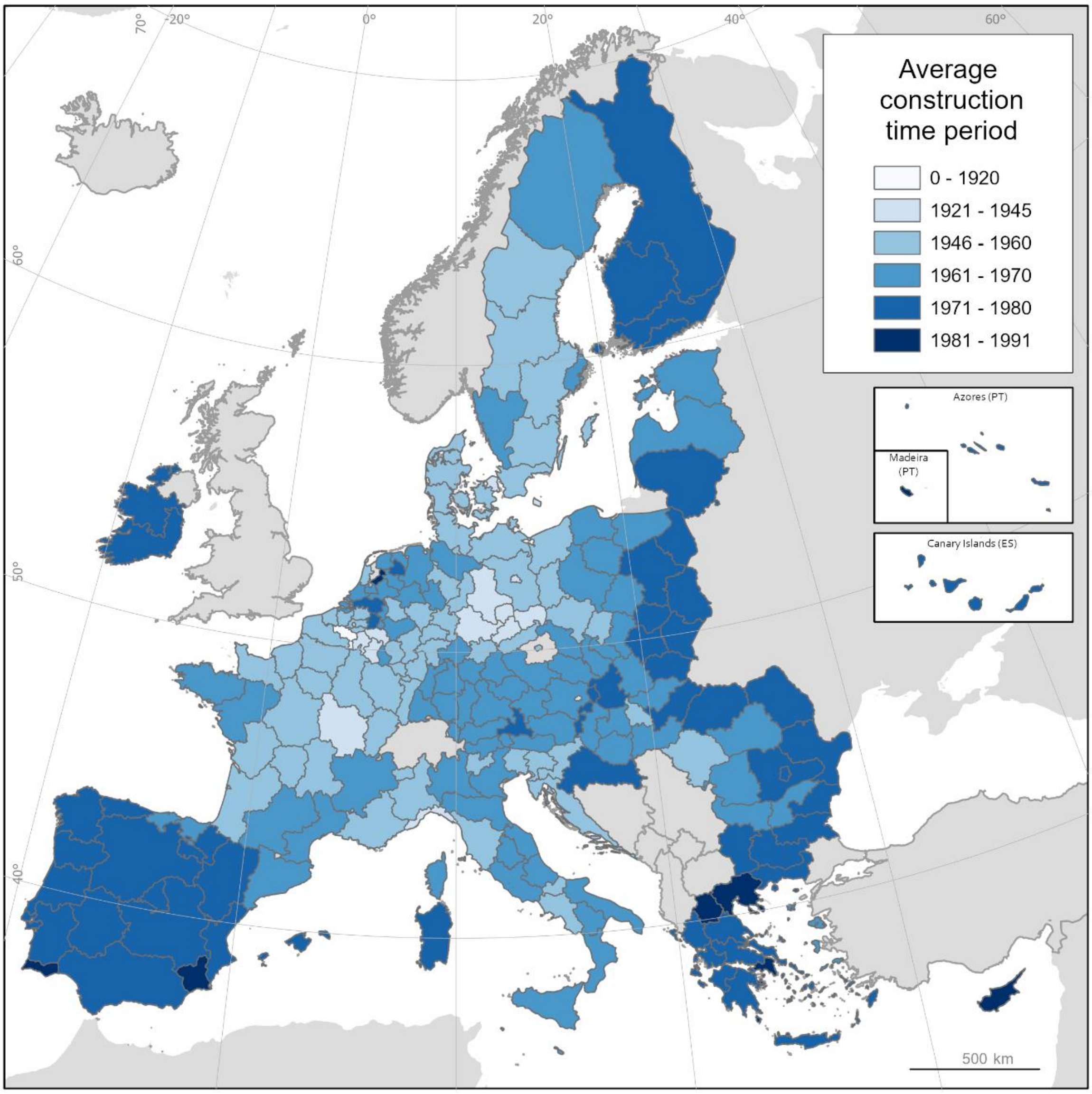
4 Indicators for deep energy renovation

As one of the main aims of this study is to prioritize EU regions for deep energy renovation (also considering the presence of asbestos), a first variable to examine is the age of the European dwellings. Buildings built before the introduction of energy efficiency requirements have poor energy performance (except for the already renovated ones). In this case, such buildings are considered to be dating before 1990.

However, not all old buildings follow this rule. Buildings of a certain era have thick walls made of brick or stone masonry, with better thermal resistance and thermal inertia compared to more recent buildings. In addition, even if identified as poor energy performing, many old buildings are part of the cultural heritage, and thus have retrofitting limitations. Dwellings built before 1920 represent this category.

