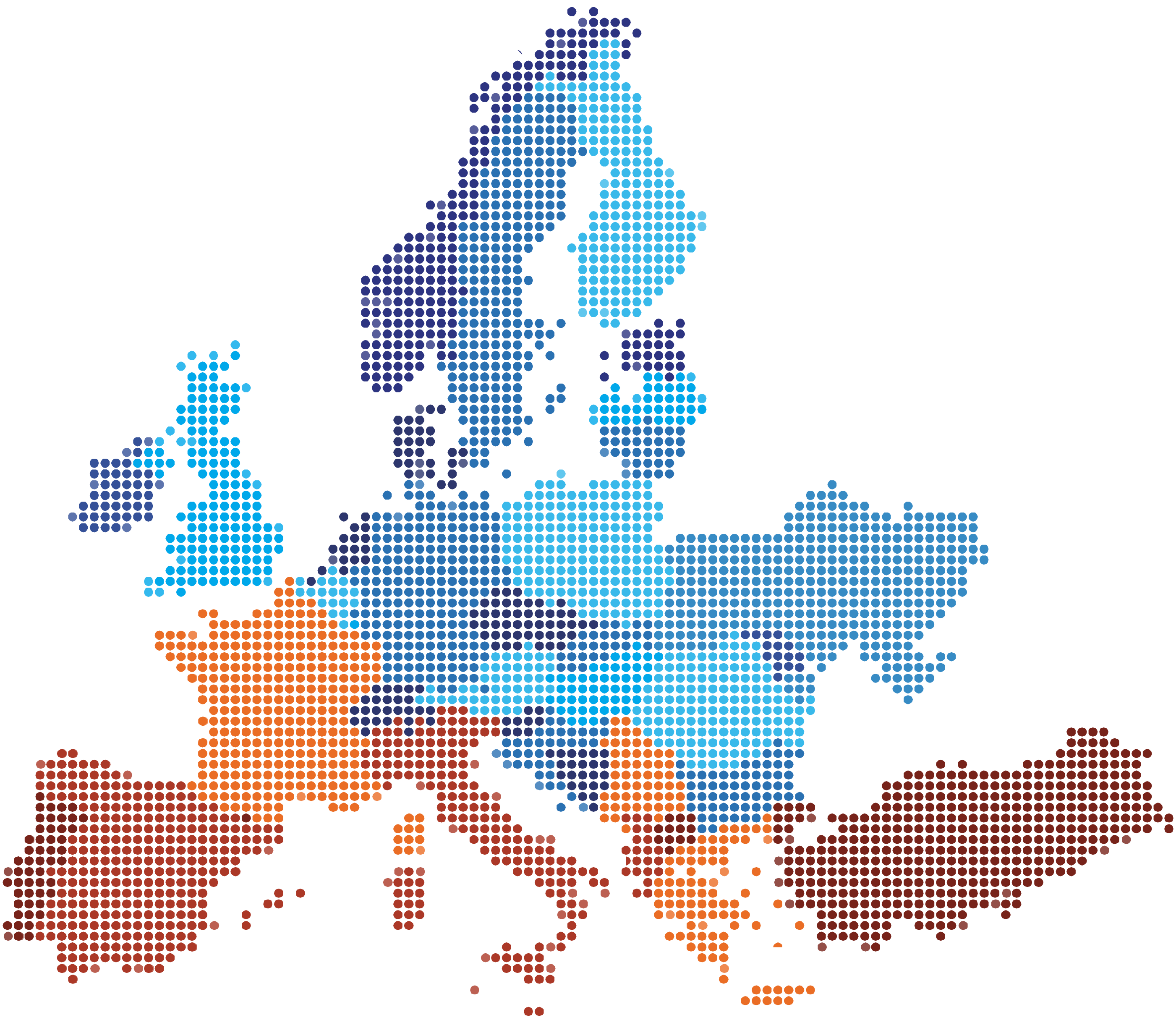
EAE
European Association for
External Thermal Insulation Composite Systems

2024 EUROPEAN ENERGY EFFICIENCY GUIDE

A true Renovation Wave for a Sustainable Future



This study was prepared by: FIW München

ETICS ARE AMAZING.
Good for the environment, the economy and the people.

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The FIW - Forschungsinstitut für Wärmeschutz e. V. München, https://fiw-muenchen.de/en/, has carried out this study on behalf of EAE (Research Report FO-2023-02).

Authors (all FIW): Kerstin Lohr, Chiara Cucchi, Sebastian Treml, Christoph Sprengard. The responsibility for the content of this report lies with the authors.

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EDITORIAL

ENERGY EFFICIENCY GUIDE 2024

A true Renovation Wave for a Sustainable Future

Ralf Pasker
EAE Managing Director

Dear readers,

already our Energy Saving Guide 2016 addressed "The long road to energy-efficient buildings in Europe." Still Europe's buildings account responsible for 40 % of Europe's final energy consumption and 36 % of its GHG emissions. However, we must not forget the positive developments since. With the Green Deal the European Commission set sails for making Europe net carbon neutral by 2050. The COVID-19 pandemic together with the Russian invasion in Ukraine showcased Europe's vulnerability in material and energy supplies. Both fostered the ambitions to make Europe less dependent. Thanks to the Fit-for-55 package numerous pieces of legislation have been adjusted – for the first time taking a coordinated and holistic approach. EAE contributed in multiple ways to the decision-making process, be it with our own contributions to consultations or jointly with our partners both at European and national level, bringing in the views and the expertise of the European ETICS sector.

For the first time ever the efficiency first principle has been introduced as guiding principle in the Energy Efficiency Directive. With the revision of the just cited Energy Performance of Buildings Directive further important steps have been taken. By 2030 all new buildings should be zero-emission buildings. EU member states will make sure that the average primary energy use of residential buildings will be reduced by 16% in 2030 and by 20-22% in 2035. At least 55% of the energy reduction will be achieved through renovation of the 43% worst performing residential buildings. Member states will revise their national legislation in accordance with the new directive in the years to come. This will include making available technical and more financial assistance to lower the barriers to deep or staged deep renovation. They will adjust their national building renovation plans. EAE and its partners will continue to support the process. This Energy Efficiency Guide may act as a valuable source of information.

The final piece of regulation that is about to come is the revised Construction Products Regulation. It will emphasize the environmental performances of products used in construction, promoting solutions contributing to a circular economy. The ETICS sector takes its responsibility, took early action and will continuously improve processes. We are willing to play our role in this important transition.

Besides all technical and environmental aspects we need to encourage building owners, architects, designers with positive examples underlining what is already possible today. This is one of the objectives of our EAE Awards. You will find some winning projects included to this document and even more on our website. Looking at them, we are convinced you will understand our slogan "ETICS are amazing". ETICS offer a unique variety of technical and design options to meet nearly all needs of property owners and to comply with building regulation. In addition our sector requests reliable framework conditions. Stop-and-go decision-making leads to uncertainties along the entire value chain and contradicts urgently needed efforts to significantly increase building renovation rates. Else achieving the EU 2050 objectives gets out of sight.

Our special thanks go to FIW Munich, namely to Kerstin Lohr, Chiara Cucchi, Sebastian Treml and Christoph Sprengard for their efforts to bring the essence of various studies together in this Energy Efficiency Guide. Let's work jointly together for a true Renovation Wave for a Sustainable Future!

Prof. Dr.-Ing. Andreas H. Holm
Institute Director of Forschungsinstitut für Wärmeschutz e. V. Munich

ENERGY EFFICIENCY GUIDE 2024

A true Renovation Wave for a Sustainable Future

As we witness the escalating impacts of climate change, the imperative for action is clearer than ever. Energy efficiency stands out as the most immediate and impactful solution to address these challenges. Global warming leads to more extreme, sometimes even life-threatening, weather events and natural disasters resulting in significant ecological and economic damages, which are also felt in Europe. Therefore, the overall goals of limiting global warming to less than 2°C and therefore reducing greenhouse gas emissions to net zero by 2050 have long been on the political agenda. The European Green Deal paves the way for that in the EU by addressing key enablers to meet EU's climate objectives such as increasing energy efficiency and shifting towards renewable energy generation.

Nevertheless, especially the Russian invasion of Ukraine in February 2022 has made obvious that in Europe we need to become more independent regarding our energy supply, reducing reliance on fossil fuels from authoritarian-led third countries. Sanctions against Russia made Russia widely stop their gas exports to EU countries, which led to an energy crisis and all-time high energy prices in the EU.

Getting to zero requires a variety of strategies and solutions. It has never been clearer than now that we need to reduce energy consumption, increase renewable energy generation in the EU itself and increase energy efficiency as fast as possible. And all of this in parallel. This means that we need full commitment and fast action from all member states. Delay is no longer an option.

Buildings account for 40% of Europe's final energy consumption and 36% of energy-related greenhouse gas emissions, which makes them one of the main focus areas when it comes to increasing energy efficiency and the share of renewable energy use as well as reducing energy consumption. Considering their service life, it can be assumed that 85 % of today's European building stock will still exist in 2050. Renovation of these existing buildings plays a crucial role to become independent, resilient and in achieving climate neutrality by 2050. A true Renovation Wave in the EU has never been more important, as it is paving the way for a sustainable future.

To meet the targets set for 2030 deep energy-efficiency renovations, associated with a shift to renewable heating and cooling systems, are essential. The efficiency-first principle needs to be applied for all building renovations. The annual renovation rate for the EU-27 plus the United Kingdom is currently extremely low and must reach 3 % and then remain at this level to achieve renovation of nearly 80 % of the existing building stock by 2050.

Today, mostly all of our buildings still rely largely on fossil fuels, particularly natural gas and oil. It has long since clear that this leads to large amounts of greenhouse gas emissions – and the current global energy crisis is a sharp reminder of the urgency of moving to more affordable, reliable and cleaner ways of heating buildings. In this context, heat pumps and district heating are the key technologies to make heating more secure and sustainable.

Well-insulated buildings and efficient heat pumps are essential to reduce the capacity of heat pumps needed to warm a given amount of space and volume of water, thereby cutting the cost of operating as well as installing them. This also allows for lower flow temperatures, enabling heat pumps to operate more efficiently and at lower operational costs.

Consequently, buildings need to get prepared for low-temperature heating systems to avoid multiplying the total electricity demand and shortages in the grids. With renewable energies being limited, energy demand reductions by energy efficiency renovations are crucial and leave more renewable capacities for other sectors. Insulating buildings' envelopes significantly decreases energy consumption by reducing the energy demand. The dependency on fossil fuels would already decrease significantly without additional measures. This eases the shift to renewable energy. Reducing the demand together with the shift to electrification boosts the process to become less dependent from imports.

Improving buildings' envelopes and enhancing renovation rates are key enablers to achieve energy transition and climate neutrality. External wall insulations mark the most substantial savings whereby ETICS mark the most used system for building renovation – as well as a well-established solution for new buildings.