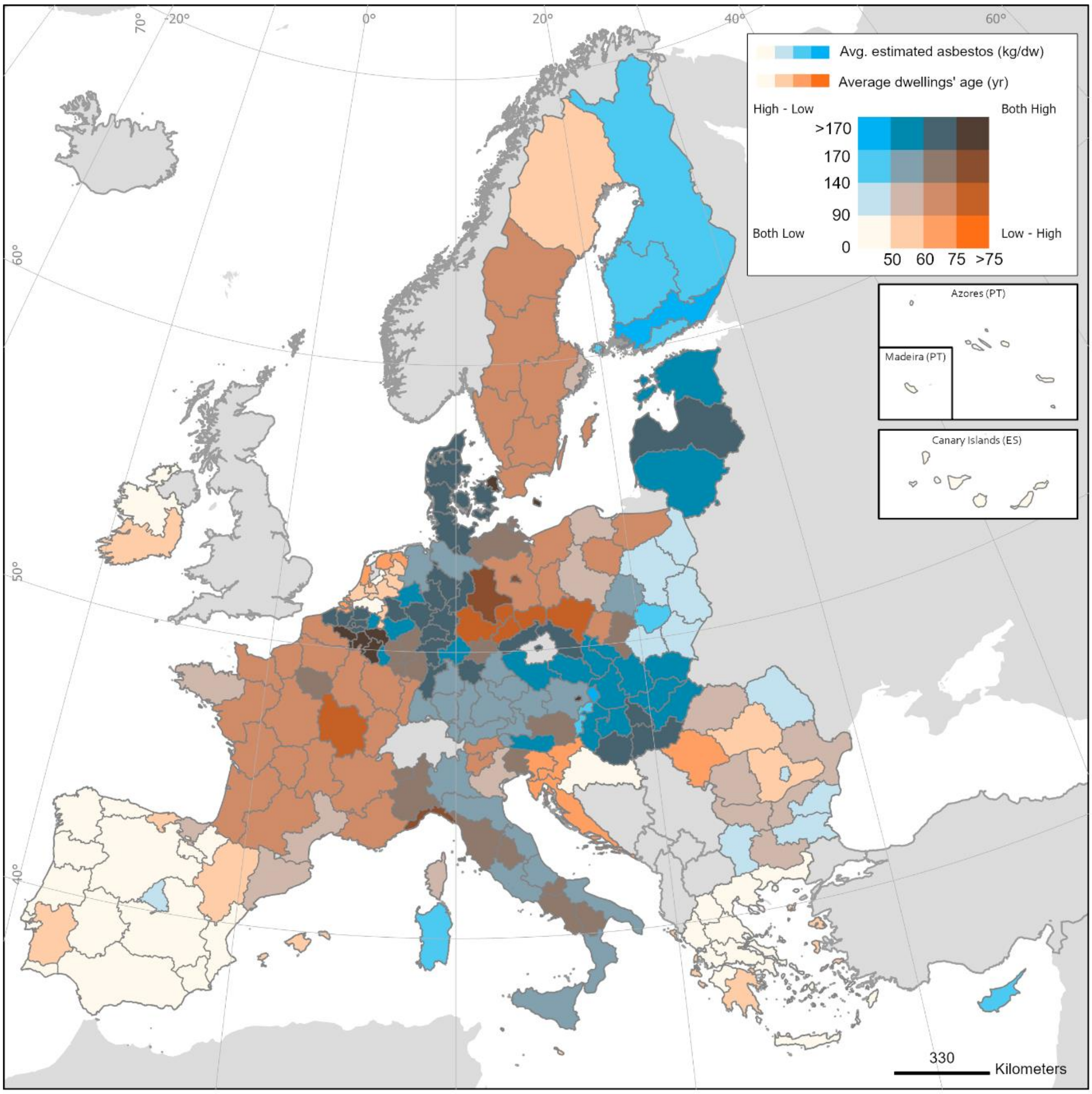
Figure 10 shows the average construction period of the residential building stock at regional level. It can be observed that central Europe is dominated by old dwellings (before 1960) while eastern and southwestern countries have regions with high share of more recent buildings (after 1970).

Figure 10. Average construction period of the residential building stock, EU27



Source: JRC, 2022

Figure 11. Bivariate map representing the average residential building stock age (years) and the average quantity of asbestos (kg/dw), EU27



Source: JRC, 2022

Figure 11 reveals the critical regions across the EU considering the estimated quantity of asbestos (kg/dwelling) and the average age (years) of the building stock at regional level ranging from both low (low quantity of asbestos, newer buildings) to both high (high quantity of asbestos, older buildings).

As expected, the most vulnerable regions are in central Europe (particularly in Germany and Belgium), including Italy and Denmark, dominated by old buildings (built before 1960) and high quantities of asbestos. A particular case is represented by some northern and eastern regions (from Bulgaria, Finland, Estonia, Latvia, Lithuania, Slovakia, Poland, Romania) where considerable amounts of asbestos are expected to be incorporated in more recent buildings (built after 1980). Ireland, Greece, and Spain show low quantities of asbestos in dwellings at regional level. These findings may indicate the EU regions where asbestos screening should be performed before the renovation works.

In addition to the presence of asbestos, several characteristics with impact on the energy consumption and renovation works are aggregated in composite indicators that highlight Europe's regions in need of renovation. These characteristics describe the climatic conditions, the residential building stock age, the economic well-being[13], the energy saving potential and the employment effect. An overview of these indicators is presented in (Zangheri et al., 2020).

Three composite indicators are created: I1 - including only building-related characteristics; I2- including key building and key economic characteristics and finally I3 - including all relevant characteristics. The exact composition and the weights of each characteristic in each of the three indicators are presented in Table 2.

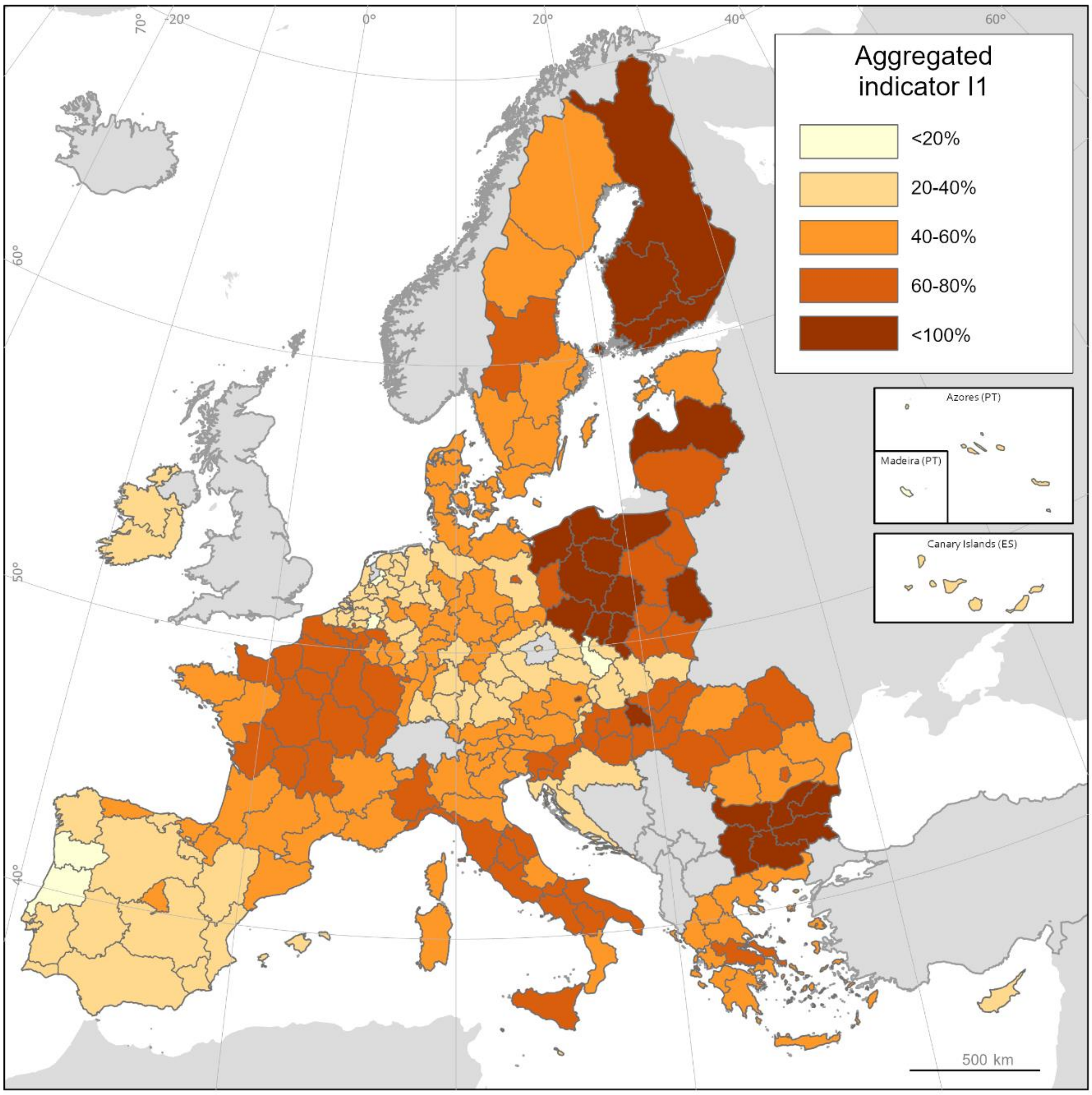
Table 2. Composition and weights of each aggregated indicator

	Indicator I1 building-related	**Indicator I2 key building and economic related**	**Indicator I3 all key characteristics**
Asbestos quantity (kg/dwelling)	30%	30%	15%
Average building age	20%	30%	15%
Share of buildings built before 1919			5%
Share of buildings built before 1991	20%		10%
Heating Degree-Days			10%
Economic well-being		20%	15%
Share of non-owner-occupied dwellings			5%
Share of rented MFH			5%
Saving rate (%)	30%		10%
Efficiency savings/costs (Wh/EUR)		10%	10%
Employment multiplier (FTE/MEUR		10%	

Source: JRC, 2022

[13] Based on the average GDP per inhabitant, the variation of the GDP per inhabitant, the average unemployment rate, and the average net disposable income of households per inhabitant, over the period 2018-2021.