Nevertheless, our current reliance on primary materials is unsustainable, worsening resource depletion. The construction sector is one of the biggest consumers of raw materials and therefore bears a significant responsibility in this regard. Today, approximately half of all extracted materials are used by the construction sector. Construction and demolition waste (CDW) counts responsible for over one third of the total waste generation in the EU, even though the current and future share of ETICS on the CDW is low. However, every market player – no matter how small – has to take its responsibilities.

The recast of the Construction Products Regulation (CPR) offers a chance to prioritize recycled content, durability and the circularity of construction products leading to a smaller ecological footprint. The ETICS sector in particular, has shown progress on recycling solutions, but challenges remain, especially on the mix of materials and the fitness for deconstruction. Economic and ecological feasibility very much depend on the availability of ETICS waste streams. Thanks to the proven ETICS durability such waste streams are still small but will grow in the future. Today's small ETICS waste streams need to be considered when setting regulatory requirements for recycled content in the future. Regulatory frameworks must evolve to incentivize the use of recycled materials, fostering innovation and collaboration across sectors. By fostering sector collaboration, the demand for recycling shares in one sector must not, under any circumstances, lead to increased consumption of raw materials in the other sector. We have to focus on minimizing the use of virgin raw materials in total.

This could also be transferred to the use of energy. The energy we do not need is the most sustainable energy. Which links the focus back to energy efficiency renovations and its many advantages and solutions to face the challenges we face in Europe.

Apart from helping to reach our 2030, 2040 and 2050 climate objectives, the Renovation Wave helps to fight poverty. Inefficient buildings with inadequate heating systems and poorly insulated building envelopes are the main sources of energy poverty, which lead to poor indoor thermal comfort. Due to energy poverty millions of people across Europe are unable to cover basic housing costs or suffer inadequate living comfort or work environments. Nearly 34 million Europeans suffered energy poverty conditions in 2018, meaning that 7.6 % of all Europeans were unable to keep their homes adequately warm. In 2022 this figure even jumped to 9.3 %. People suffering from difficult financial conditions usually have problems managing their energy expenditure, generating a circle of high energy bills, debts and account arrears and even leading to problems with well-being and health. In contrast, reduced household energy expenditures release budgets stimulating consumption, supporting economic growth and social participation of most vulnerable parts of our societies.

By boosting energy-efficiency renovations especially by ETICS and other insulation measures, we can fight the burden of energy costs on people, whilst stimulating alternative consumption, supporting economic growth and enabling social participation. Additionally, the Renovation Wave leads to accelerated deployment of renewable energies and makes the EU less dependent on energy imports from third countries. All policies targeting the reduction of greenhouse gas emissions in the building sector lead to the creation of new jobs, reshaping the European labour market and significantly increasing the employment in the construction sector.

In conclusion greenhouse gas emissions from buildings mark 36 % of the problem. The Renovation Wave initiative offers 100% of the solution. It presents a historic opportunity to reshape our built environment and secure a sustainable future for generations to come.

1

TIME FOR RENOVATION IS NOW

Climate change is one of the greatest challenges facing mankind because it is an existential threat to all living beings and nature around the globe. Worst of all, it is man-made. **Figure 1** shows the evolution of the annual average global temperature in the world in the period from 1850 - 2018. These so-called "global warming stripes" were developed by Ed Hawkins, who aimed to illustrate the effect of global warming in a universal and easily understandable way. It becomes obvious that especially from 1980, the temperature has increased dramatically, compared to the temperature level of the previous 100 years.

Specific climate scenarios for Europe try to predict the future evolution based on assumptions concerning socio-economic developments (Shared Socioeconomic Pathways (SSP)) that result in a representative concentration of greenhouse gas (GHG) emissions thus leading to global warming (Representative Concentration Pathways (RCP)). The scenario SSP5-8.5 describes the so-called "fossil path". The derived climate change according to the ongoing use of fossil energy sources fosters massive impact on climate related risks. On the contrary, a sustainable development of the socio-economic is described in the SSP1-2.6 scenario that is called the "2 °C path". Most important are energy efficiency and the use of renewable resources to minimize GHG emissions. But even in this scenario, impact on natural and socio-economic systems occurs requiring global efforts to cope with ecological and economic damages, especially in the global south [1].

Global warming stripes according to Ed Hawkins for the period from 1850 – 2018 [2] combined with the evolution of number of heating (Heat) and cooling (Cool) days in the EU in the period from 1979 – 2018

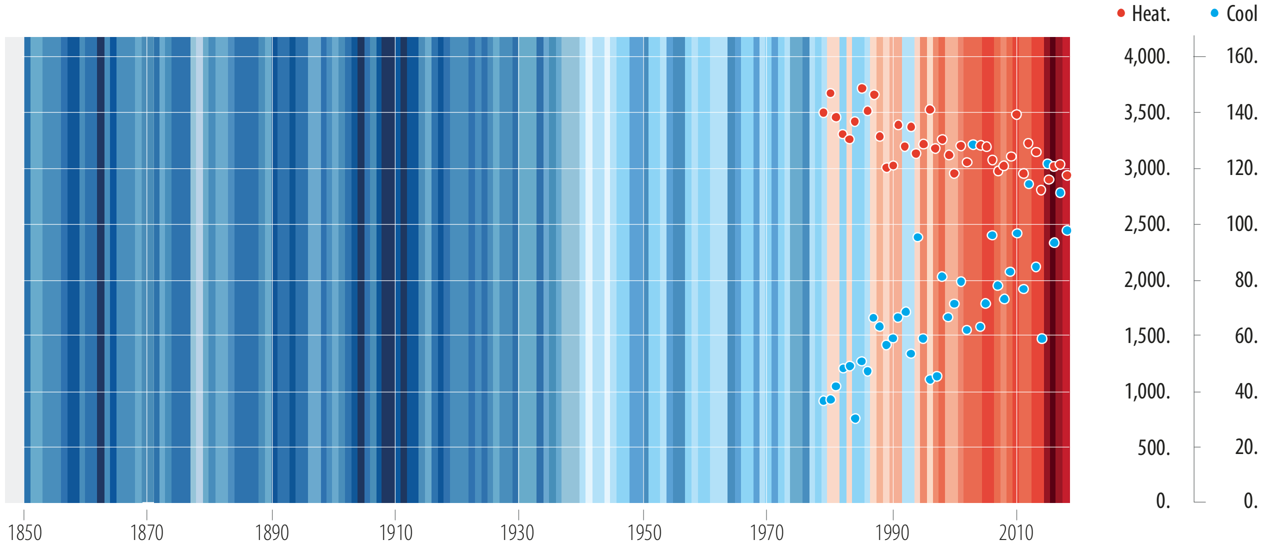

Figure 1 Global warming stripes according to Ed Hawkins for the period from 1850 - 2018 [2] combined with the evolution of number of heating (Heat) and cooling (Cool) days in the EU in the period from 1979 - 2018. Source: Eurostat (nrg_chdd_a)

However, the observed climate change during the last decades is of impact – even in Europe. To illustrate this, the number of heating and cooling days in Europe is overlapped with the global warming stripes from Ed Hawkins. Doing so, it becomes obvious that on the one hand, the number of heating days is decreasing across Europe, whereas on the other hand an even more severe impact is visible when looking at the evolution of cooling days. The topic of summer heat protection becomes an issue, that requires more and more attention in the south, but also in central regions of Europe.

The global warming leads not only to higher temperatures, but to disastrous consequences, such as floods, droughts, rising sea levels and extreme weather events which are also noticeable in Europe. Examples are the flooding in Austria and Slovenia caused by torrential rains in August 2023, which resulted in the collapse of bridges and houses or wild fires in Greece, Spain, and other European countries caused by excessive droughts. Such natural catastrophes do not only lead to ecological but significant economic damages. To mitigate the effects of climate change, the European Union (EU) is pursuing the goal of becoming the first climate-neutral continent by 2050.

This is at the heart of the European Green Deal as launched in 2019, which aligns the EU's contribution to global climate action with the Paris Agreement of 2015. The European Green Deal highlights the importance of energy efficiency and the use of renewable energy to achieve the objectives of the energy transition [3].

To make the overall goal of becoming a climate-neutral continent by 2050 legally binding, the European Climate Law entered into force in July 2021. It states that the net greenhouse gas emissions must be zero by 2050 and additionally sets an ambitious interim goal that net GHG emissions must be at least 55 % lower than in 1990 by 2030. This goal laid the ground of the Fit-for-55 package (as part of the European Green Deal) which is a set of legislative proposals to align EU legislation with the objectives of the Climate Law, to ensure that the EU will reach its climate objectives.

In 2022, Russia's war against Ukraine has led to significant disruptions in Europe's energy supply and demonstrated the EU's dependence on Russian oil and gas imports. To make Europe less dependent from fossil energy supply of Russia and to strengthen the European Green Deal, the Renewable Energy Directive and the Energy Efficiency Directive were reinforced as part of the REPowerEU [4] plan.

The Energy Efficiency Directive has been revised and officially published in September 2023. The directive underlines the fundamental principle of "energy efficiency first" [5], which will be explained in detail later. Complementary, the Renewable Energy Directive has been revised and cited in November 2023 [5]. With the reinforced directives the European Parliament and the Council agreed on strengthening the existing energy and efficiency targets:

- The share of renewables in total final energy consumption must achieve at least 42.5 % (aim 45 %) by 2030 [5]. The share of renewable energy for final energy consumption in buildings must achieve at least 49 % by the year 2030 [5].
- Energy efficiency must increase to 40.5 % (primary energy consumption) respectively 38 % (final energy consumption) by 2030 compared to 2007 levels [6, 7].

To achieve Europe's objectives of climate-neutrality, each Member State is obliged to reduce emissions, to increase energy efficiency and the share of renewable energy in all sectors, e. g. industry, energy, transport, buildings, etc. Those topics and a few other ones must be addressed in the National Energy and Climate Plans (NECP) of each Member State.

TIMELINE OF EU CLIMATE POLICIES

Kyoto Protocol (1997)

World's first GHG emissions reduction treaty that legally binds developed countries to emission reduction targets (an average of 5% by the period 2008-2012).

Paris Agreement (2015)

Universal, legally binding global climate deal, which aims to:

- maintain the increase in global temperatures below two degrees Celsius above pre-industrial levels
- and limit the increase of temperature to 1.5 degrees.

Renovation Wave (2020)

Plan to boost renovation of EU buildings containing 3 focus areas:

- energy poverty and worst-performing buildings
- public buildings and social infrastructure
- decarbonization of heating and cooling

National Energy and Climate Plan (NECP) (2019)

Plan how EU member states address decarbonization, energy efficiency, energy security, international energy market and research, innovation and competitiveness.

European Green Deal (2019)

Highlights the importance of energy efficiency and the use of renewable energy to reach the goals of the energy transition and climate neutrality by 2050.

European Climate Law (2021)

Law to make the targets stated in the European Green Deal legally binding. EU and all member must reach climate neutrality by 2050 (net GHG emissions must be zero). It also sets an ambitious 2030 target of 55% reduction of net GHG emission compared to 1990 levels

Recovery and Resilience Facility (RRF) (2021)

Temporary instrument and centerpiece of the NGEU. The Facility helps to raise funds for the EU member states so they can make their economies and societies more sustainable and resilient.