Figure 12. Aggregated indicator I1 revealing vulnerable regions based on building-related characteristics, EU27



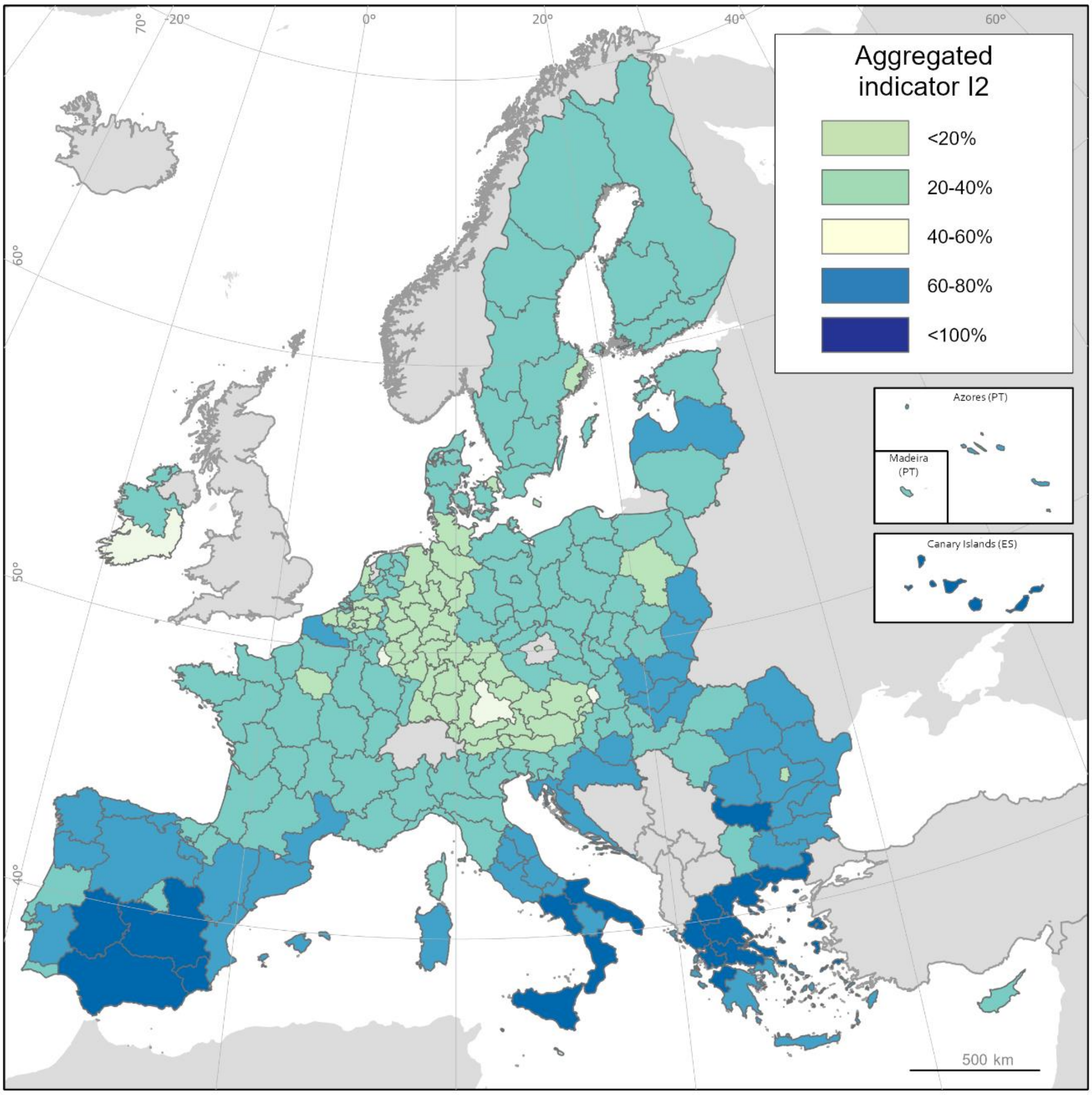
Source: JRC, 2022

Indicator I1 classifies the EU's regions from high (above 80%) to low (below 20%) criticality in terms of a) average age of the residential buildings built before 1991 (before energy efficiency requirements), b) prospective asbestos quantity and c) the energy saving potential of deep renovation of residential buildings expressed in energy saving rate (Zangheri et al., 2020).

From this perspective, the vulnerable regions are in eastern EU, which is governed by high energy saving potential and high quantities of asbestos in residential buildings. Particularly Finland's regions Etelä-Suomi and Länsi-Suomi, Poland's regions Dolnoslaskie and Slaskie and Severozapaden from Bulgaria could be priority regions for deep renovation. On the opposite side, Flevoland region from The Netherlands, Madeira, Centro and Norte from Portugal as well as Limburg from Belgium have the lowest vulnerability under I1 aggregation.

Indicator I2 (Figure 13) combines the building related characteristics (average age of the building stock and estimated asbestos quantities) and key economic aspects, such as the economic well-being, the employment multiplier and the renovation efficiency (ratio between energy benefit and economic expenditure).

Figure 13. Aggregated indicator I2 revealing vulnerable regions based on key building and economic related characteristics, EU27

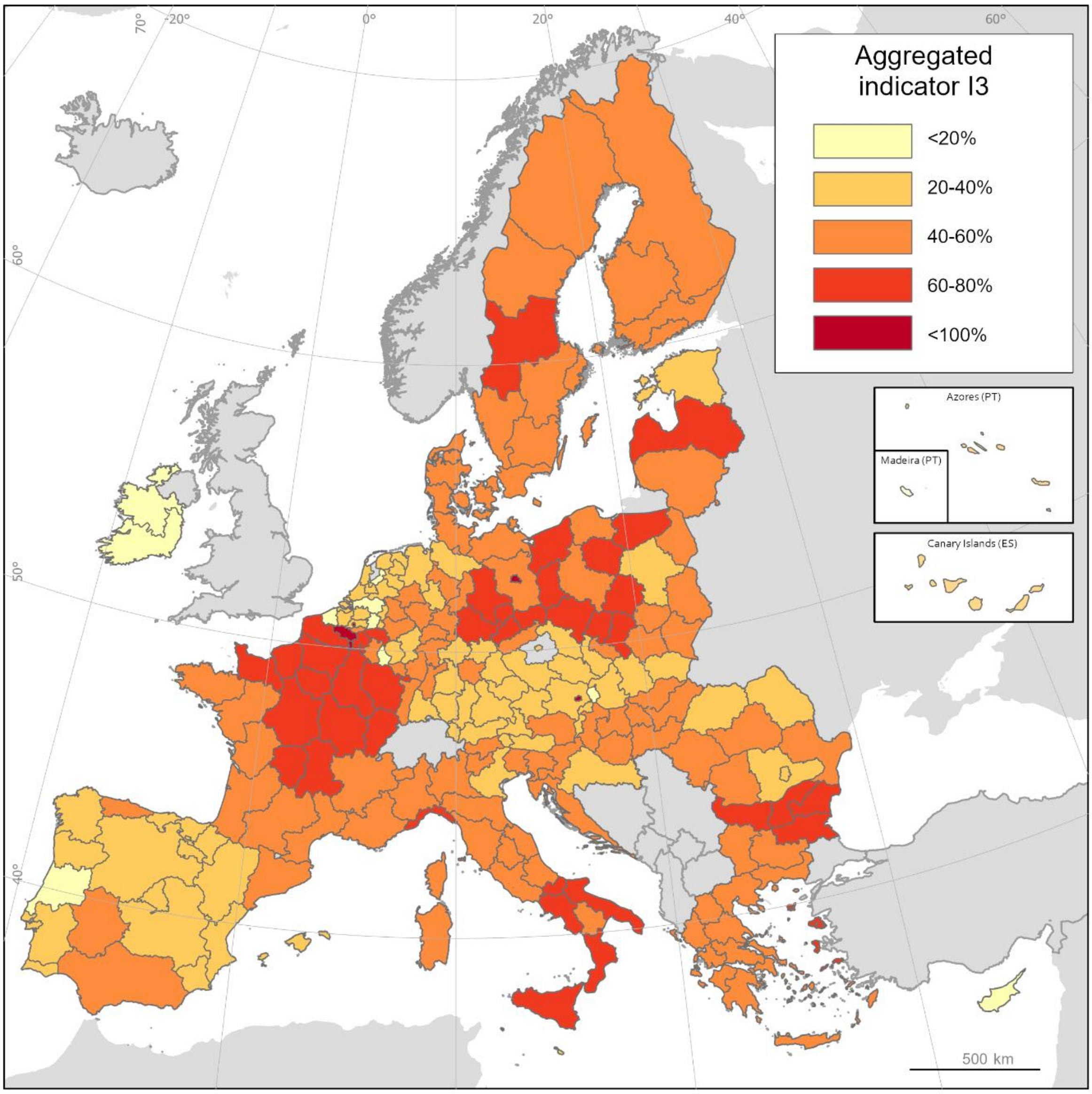


Source: JRC, 2022

In this case, the criticality shifts from eastern EU to southern EU, revealing regions with low economic well-being over the period 2018-2021. Dytiki Ellada and Makedonia from Greece, Calabria from Italia and Extremadura and Andalucia from Spain are the worst affected regions while Luxembourg, Bratislavsky Kraj from Slovakia, Oberbayern from Germany, Southern and Eastern Ireland and Praha from Czechia are the less affected considering the I2 combination.