Proposal: 2040 Climate Target (2024)

European Commission's recommendation: 90% reduction of net GHG emmissions compared to 1990 levels.

Revised Renewable Energy Directive (2023)

Share of renewable energy shall be at least 42.5%, aiming for 45% by 2030.

Revised Energy Efficiency Directive (2023)

Improves the EU energy efficiency target, making it binding for EU countries to collectively ensure an additional 11.7% reduction in energy consumption by 2030 under the 2020 EU reference scenario.

Revised Energy Performance of Buildings Directive (2024)

By 2030 all new buildings should be zero-emission buildings; average primary energy use of residential buildings will be reduced by 16% in 2030 and by 20-22% in 2035; ≥ 55% of energy savings through renovation.

Revised Construction Products Regulation (expected 2024)

Emphasizes the environmental performances of construction products, promoting solutions contributing to a circular economy.

National EPBD implementation (2026)

Member states need to finally adjust national legislation to the revised EPBD.

Figure 2 Timeline of EU climate policies. Source: FIW

KEY MESSAGES - TIME FOR RENOVATION IS NOW

- Global warming leads to more extreme weather events.
- Such natural catastrophes do not only lead to ecological but significant economic damages.
- Costs to mitigate climate change must be recognized as investments into our future. It must be understood that the business-as-usual case will lead to constantly increasing costs for our societies.
- The Green Deal paves the way to make Europe net carbon neutral by 2050.
- Both, improving energy-efficiency and shifting to renewable energy generation are key enablers to keep global warming below the +2° C target.
- Member States must update their National Climate and Energy Plans to more ambition. Any delays and less ambitions will make the challenge in the remaining period even harder.

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© PHOTO : François BRIX

© Photo: Quentin Olbrechts (SAMYN and PARTNERS)

© Photo: Quentin Olbrechts (SAMYN and PARTNERS)

EAEAWARD
2021
WINNER

Category **„Non-residential buildings"**

Project: Maison de la Culture de la Province de Namur in Le Delta/Belgium
Architect: Philippe SAMYN and PARTNERS, architects & engineers
Project owner: La province de Namur, www.ledelta.be
Installer: Allfac, www.allfac.be
ETICS manufacturer: Sto, www.sto.com

2 RENOVATE TO MITIGATE CLIMATE CHANGE

According to the European Environment Agency [8] almost three quarters of today's European building stock is energy inefficient leading to significant energy waste. Buildings account for approximately 40 % [9] of the European final energy consumption and 36 % [10] of the region's energy-related GHG emissions. Buildings are therefore major contributors to GHG emissions [11] and energy consumption in Europe. Since the post-war boom era, where many buildings needed to be built quickly, the rate of new building construction has decreased significantly. Not many old buildings have been demolished since. Therefore, according to the European Environment Agency [8] at least 85 % of today's European buildings will exist in 2050. This is why the building stock is a crucial focus area when it comes to climate action. The renovation of existing buildings plays a key role in achieving climate neutrality by 2050 and the interim targets for 2030.

The good news is: Historical emissions of GHG in the European Union's building sector have declined by 29 % from 2005 to 2019 (see **Figure 3**). This decline can be attributed to several factors, including efforts to enhance the energy efficiency of existing buildings (e. g. improving thermal insulation or changing heating systems), initiatives to transform the electricity sector towards lower-carbon sources, and the influence of raising temperatures. However, emission reductions could have been even higher if the number of dwellings and the average floor space of buildings would not have increased in parallel. It is predicted that the trend of reducing emissions will continue, however achieving the EU's overall 2030 and 2050 emissions targets will remain challenging and requires a substantial increase in the rate of building renovations [12].

GHG emissions caused by energy use of European buildings

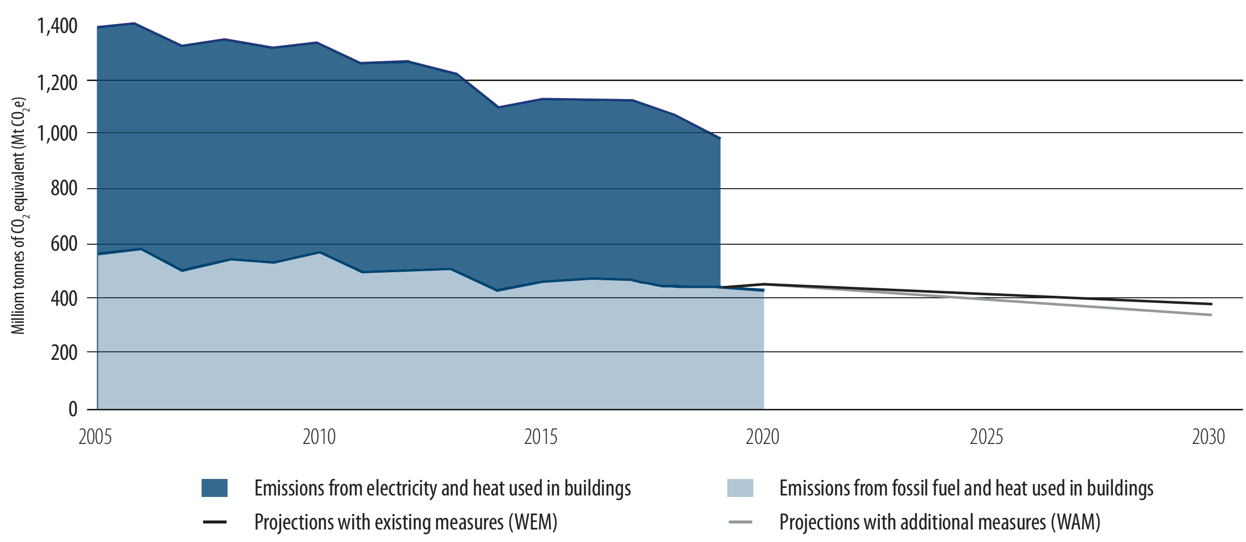


Figure 3 GHG emissions caused by energy use of European buildings. Source: European Environment Agency [12]

GHG emissions from energy use in buildings by country

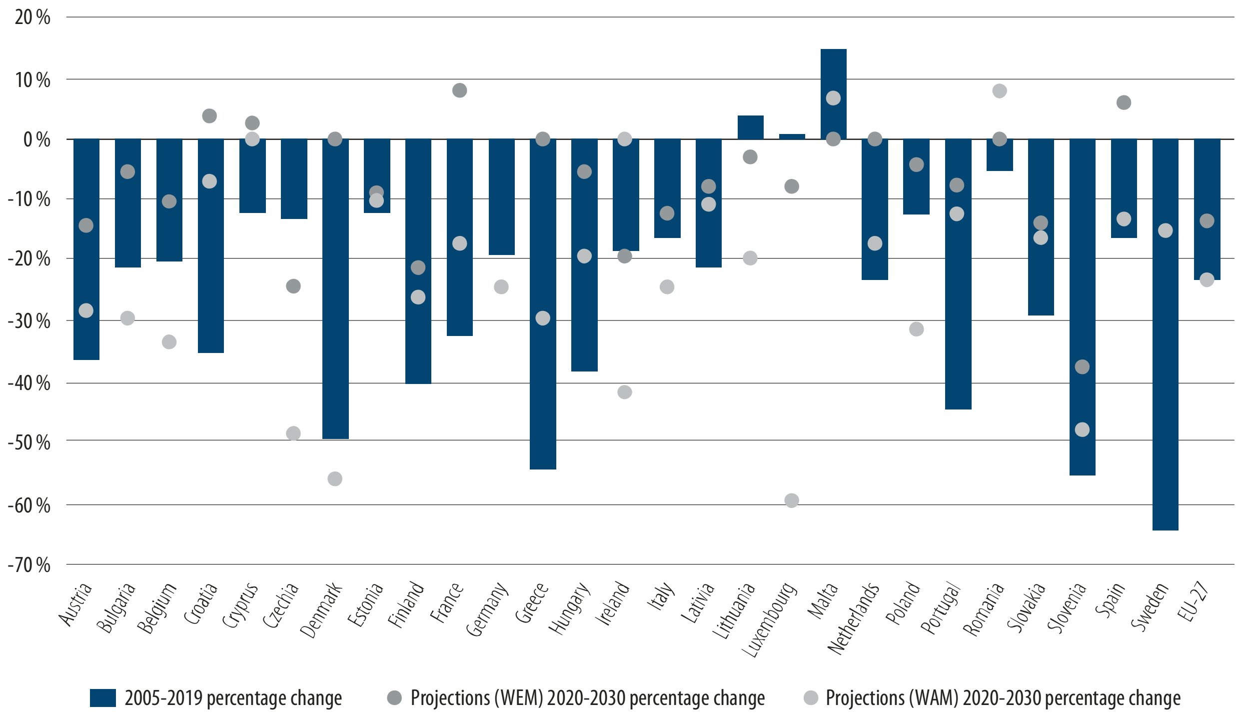


Figure 4 GHG emissions from energy use in buildings by country. Source: European Environment Agency [12]

The historical and anticipated emissions resulting from the use of fossil fuels in buildings show considerable variation among EU Member States (see **Figure 4**).

Over the period from 2005 to 2019, the majority of EU Member States reported decreasing emissions, with Denmark, Greece, Slovenia, and Sweden leading the way with reductions ranging from 49 % to 64 %. On the other hand, emissions increased slightly in three Member States: Lithuania, Luxembourg, and Malta.

National projections indicate that Croatia, Cyprus, Malta, Romania, and Spain face rising emissions in the future. However, when factoring in additional measures currently planned at national level, only two Member States, Malta and Romania, would still expect increasing emissions in the building sector. With these supplementary measures included, Czechia, Denmark, Ireland, Luxembourg, and Slovenia project substantial emissions reductions of 40 % or more between 2020 and 2030 [12].

Total final energy consumption for the EU building stock and GDP

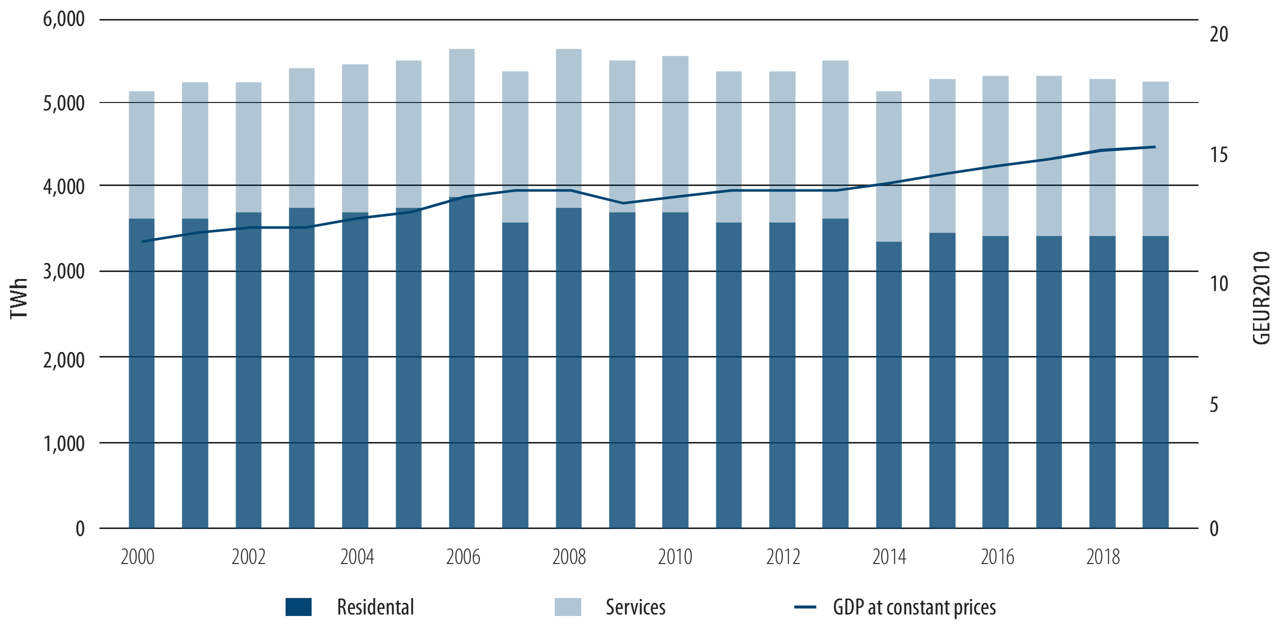


Figure 5 Total final energy consumption for the EU building stock and GDP. Source: Odysee [17]

To achieve the EU's goal of reducing GHG emissions by at least 55 % by 2030 compared to 1990 levels, the building sector must target 60 % emission reductions, 14 % total energy consumption reductions and 18 % energy consumption reductions for heating and cooling (compared to 2015 levels), as outlined in the EU Renovation Wave initiative [13]. In order to achieve this, there must be a significant boost in the rate of energy-efficiency renovations in the building stock to reduce its energy demand and carbon footprint. The Renovation Wave initiative aims to at least double the annual energy renovation rate by the year 2030, a highly challenging goal when considering the current renovation rate of just 1 %, for both residential and non-residential buildings [13]. However, the rate for "deep energy renovations" is even lower at 0.2 % [13]. "Deep renovation" is defined in the Commission Recommendation on Building Renovation [14] as a package of renovation measures, which can be carried out in more than one step, to improve the energy efficiency of the building by at least more than 60 % compared to the initial energy performance. However, this definition is not legally binding, leaving room for maneuver for EU Member States that have implemented heterogeneous measures. It does not provide a precise definition of which requalification measures need to be undertaken to achieve a 60 % improvement. Nevertheless, the „deep renovation" of the European building stock is crucially important to achieve the objectives set out in the Green Deal. Without the complete decarbonization of the building stock, it will be impossible to achieve climate-neutrality since the gap left by the

Primary energy consumption (PEC), final energy consumption (FEC) and the ratio of FEC to PEC in EU from 2000 – 2021

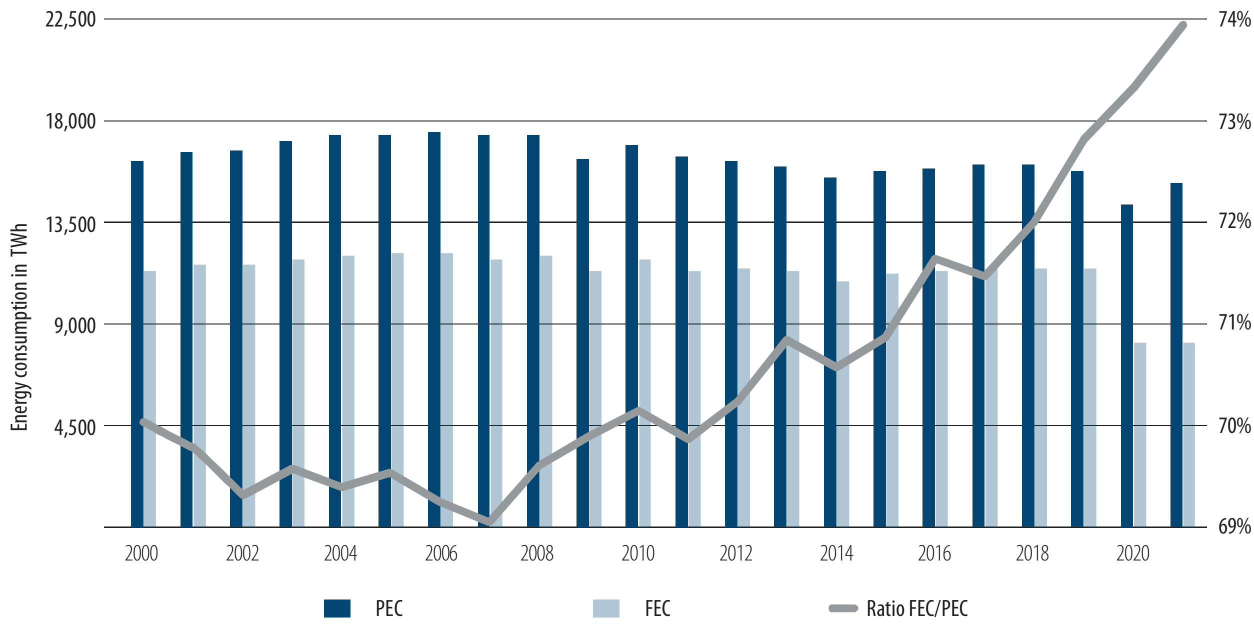


Figure 6 Primary energy consumption (PEC), final energy consumption (FEC) and the ratio of FEC to PEC in EU from 2000 - 2021. Source: Eurostat (sdg_07_10 and sdg_07_11)

building sector cannot be compensated by the other sectors as highlighted by BPIE [15]. Therefore, the focus is on promoting comprehensive energy-efficient renovations to reach the goal of renovating 35 million building units in Europe until 2030 [13]. Recent research [16] indicates that by 2030, the annual renovation rate for the EU-27 plus the United Kingdom must reach 3 % and then remain at this level to achieve renovation of nearly 80 % of the existing building stock by 2050 and to meet Europe's GHG reduction and energy savings goals.

The final energy consumption of the EU's building stock is presented in **Figure 5**. The diagram shows that the final energy consumption has neither increased nor decreased since 2000. So, this creates a slightly different picture than **Figure 3**. The share of the final energy consumption of the residential sector accounts for 2/3 whereas the non-residential sector is responsible for only 1/3. Whereas the final energy consumption did not change significantly, the gross domestic product (GDP) has increased.

The relatively stable final energy consumption in the EU's building stock since 2000, despite a significant decrease in GHG emissions of approximately 29 % between 2005 and 2019, can be mainly attributed to the decarbonisation of the electric grid and the switch into heating systems with higher share of renewable energy sources. This is evidenced by **Figure 6**. The primary energy consumption in the EU (all sectors, not only households) has been decreasing on a larger scale since 2006 compared to the final energy consumption, which compared to 2000 level has only decreased by 1%.

Therefore, the share of final energy consumption in primary energy consumption is increasing. If final energy consumption remains the same, a decrease in primary energy consumption is an indicator for a higher share of renewable energies (wind, hydropower, solar), as the conversion losses are lower than with fossil fuels. Therefore, a reduction in GHG emissions has been achieved although the final energy consumption remained the same. Compared to the total energy consumption, which includes all other sectors like traffic/transport and industry in which the share of fossil-based energy is still dominating, the effect is mutually more pronounced in the building sector.

Looking at Figure 5 one might conclude that the energy efficiency of the building stock has not changed much over the last decades. This is not quite correct, because even though the renovation rate is quite low, it leads to a slow but steady reduction of final energy demand over time. The main reason why there is hardly any change in the total final energy consumption of the EU's building stock is an increasing number of buildings in the EU. Even if new buildings are built under more restrictive energy efficiency regulations, leading to low final energy demands and implementing much higher shares of renewable energies for heating, ventilation and cooling, they still add to the energy consumption of the building sector. Key reason for the stagnating final energy consumption are demographic changes and rebound effects. In recent years, the average size of dwellings per capita in the EU has grown dramatically. It is not surprising, that a larger average floor space per capita results in a higher demand for heating energy (or cooling, where applicable) compared to a smaller floor space per capita (same boundary conditions assumed – energetic quality, location, user behaviour, etc.). According to Odyssee-Mure [18] the increase in the average floor space per capita in the EU offsets the efforts in reducing heating energy demand by efficiency measures by 20 %.

To compensate this offset, it is obvious that great efforts must be made in energy-efficient building renovations. Driven by lower initial investments, building owners tend to only replace the heating system and leave efficiency measures of the building envelope for later. This contradicts the "energy efficiency first" approach as set out in the Renovation Wave. As this will lead to long term problems, the newly revised Energy Efficiency Directive (EED) has legally established the efficiency first principle (Article 3). To make the building stock climate-neutral by 2050 heat pumps mark a promising approach to replace old fossil-based heating systems by a system that can be operated climate neutral, provided enough electricity from renewable resources will be available in the future.

Installing heat pumps in poorly insulated buildings not only leads to a poor performance of the heat pump itself as many buildings are not ready for low temperature heating systems without measures to improve the building envelope, but also imposes a huge additional electricity demand. This is to be considered in parallel to the ongoing development towards electric vehicles (EV) and electrification in other energy intensive industry processes, especially the uptaking production of green hydrogen. Together it will multiply today's electricity demand. Not only the amount of electricity will be challenging for the growth of the renewable sources, but also the simultaneity of the power demand will exceed the capacities of existing high voltage power lines and medium and low voltage distribution grids in residential areas, multiplying the financial investments needed for updating the grids to future needs. Similar challenges are anticipated in the adoption of green hydrogen. The integration of green hydrogen as an alternative energy source requires substantial energy (electricity) inputs, huge additional renewable energy sources and massive grid infrastructure upgrades. All this increases the risk of heat-pump and EV induced electricity shortages, which could result in a fast increase of energy prices (both for electricity and green hydrogen) and bears potential for future energy poverty of larger groups of our society. Finally, the building sector would simply shift its

Forecast of heat pumps' electricity demand and heating load for residential buildings in Germany until 2045