The indicator I3 aggregates building, economic and climate related characteristics are shown in Table 2.

Figure 14. Aggregated indicator I3 revealing vulnerable regions based on all key characteristics, EU27



Source: JRC, 2022

In this case, both the most and the least vulnerable regions are scattered across Europe. As may be observed the highly affected areas are some big urban regions (Wien, Berlin, Brussels region) but also many Italian regions with Campania as a leader. Bulgaria, Poland, France, and the Nordic countries also show high criticality. Also here, Bratislavský Kraj from Slovakia, Flevoland from The Netherlands, Southern and Eastern Ireland, Limburg from Belgium are the least affected. Regions from Austria, Cyprus, Czechia, Croatia, Estonia Hungary, Ireland, Lithuania, The Nethelands, Portugal, Romania, Slovakia, Slovenia, and Spain are less affected considering the I3 composition.

This finding may indicate the regions that should be prioritized within a MS or at EU regional level for deep energy renovation to address energy performance, health and economic related aspects. Furthermore, such information could be considered to design renovation programmes incentivising the removal of asbestos from the built environment in the regions identified as vulnerable also financed by the planned Next Generation EU.

5 Good practices of asbestos removal strategies in the EU

This section presents good practices of asbestos removal from the building stock across the EU. Some MSs are successfully coordinating the removal of asbestos with the energy renovation of buildings. Two common mechanisms are (1) offering additional top-ups on energy renovation subsidies if asbestos is identified and removed and (2) making the installation of solar collector and PV panels conditional on the removal of asbestos. An innovative approach is identified in Flanders region (Belgium) where the introduction of asbestos free certificate in buildings is planned. Among the EU countries, only Poland has adopted an action plan to remove all asbestos.

Belgium

Belgium has one of the highest mesotheliomas (asbestos triggered disease) mortality rates in the world (Van den Borre and Deboosere, 2014). The removal and disposal of asbestos are regulated at a regional level.

Brussels-Capital

In Brussels-Capital region, the 2020 Long-Term Renovation Strategy reports that before renovation, a diagnosis of the building is performed. If during this procedure, asbestos is detected, the renovation plan must include specific recommendations for its safe removal (BE-BR LTRS, 2020).

Flanders

The Flemish Government decided to make Flemish buildings and infrastructure asbestos free in phases by 2034 (by 2040 at the latest) by implementing an accelerated phasing-out asbestos plan in July 2018. The amount of ACMs was estimated to be around 3.7 million tonnes from which 1.9 million tonnes in buildings and 1.8 million tonnes in utility pipes (OVAM, 2016).

To trigger the removal of asbestos, the energy renovation of buildings is conditioned by the presence of asbestos, for instance installing solar panels is prohibited if asbestos is present. Removal protocols have been initiated for target groups such as schools, healthcare buildings, agriculture, and social housing.

In addition, subsidies are offered to citizens, associations, and local authorities by the Flemish government to support the collection and disposal of asbestos waste. Since 2021, a premium is granted for the renovation of dwellings with asbestos containing roofs.

The introduction of asbestos certificate for buildings for sale is planned for 2022, which will be a strong incentive for building owners to make the buildings asbestos-free. The asbestos removal cost was estimated to be around EUR 3.2 billion for the period 2019–2040 which includes dismantling, removal and processing asbestos waste costs (BE-FL LTRS, 2020).

Italy

Italy was the main asbestos producer and one of the greatest consumers until the asbestos ban was introduced in 1992. In the past 30 years, the involvement of stakeholders allowed advances in the industrial asbestos replacement process and contributed to the integration of environmental and health policies at national, regional and local levels (Marsili et al., 2017).

At the end of 2021, the Italian Government approved the new transposition of Directive RED II (Decree 199/2021), including a focus on asbestos. In particular, incentives are provided to those who install photovoltaic systems following the removal of asbestos, with concessions and participation procedures as wide as possible. For these purposes, the area where the asbestos replacement took place does not need to coincide with the one where the system is installed, as long as the system is installed in the same building or other buildings with the same ownership. Moreover, the photovoltaic systems can occupy a greater area than that of the replaced asbestos.

France

France is seen as a major asbestos consumer in the European Union and 10% to 20% of lung cancer cases and 85% of mesotheliomas are assumed to be caused by asbestos (Kazan-Allen, 2018a). While asbestos was used in many industrial applications, the main quantities went into the production of asbestos-cement products.