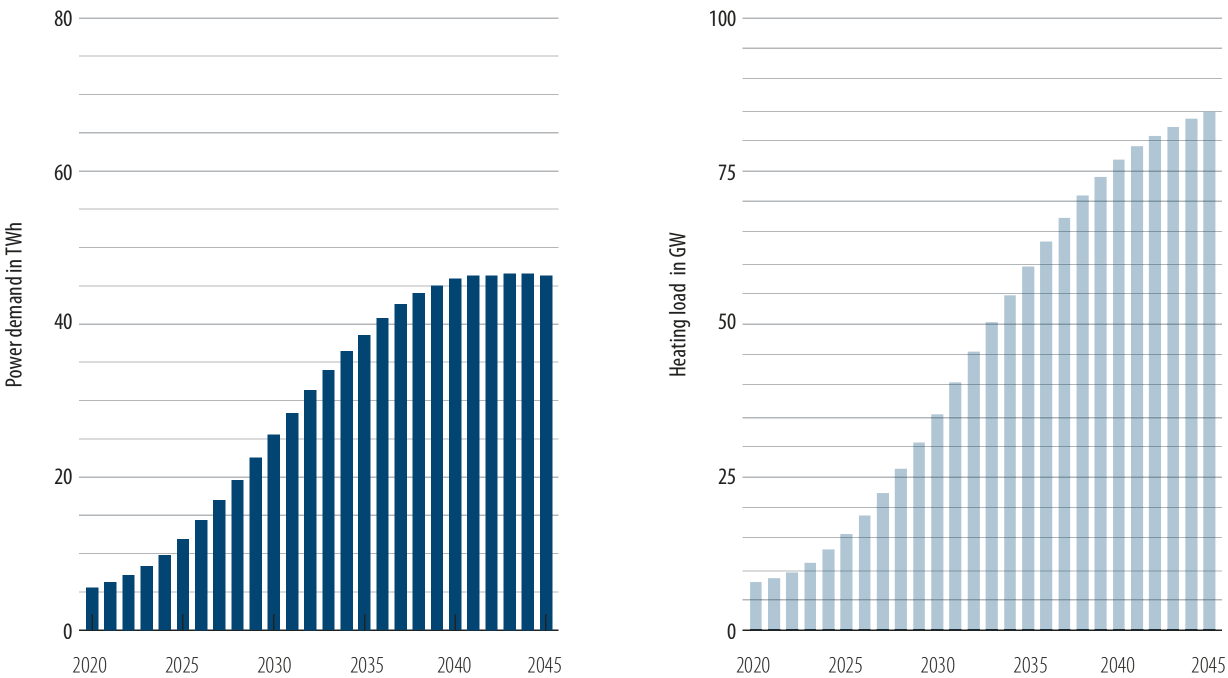


Figure 7 Forecast of heat pumps' electricity demand and heating load for residential buildings in Germany until 2045. Source: FIW

responsibilities to achieve climate-neutrality to the energy sector. All Europeans would need to pay the bill for this in the end.

As an example, **Figure 7** shows the projection of the increase in electrical energy demand and electric load of the German residential building stock until 2045. The projection considers Germany's decarbonization/electrification strategy and heat pump expansion targets. The graph shows that by 2045 the electricity demand of residential buildings will be nine times higher compared to 2020. In terms of the electrical connection capacity the factor is even higher, between nine and ten. A similar scenario is expected for other European countries, underscoring the huge importance of reducing the energy demand in buildings by measures improving the building envelope as key enablers to achieve energy transition and climate neutrality.

To reduce the GHG emissions and to achieve climate targets, a holistic approach is urgently needed that starts with reducing the energy

Share of energy savings of certain building envelope elements in different countries in relation to the total savings of the refurbishment.

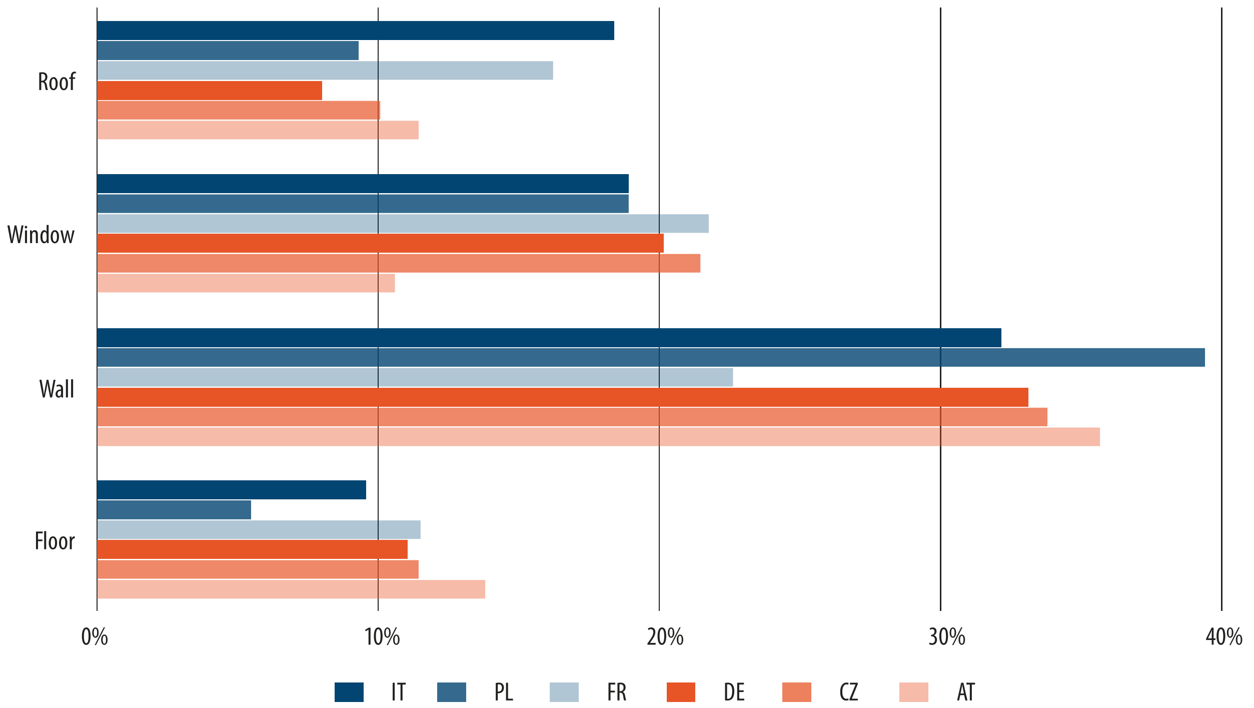


Figure 8 Share of energy savings of certain building envelope elements in different countries in relation to the total savings of the refurbishment. Source: FIW calculations by using Ambience database of grey-box model parameters [19], Eurostat (nrg_chdd_a) and Joint Research Centre Data Catalogue [20]

demand of old and poorly insulated buildings via improved thermal insulation and then replacing non-renewable energy sources by renewable ones. For the insulation of walls, External Thermal Insulation Composite Systems (ETICS) are a common solution. Jointly, this can yield more sustainable and cost-effective results in the long run. "Insulation first" enables to opt for "smaller" heat pumps, requiring less upfront investments, thanks to a lower energy demand of insulated buildings and the fact that the heat pumps could operate at lower heating flow temperatures and therefore at much higher efficiency levels (higher coefficient of performance, COP). This self-reinforcing effect is only triggered by a lower heating demand of buildings, which is directly related to the installed insulation. Renovating the building stock and especially improving the thermal building envelope by insulation e. g. with ETICS presents an opportunity to improve energy efficiency dramatically and ensures that the buildings become low-temperature ready enabling an efficient operation of heat pumps.

Figure 8 shows the percentage of the energy improvement potential of individual elements in the renovation of the residential building stock in different European countries. The U-values and heating degree days used for the calculation are taken from Ambience [19], Eurostat (nrg_chdd_a) and JRC-EU-TIMES Building Stock Module [20]. Different initial energy performances (U-values) of different elements of the building envelope are considered. The initial U-value is a weighted average value of the individual element (roof, wall, window, floor) which represents the current residential building stock of each country, taking into account the building envelope elements' surface area and the building age class distribution. The improvement potential is determined for the final energy performance of each element and country, considering a deep retrofit scenario [20]. The percentages express the ratio of the difference in transmission heat losses between the initial and final state of each building element and country, relative to the total transmission heat losses before the refurbishment of the whole building.

In all listed countries, the potential for energy-efficient building renovation is evident, with all building components offering great potential for improvements. Notably, measures targeting walls represent the most substantial savings in every considered country for two reasons. On the one hand, walls offer the largest heat transfer surface of buildings. On the other hand, the existing U-value is still high, compared to roofs and ceilings. They typically mark the first measures when it comes to energy retrofit. This highlights the pivotal role of energy retrofits of walls to reduce the energy consumption of European buildings and to achieve climate protection objectives. It highlights the importance of thermal insulation of walls as cornerstones in the efforts to curtail energy demand and GHG emissions across the European building stock.

In general, four solutions come to mind when it comes to improving the insulation of external walls of buildings. These are ETICS, ventilated façade insulation systems, cavity wall insulation and interior insulation. In comparison, there are advantages and disadvantages for one or the other application.

ETICS are the most relevant insulation system when it comes to refurbishing the walls of existing buildings, but also to insulate new built living space. In terms of design aspects most buildings (especially residential buildings) in Europe have rendered facades anyway. Therefore, ETICS fit perfectly into the urban appearance and offer all possibilities of conventional façade designs by choice of color, adaption of structured finishing coat or the application of outer layers by tiles. Due to the continuous exterior insulation layer that minimizes thermal bridges and its almost non-restricted thickness, they offer a high energy saving potential. ETICS offer a good protection of the buildings' fabric and lead to lower maintenance and repair work on the rendering and masonry, as temperature stresses between masonry and rendering are reduced due to the thermal de-coupling of both layers. Therefore, ETICS help to provide a durable permanent weather protection of the building structure. Due to the high market penetration, ETICS are also a cost-effective solution. Further on, the systems are designed for an easy installation. Many craft shops for paint and plasterwork have specialized on that business throughout the last years, which helps to find trained craftsmen that are able to deliver a high-quality installation work.

Assessing GHG emissions necessitates a comprehensive life cycle analysis (LCA) of buildings. The LCA-phases are shown in **Figure 9**.

While all building materials, including insulation, contribute to emissions during production, insulating materials stand out for their capacity to substantially reduce GHG emissions during the operational phase. These materials are expressly designed to enhance energy efficiency. To substantiate this, a detailed GHG emissions calculation was conducted at the building element level, specifically focusing on the external wall, as depicted in **Figure 10**.

Life cycle stages

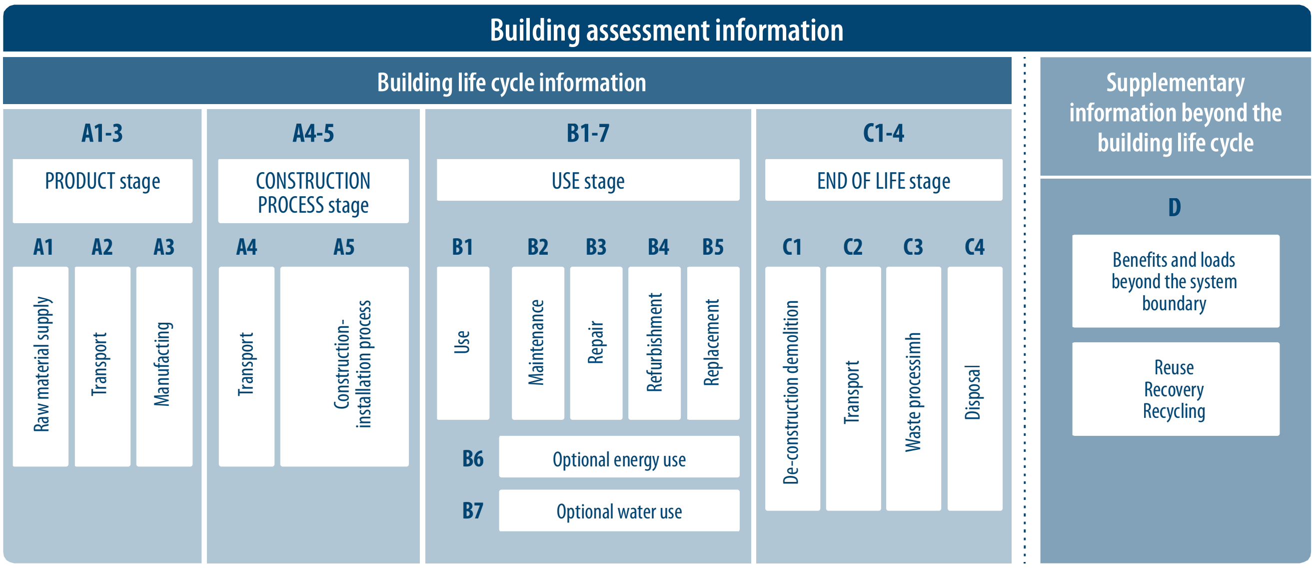


Figure 9 Life cycle stages. Source: EN 15978 [21]

One can analyse the GHG emissions associated with the production and eventual disposal of insulation materials in comparison to the potential GHG reductions attainable when energetically renovating building elements. To do so, three distinct scenarios were examined, each aimed at achieving a target U-value of 0.24 W/(m²·K) through refurbishment. The GHG emissions linked to production (A1-A3) and deconstruction (C3 and C4) of the insulation layer are presented as a range, encompassing minimum, median, and maximum values, thereby encompassing the spectrum of insulation materials available on the market. Additionally, the GHG savings achievable over a 40-year service life in various countries were evaluated, assuming electricity as the energy source for heating via heat pumps. For each country the specific GHG emissions in relation to the country's electricity mix were considered according to Sustainability Impact Metrics [22]. Generally, the results reveal that the more suboptimal the initial condition of a building, the thicker the insulation required and, consequently, the greater the associated embodied emissions. However, these higher embodied emissions deriving from construction result in proportionally higher savings during the operational phase of the building. In all considered scenarios, across different countries, the GHG reductions substantially outweigh the emissions incurred for the insulation layer ("embodied emissions").

Comparison of embodied emissions and achievable GHG savings over 40 years for refurbishment to a U-value of 0.24 W/(m²·K) for various existing situations.

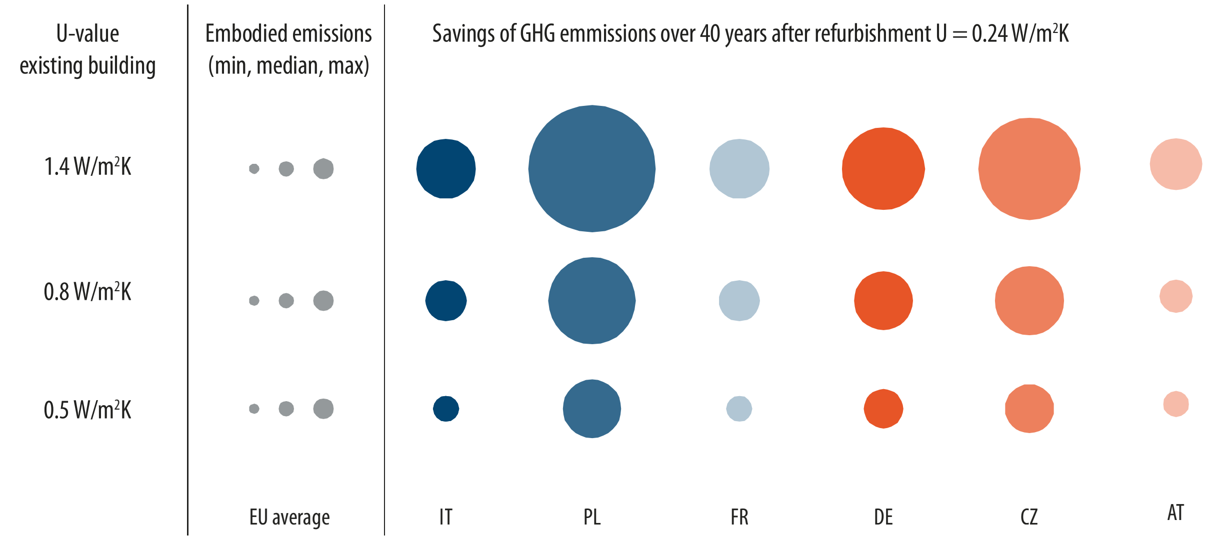


Figure 10 Comparison of embodied emissions and achievable GHG savings over 40 years for refurbishment to a U-value of 0.24 W/(m²·K) for various existing situations. Source: FIW

Differences in the GHG emissions savings between countries originate from the individual electricity mix of each country. Countries like Czech Republic and Poland still operate larger capacities of fossil-based power plants, thus provoking higher GHG emissions compared to other countries like Germany, Italy and Austria, which have consequently invested in the expansion of renewable energy (wind, solar, hydro). Also, in France low GHG emissions can be observed related to electricity generation. It is worth mentioning that this is attributed to the high share of nuclear energy in power generation, which in fact does not actually contribute to GHG emissions. Nevertheless, one cannot speak of renewable energy in this case, as nuclear power plants entail other environmental issues, such as the disposal of nuclear waste, and can pose a danger to humans and the environment (see the Tschernobyl or Fukushima nuclear disasters). These aspects must not be neglected.

However, **Figure 10** shows that although thermal building renovations require upfront GHG investments, the long-term energy and GHG savings outweigh such investments by far. The savings continue and further increase, when considering a longer service life. This illustrates that durability of thermal insulation systems plays an important role.

KEY MESSAGES - RENOVATE TO MITIGATE CLIMATE CHANGE

- Buildings account for 40 % of Europe's final energy consumption and 36 % of energy-related GHG emissions. 85 % of today's European buildings will still exist in 2050.
- Renovation of existing buildings plays a crucial role in achieving climate neutrality by 2050 and in achieving the interim targets for 2030 and 2040.
- To achieve GHG emissions reductions by 55 % by 2030, the building sector must target 60 % emission reductions, 14 % total energy consumption reductions and 18 % energy consumption reductions for heating and cooling.
- Focus must be on promoting deep or staged-deep energy-efficiency renovations with the goal of renovating 35 million building units in Europe by 2030.
- The annual renovation rate for the EU-27 plus the United Kingdom must reach 3 % and then remain at this level to achieve renovation of nearly 80 % of the existing building stock by 2050.
- The efficiency-first principle needs to be at the forefront of building renovation.
- Buildings need to get prepared for low-temperature heating to avoid multiplying the total electricity demand and shortages in the grids. Else, the building sector would shift its responsibilities to the energy sector.
- Improving the building envelope is a key enabler to achieve energy transition and climate neutrality; wall insulations mark the most substantial savings with ETICS being the most used system for building renovation – as well as for new buildings.
- GHG reductions over the building life-cycle outweigh by far the "embodied missions".

EAEAWARD 2021 WINNER

Category **„Residential New Built Family Homes"**

Project:	Globe Works in Birmingham/United Kingdom
Description:	New construction of 5 buildings with 520 student flats
Architect:	Steve Ritchie Partnership
Project owner:	NIDO Student Accommodation
ETICS manufacturer:	Alsecco UK

3 RENOVATE FOR SUSTAINABILITY AND ENVIRONMENT

Being developed by the forestry in the 19th century, where it describes the principle that only such amount of wood shall be taken from the forest that is able to regrow in the same period, the term sustainability became an inflationary used buzzword throughout the last decade. Sustainable business models develop sustainable goods and services that allow a sustainable lifestyle of consumers. Besides the threat of being trapped by so-called green-washing strategies of companies, the meaning of sustainability has been significantly enlarged, compared to the initial meaning. It nowadays focusses on different fields of action. Most common is the model of the three pillars of sustainability that represent environmental targets, economic targets and social (or: socio-cultural) targets (**Figure 11**).

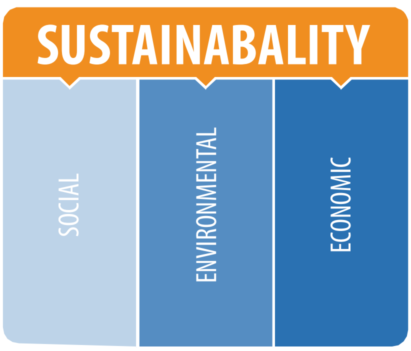


Figure 11 Three pillars of sustainability

Socio-cultural targets describe the interaction with human health, security and well-being, as well as the functionality and quality of the design. Associated topics related to ETICS would be work safety during installation (e.g. fibers and dust), indoor air quality during use (e.g. minimization of emissions and risk of mold fungi), minimization of fire related risks during use, avoidance of energy-poverty and the appearance of ETICS in the context of urban development.

Economic targets are dedicated to ensure low life cycle costs, improve cost-effectiveness, and help to preserve capital values. For ETICS, this pillar touches the question of costs and amortization, the topic of durability (e.g. frequency and costs for maintenance as well as ETICS-on-ETICS renovation), the protection of the underlying wall structure (e.g. minimization of hygro-thermal damage) and subsequently the conservation or increase of property values.

Environmental targets, typically foremost associated with sustainability, describe measures to save natural resources and protect the eco-system. In case of ETICS this relates to the ecological impacts of production (e.g. energy use, GHG emissions and other environmental indicators), possible emissions during use (e.g. leaching), the end-of-life scenario (e.g. recycling and disposal) and an effective use of material resources (e.g. possibility to minimize material consumption for load-bearing wall structures without losing thermal performance).

As ETICS are the key construction product contributing to the energy efficiency of the building fabric over its entire lifetime, all possible impacts (i.e. negative implications) have to be rated against the positive impacts ETICS provide. This general remark sounds like an easy task, but is complicated in reality as the prerequisites may differ largely.

The very first difference is the case of renovation in comparison to the case of new built living space. In case of renovation the comparison of impacts and benefits can be based on the non-renovated scenario or based on a different approach for energy renovation. In the latter case a comparison can be drawn either to an alternative passive insulation approach (e.g. curtain façade vs. ETICS) or to an additional or parallel renovation of the heating system (e.g. replacement of gas burner by heat pump).