In the 2020 Long-Term Renovation Strategy, France acknowledge that asbestos is still present in huge quantities in buildings and the renovation works could be source of high exposure of asbestos thus requiring a preliminary assessment of the site. This is regulated by the decree of May 2017 concerning the identification of asbestos before certain operations (with amendments in 2019 and 2020).

Approximately 3 million social housing units out of 15 million have been identified with asbestos related problems and the estimated costs are EUR 25 billion to safely remove the asbestos (EESC, 2015). The eco-loan for social housing, the main mechanism for social housing energy renovation in France, includes an additional top-up of EUR 3 000 per dwelling if asbestos is identified in the building (FR LTRS, 2020).

Germany

Germany started the process of asbestos removal as early as 1983 when a project group for the removal of asbestos was formed and guidelines for its safe removal were established. The guidelines were amended in 1996 and again revised in 2019 (BAuA, 2014).

However, the presence of asbestos in existing building is still an open issue. The German renovation strategy of buildings states that all building built before 1993 (the year of general ban of asbestos), are considered affected by this issues. The share of such buildings is estimated to be around 80%.

As a result of the National Asbestos Dialogue, information on the safe renovation of existing buildings containing asbestos will be available soon (DE LTRS, 2020).

The Netherlands

The Dutch government proposed to ban all asbestos roofs by 31 December 2024 but the proposal did not pass the Senate (Government of the Netherlands, n.d.).

A recent study by (Duregger, 2021) reviews the initiatives for the removal of asbestos roofs across The Netherlands. Some of them are mentioned below.

In January 2016 a national programme subsidizing the removal of asbestos roofs with a budget of EUR 75 million, intended for four years, covering both private and public buildings. The programme was in high demand and by December 2018, the budget has been exhausted. In additions, financial arrangements, such as loans, dedicated to stimulate energy efficiency in buildings with the possibility to address asbestos removal were identified both at national level (The National Energy Saving Fund) and at provincial level, in Limburg and Drenthe. Programmes for monitoring the removal of asbestos as well as a One-Stop-Shop initiative (Asbestoslink) for asbestos roof replacement are also reported.

Poland

Poland has in force an exemplary national programme for the safe removal of asbestos (Asbestos Removal Programme 2009-2032), involving both public and private financing. Moreover, since 2013, an Asbestos Database is in use.

In 2010, it was estimated that 14.5 million tonnes of asbestos products are to be removed within the framework of the programme with a total budget of EUR 8.83 billion. However, in August 2021, only 8.4 million tonnes of asbestos products were registered in the Asbestos Database[14]; out of which 1.3 million tonnes of asbestos waste have been removed and neutralised. This means that only 57% of the estimated asbestos-containing materials are registered in the database (ECSO, 2021).

The programme includes legislative measures on asbestos removal, information and training activities, asbestos removal task from all sector, monitoring activities through Spatial Information Systems and activities for exposure assessment and health protection. Between 2009 and 2014, 71 information and education projects were implemented with a total cost of EUR 0.9 million (Ministry of Economy, Poland, 2010).

It also includes financing mechanisms that combines thermal efficiency upgrades with asbestos removal in the residential sector and dedicated packages for freeing the public sector from asbestos. Asbestos roofing removal is a precondition to finance solar collector and PV modules. Grants up to 85% are provided to municipalities that have inventories of asbestos and local programmes of asbestos removal (Pawelec, 2017) (Ministry of Economy, Poland, 2010).

[14] https://bazaazbestowa.gov.pl/en/about-asbestos/asbestos-statistics

6 Conclusions and recommendations

The European Union committed to address climate changes through the European Green Deal, a strategy for green and digitalised society with less energy-consuming and healthier buildings by 2050. In this sense, the Renovation Wave strategy aims to at least double the annual energy renovation rate of buildings by 2030 across the EU and to foster deep renovation.

As an essential legislative tool to support the Renovation Wave, the Energy Performance of Building Directive (EPBD) frames the concept of deep renovation. The Directive asks, inter alia, for energy performance upgrades that improve the indoor environmental quality including the removal harmful materials from the existing building stock, such as asbestos, which was widely used in the 20^{th} century in the construction sector.

Although banned in the EU approximately 20-30 years ago, asbestos is still present in large quantities in existing buildings. As the building stock ages and deteriorates, the risk of asbestos exposure is increasing for occupants and technicians during maintenance and renovation activities.

This study identified the European regions at risks of having high amounts of Asbestos Containing Materials (ACMs). Based on the asbestos consumption in MSs between 1920 and 2003, the percentage of raw asbestos used in building materials, the age of dwellings and their share from the total number of building units built during the indicated periods, the potential quantity of asbestos in dwellings was estimated.