In case of new built living space, different insulation systems, or even a thermally equivalent monolithic design could be compared, bearing in mind that these questions are also related to national or regional building regulations and general design aspects as well as associated with the building use (single-/multifamily homes, office or other non-residential buildings). Related to the building use and associated building regulations, restrictions concerning the choice of insulation materials (for ETICS as well as for other insulation solutions) may differ throughout Europe. Most relevant in this regard is the reaction to fire. Depending on the construction flame-retardant or even non-combustible materials are available for the whole insulation work or to act as a so-called fire barrier in case combustible materials are used. As a rule of thumb – the higher the building, the more important becomes the reaction to fire classification of the thermal insulation system.

Besides that, climatic conditions are of relevance. Until now, in central and northern Europe an energy-efficient building envelope mainly minimizes the energy demand for heating by minimizing thermal losses and helps to provide a comfortable indoor climate due to the minimization of the difference between wall-temperature and air-temperature. Furthermore, it decelerates the cool-down of the building in case the heating source is turned-off, be it planned for the night or unplanned in case of energy shortages. Only few years ago, the risk of energy-shortage was deemed unrealistic. Then, it suddenly became a reality due to the disconnection from Russian energy supplies as a consequence of the aggressive war against Ukraine.

Nevertheless, as shown in Chapter 1, **Figure 1**, the number of cooling degree days has been increasing over the last decades. As a consequence, the same implications as for the room heat conservation in the winter apply to the so-called summer heat protection – only the algebraic sign changes. Besides the necessity to minimize the impact of radiant heat through translucent parts of the building shell, external insulation like ETICS are key to provide a comfortable indoor climate during summer. This is mainly due to the fact that the external insulation prevents the wall structure from heating during daytime. This enables effective cooling of the indoor environment during nighttime by means of natural ventilation. Additionally, it lowers the energy demand for air conditioning, where installed, preventing electricity shortages during heat waves.

The last relevant topic to be considered when assessing the sustainability of ETICS and insulation in general is the energy mix and available heat source. However, this topic may differ largely across Europe, depending on the prerequisites in terms of the possibilities to change the heating system and the development of the production of renewable energy.

The model of three pillars implies that all three aspects of sustainability are of equal importance. Therefore, one could say that true sustainability is only achieved where all three aspects are achieved in parallel. Realistically, it is not always possible to meet such holistic objectives. This raises the question of a hierarchy between environmental, social and economic targets.

A possible solution to illustrate such hierarchy is the nested approach (**Figure 12**). It emphasizes the overwhelming importance of the environmental aspects to achieve sustainability. In this structure, the interaction with the environment is seen as basis for social and economic interests.

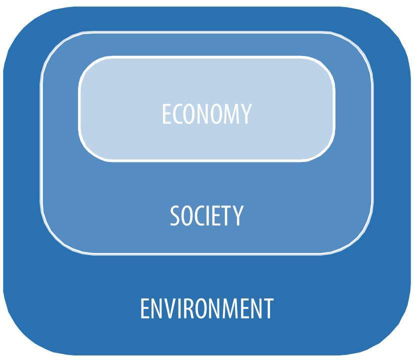


Figure 12 Conecentric approach of sustainability

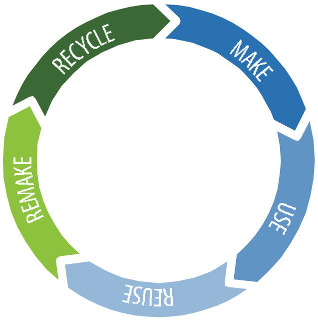
Based on these basic approaches several other models have been developed in recent years that refine the definitions and interactions between the three pillars. The topic of sustainability has become a research field of its own that cannot be reviewed to full extent in this publication. In the following chapters several topics related to sustainability of thermal insulation and ETICS kits will be detailed. Further literature and references are given in the text.

To choose the most important fields of interest it is necessary to analyze the product life cycle of ETICS and thermal insulation exemplary for one kit component. The product life cycle describes all relevant stages along the value chain, starting with production of the material, considering the installation and the service life and ending with the dismantling and subsequent possibilities of reuse/recycling, respectively disposal. Thus, the product life cycle determines the boundaries for the life-cycle assessment, that comprises a methodological framework to structure a holistic view on possible interlinks between the product and the environment respectively the user. Usual periods of interest are referred to as „cradle to gate" (from manufacture to factory gate) or „cradle to grave" (from manufacture to disposal or landfill). The principle of „cradle to cradle" (C2C) takes an even broader view of the product life cycle and calls for the development of products that can be reused in closed cycles at the end of the product's life.

These closed loops of product life are one of the main goals of the European Commission to foster a so-called circular economy. It is not long ago when most products were designed to be disposed after their typical service life. In view of limited raw material resources and the aim to limit emissions and energy consumption for production it is essential to overcome this. However, several prerequisites require attention.

Figure 13 shows a circular economy approach with a life cycle starting with the extraction of raw materials and the production of the product, followed by the delivery and the installation on site. During the service life, maintenance may be required to ensure the long-term functionality of the system. The aspect of durability is key for environmental performances and renovation cycles. For dismantling and the following reuse or recycling, the main challenges are separability and the achievable pureness of dismantled materials. Not only in case of disposal of the whole system or parts of it, the question of dangerous substances and ways of environmental impact become rele-

Circular economy approach of life cycle for ETICS with possible steps and interactions between the product and the environment, resp. the user



Steps	Possible Interactions/fields of interest
Raw materials	Origin / Availability / Extraction
Production	Energy / Emissions
Delivery	Energy / Emissions
Construction	Workmanship
Use / Maintain	Emissions
Renovation	Durability
Dismantling	Separability
Reuse / recycle	Durability / Pureness
Dispose	Emissions / Energy production

Figure 13 Circular economy approach of life cycle for ETICS with possible steps and interactions between the product and the environment, resp. the user

vant as for example hazardous substances must be phased-out before reuse or recycling.

It becomes obvious that in a circular economy there are numerous interdependencies between the product and the environment - respectively users - that require attention. In the following several topics will be discussed in detail and broken down for ETICS.

The circular economy needs to be seen umbrellaing the framework of the European Green Deal which stands for a concerted strategy to achieve a climate-neutral, resource-efficient and competitive economy while leaving no one behind. Saving resources by following the principles of a circular economy provides a distinct contribution to achieve climate neutrality and preserve biodiversity as half of the total GHG emissions are expected to origin from resource extraction and processing as well as 90 % of biodiversity-losses. A total of seven key product value chains have been identified contributing to the circular economy approach. These are electronics and ICT, batteries and vehicles, packaging, plastics, textiles, construction and buildings, plus food, water and nutrients. Especially the field of construction and buildings is of high impact as it requires large amounts of resources and generates a lot of waste. Today approximately half of all extracted materials are used in the construction sector, that in turn accounts responsible for over one third of the total waste generation in the EU. In particular, GHG emissions generated along the value chain of construction products accumulate to roughly 5 - 12 % of total GHG emissions [23].

To fight against this, the European Commission brought forward the so called New Circular Economy Action Plan. It explains general principles to foster circularity approaches but also contains distinct principles for all of the seven key product value chains. For construction and building the following actions have been proposed:

- Recast of the Construction Products Regulation, introducing – among others – recycled content requirements;
- Improve durability and adaptability;
- Foster the Level(s) framework to implement life cycle assessment in public procurement and the EU sustainable finance framework;
- Consider a revision of material recovery targets as set in EU legislation for construction and demolition waste and its material-specific fractions;
- Promote initiatives to reduce soil sealing, rehabilitate abandoned or contaminated brownfields and increase the safe, sustainable and circular use of excavated soils.

Besides the fact that the waste stream from insulation materials is explicitly mentioned in the New Circular Economy Action Plan in relation to the revision of material recovery targets, all abovementioned aspects are directly linked to production, installation, use and recycling options of insulation materials/systems. The same document also addresses the Renovation Wave initiative as announced in the Green Deal. It requires measures to improve energy efficiency in the building sector which shall explicitly be implemented in line with the principles of the circular economy [23].

Before entering into details of the circular economy, it may be useful to become clear about some basics concerning waste. In Europe, the Waste Framework Directive (2008/98/EC) [24] sets the scene for the national waste regulations that are legally binding in Member States. The directive was substantially revised in 2018 [25] to cover the aspects of a circular economy that were developed throughout previous years. The aim of this directive is to reduce the amount of waste and optimize the utilization of resources. As a precondition, waste must be collected separately wherever technically, environmentally and economically feasible. For construction and buildings this means that selective dismantling becomes relevant distinguishing between several fractions like minerals, wood, metals, glass, plastics and gypsum that can be recycled mutually. Distinct claims on reuse and recycling are given in Article 11 of the Waste Framework Directive. It requires from manufacturers since 2020 to increase the reuse and recycling to 50 % of waste streams generated by private households to a minimum of overall 50 % (measured by weight) and to a minimum of 70 % by weight for construction and demolition waste.

However, recycling is not the first choice. Measures to avoid waste and to reuse materials are prioritized. The ranking of measures is illustrated in Article 4 of the waste directive and called "Waste hierarchy" (**Figure 14**).

As the prevention of waste is of upmost priority, the aspect of ETICS durability is highly important. In Chapter 1.2.2 of EAD 040083-00-0404 [26], it is stated that the methods provided by this European Assessment Document are intended to assess the functioning of the insulation system against an intended use of 25 years. However, the document also points out that the real working life depends on specific environmental conditions and on the quality of design, installation and maintenance. Test procedures set out in this EAD and other standards for insulation materials must be understood as stress tests (extreme conditions compared to the intended use), e. g. dimensional stability at 70°C/90 % RH and standard cycles, such as freeze-thaw cycles. In both examples no direct correlation to the behaviour under real use conditions is achieved. But the methods are suitable to decide if the material withstands such degradation impacts (hydrolysis, temperature induced stress, etc.) in principle. The suitability of such methods to proof the fitness for use is based on experience only.

Waste hierarchy and associated topics for ETICS

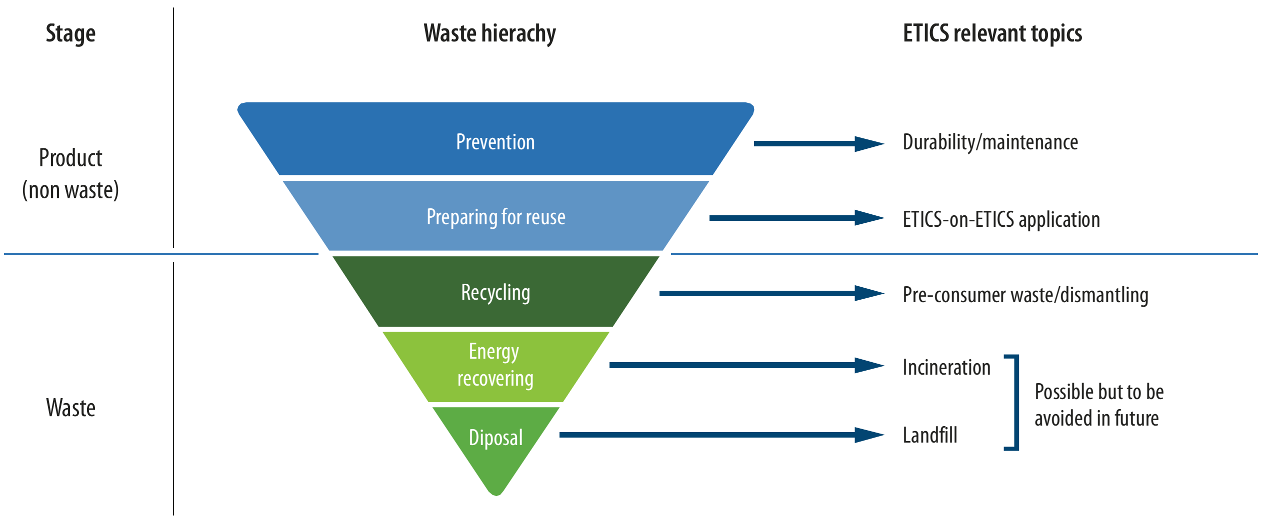


Figure 14 Waste hierarchy according to directive 2008/98/EC (REF) and associated topics for ETICS. Source: FIW.