In most EU countries, higher quantities of asbestos are expected in dwellings built between 1970 and 1990. However, in Cyprus, Belgium, Denmark, France, Luxembourg, The Netherlands, and Sweden it appears that dwellings dating before 1970 are at higher risk of having significant quantities of asbestos, while in Croatia, Slovenia, Slovakia and Romania, this risk is in newer residential buildings, built between 1990 and early 2000s.

Furthermore, the asbestos presence in buildings was disaggregated at regional level (NUTS2) across all MSs. In addition to the presence of asbestos, several characteristics with impact on the energy consumption and renovation works are aggregated in composite indicators that highlight Europe's regions in need of renovation. These characteristics describe, the residential building stock age, the climate conditions, the economic well-being, the energy saving potential and the employment effect.

Considering the average age of the building stock and the estimated quantities of asbestos, the most vulnerable regions are located in central Europe (particularly in Germany and Belgium), including Italy and Denmark where buildings are old and the presence of asbestos is estimated to be high. A particular case is represented by the northern and eastern regions (from Bulgaria, Finland, Estonia, Latvia, Lithuania, Slovakia, Poland, Romania) where excessive amounts of asbestos are expected to be incorporated in more recent buildings.

Including the energy saving potential, the criticality of the regions shifts from central Europe to eastern European regions that are governed by both high energy saving potential and high quantities of asbestos.

Adding key economic aspects (the economic well-being, the employment multiplier and the renovation effectiveness), the indicator points out the regions with low economic well-being over the period 2018-2021 located in southern Europe while central Europe is less critical under this combination.

Finally, aggregating all building, economic and climate related characteristics, both the most and the least vulnerable regions are scattered across Europe. The worst affected are some big urban areas (Wien, Berlin, Brussels region) but also most of the Italian regions. Many regions from Bulgaria, Poland, France and the Nordic countries also show high criticality.

The report offers, for the first time, a figure on the potential quantities of asbestos in residential buildings revealing the European regions with dwellings at risk of having high quantities of ACMs. The findings may indicate where asbestos screening before renovation should be a priority, since the identification of ACMs during renovation works may be grounds for delay. Such information could be added in the renovation passport, whose main purpose is to provide a clear renovation roadmap helping owners and investors plan the best timing (EC, 2021a).

In the context of accelerated renovation of the building stock and given that most MSs have set renovation milestones in 2020 Long-Term Renovation Strategy, it is essential to anticipate the possible delays. Particularly the late identification of the presence of asbestos, not only would delay renovation but it could also create a health hazard.

Moreover, MSs should ensure through local or regional authorities that construction companies and workers carrying out renovation works in buildings with high risk of having asbestos are rigorously trained to remove in safe conditions any ACMs found in buildings.

In addition, based on these findings and aiming at an asbestos-free building stock, MSs may prioritize for renovation buildings with both high energy saving potential and high quantities of ACMs. Actually, the staged removal of asbestos could be added as milestone in the renovation roadmap also evaluating the wider benefits of the avoided asbestos related diseases. However, for this to be possible there is a need for robust inventory of ACMs in buildings across the EU.

Finally, our findings can provide guidance to policy makers and national and regional authorities to design renovation programmes incentivising the removal of asbestos from the built environment in the regions identified as vulnerable.

Several MSs are already successfully coordinating the removal of asbestos with the energy renovation of buildings. Two common mechanisms are (1) offering additional top-ups on energy renovation subsidies if asbestos is identified and removed and (2) making the installation of solar collector and PV panels conditional on the removal of asbestos.

While this study focuses on the residential sector, ACMs are also common in non-residential buildings. An intriguing case is represented by The Barleymont, the office building located in Brussels, Belgium which has hosted the European Commission's headquarters since 1967. In 1991 the presence of asbestos was discovered and the building was evacuated. The whole steel structure of the building was coated with sprayed asbestos. In 1995 the operation of asbestos removal started and only 4 years after, in 1999, the asbestos removal was certificated as completed (EC, 2004). It is estimated that approximately 1 500 tonnes of asbestos and other large amounts of contaminated materials and products were removed (Beary, 2004).

However, the lack of consistent data on the non-residential building stock makes estimating the potential quantities of asbestos difficult. Public authorities should lead by example and address the safe removal of ACMs from public buildings while fulfilling the renovation requirements framed by the Energy Efficiency and Energy Performance of Buildings Directives. This action should be underpinned by comprehensive inventories of hazardous materials still present in public buildings.

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List of abbreviations and definitions

ACM	Asbestos-Containing Material
EECS	European Economic and Social Committee
EPBD	Energy Performance of Buildings Directive
EU	European Union
FTE	Full-Time Equivalent
HDD	Heating-Degree Day
IEQ	Indoor Environmental Quality
JRC	Joint Research Centre
LTRS	Long-Term Renovation Strategy
MS	Member State
MFH	Multi-Family House
NUTS	Nomenclature of Territorial Units for Statistics
WHO	World Health Organization

List of figures

List of tables

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