Alternatively, the investigation of durability in terms of a real service life prediction would require more advanced methods based on test regimes that provide a correlation to natural ageing. Such methods can be developed according to ISO 15686-2 [27]. The procedure given therein, consists of a row of phases (definition-, preparation- and pretesting phase), wherein the application, performance requirements (end-of-life criteria), use-conditions and material characterization are collected and the impact of selected degradation agents is verified. Based on the achieved knowledge, combinations of degradation agents can be summarized to accelerated test regimes that have to be validated by long-term exposure under lab conditions as well as by field exposure. In the best case it is possible to derive general dose-response functions (e.g. Arrhenius behaviour), that can be used to generalize and extrapolate the results to different exposure scenarios.

Due to the unavoidable contradiction between generality and accuracy, such investigations are rare. An example of an ageing procedure for ETICS cladding according to ISO 15686-2 has been presented by Daniotti et al. 2013 [28]. The authors developed a method based on a combination of ageing cycles with UV impact, summer and winter thermal shock-cycles and freeze-thaw cycles. In effect an influence was visible on thermal shock and dilatation-contraction events, resulting in blistering and deformation of the finishing coat. Other degradation modes are mould growth, cracking over joints of insulation boards, imperfections at the connection to other building elements and subsequent water absorption. These results underline the special importance of the finishing coat of the rendering system for the long-term performance of ETICS. As this component is in direct contact with weathering, it protects the insulation layer underneath from moisture uptake and subsequent impact on the relevant hygrothermal properties.

In that regard, the necessary maintenance of insulated and non-insulated facades is equal. In both cases, care should be taken to repair initial defects in the finishing coat to avoid the start of penetration of moisture into the structure of the rendering that results in a risk of further damage.

Besides laboratory-based approaches, monitoring of real built ETICS facades helps to draw conclusions on the durability and necessary maintenance. Such investigations have been started by Fraunhofer IBP back in 1975, and has been under continuous observation since then. An extended report from 2006 [29] summarizes that damages of ETICS facades even occur more scarcely than compared with conventional rendering on masonry. The effect has been explained with the de-coupling effect of the soft insulation layer from the rigid brickwork. On the other hand, a greater impact has been described regarding microbial growth, as the presence of moisture may be prolonged due to the lower surface temperature of insulated facades. Beside the use of biocides in renders or coats, also other measures can help to avoid microbial growth. In this manner the hydrophilic properties of the rendering are of great importance. In case of mineral renders, the approach is that the rendering system "takes control of the moisture". This means that moisture can be incorporated in the material structure and dispensed as soon as adequate redrying conditions are reached. Another approach is the use of hydrophobic surfaces, whereon the water drains off quickly. Both solutions aim to keep the surface dry as long as possible.

An update of the IBP study has been provided in Lengsfeld et al. 2015 [30]. At that time, the age of the inspected facades was already between 29 and 45 years. Only minor optical defects like greying or water streaks occurred. They would occur similarly on non-insulated facades. Only one façade showed more severe defects in form of blisters and cracks. This defect has been explained by the use of a non-appropriate paint and underlines the importance using only components as foreseen by the relevant system manufacturer. The authors state that the required maintenance of ETICS is rather low (after 15 - 29 years) and comparable to non-insulated facades with traditional plasters/ rendering systems.

ETICS-on-ETICS renovation

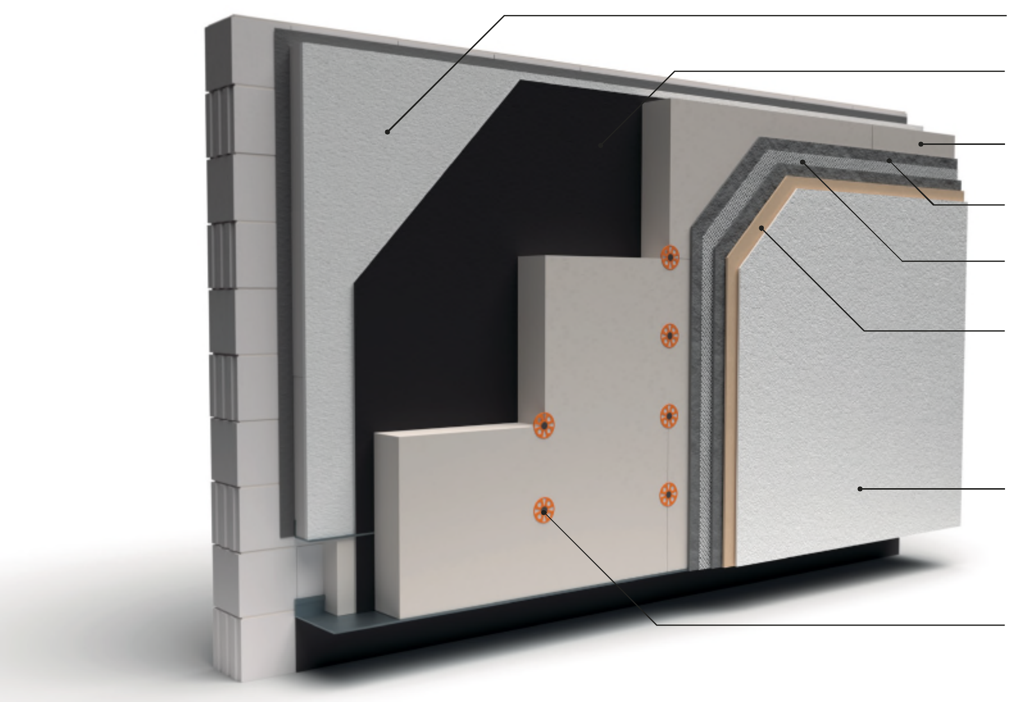


Figure 15 Principle of doubling ETICS („ETICS-on-ETICS“ renovation)

Early generations of ETICS as installed between 1970 - 1990 used mean insulation thicknesses of 5 - 6 cm. To keep up with the development of energy efficiency requirements such facades need to be upgraded with thicker insulation. Instead of removing the existing ETICS and installing a new system, it is favourable to check, if the existing structure can be maintained, as it is usually the case in practice. Then, the life-time of the existing ETICS system is further prolonged (prevention in the sense of the waste hierarchy) and additional resource consumption is limited to the new ETICS layer.

Such doubling of ETICS ("ETICS-on-ETICS") is common practice since many years and underlines the durability of ETICS systems. The precondition is that the existing façade is sufficiently stable and provides a solid and plane surface to ensure a proper adhesion of the new ETICS. **Figure 15** illustrates the ETICS-on-ETICS application. To check if the structure is sound, the existing ETICS layer must be examined. This is easily done by cutting out several sections located in different façade areas. In case the structure is sound (among others: condition of the insulation, function of the adhesion to the wall), the new ETICS layer is installed by using adhesive and anchors that penetrate both ETICS layers to ensure fixation of the entire system (old + new) in the wall structure. National application rules apply.

From twelve facades in the IBP study six had already been doubled within typical façade renovation cycles at the time of the inspection as described in Lengsfeld et al. 2015 [30]. All doubled facades did not show any defects.

It needs to be mentioned, that not in all renovation scenarios the ETICS can remain on the façade. At the latest at the end of the service life of a building,

Selective dismantling of ETICS

Figure 16 Left: selective dismantling of the rendering system creates a clean insulation surface. Middle: removal of the insulation layer from the wall. Right: stripping of existing ETICS leaves already a relatively clean wall (residuals of adhesive mortar visible). ©Ralf Pasker

the system needs to be removed. To meet the requirements of the Waste Framework Directive, the components shall be dismantled separately. This requirement sounds somehow contradictory to the durability of the system, as the inherent compound between the wall, the adhesive, the insulation and the rendering is a prerequisite for the functioning and resistance against wind loads, the airtightness and the protection against impacts and weathering.

In most cases selective dismantling is possible using scrapers (manually or machine driven). The detachment of the rendering system normally is easy thanks to the reinforcement mesh that acts like a predetermined breaking layer. More difficulties may arise when detaching the insulation layer from the wall structure in case of bonded systems. **Figure 16** shows the procedure exemplary in case of a smaller building. Under practical conditions the quality of separation may not be as proper as shown here.

To further improve selective dismantling, manufacturers have started to develop ETICS with focus on design for recycling. Some manufacturers foresee an extra separation layer embedded in the rendering system that works as a detachment aid, others use the anyhow existing reinforcement mesh. The principle remains the same: after vertically cutting the rendering system, the entire rendering system is easily be pulled-off the insulation layer (from top to down) and provides a clean surface of the insulation (**Figure 16, left**). In a second step the mechanically fixed insulation layer can be removed from the wall together with the anchors. After separation of insulation and anchors both waste fractions can be recycled. The rendering can potentially be separated from the reinforcement mechanically off-site [32].

After the selective dismantling the ETICS components are separated. According to the Commission Regulation 849/2010, waste statistics have to be set up by member states on the quantity of waste generated for so called waste categories and waste generating activities. Waste categories distinguish between hazardous and non-hazardous materials in different material groups like mineral waste, wood, plastics, etc., while waste generating activities discriminate the origin of waste allocated to different industries. In case of ETICS the waste generating activity is "construction". Therefore, information about so-called Construction and Demolition Waste (CDW) is available through the official statistical services of the EC (EUROSTAT). The regulation 849/2010 contains further specifications of so-called waste keys. These keys consist of three groups of numbers, that indicate the origin (e.g. 17 for construction and demolition waste), the group of materials (e.g. 17 06 for insulation) and the specific waste (e.g. 17 06 04 for insulation without asbestos and hazardous substances).

To evaluate the contribution of ETICS to the amount of CDW a rough calculation of the mean area related masses of the different components can be made as follows. ETICS consist of different components that are (from warm to cold side) the adhesive mortar, the insulation material, the anchors, the base coat, the embedded reinforcement mesh, and the finishing coat. For the adhesive mortar, base coat and finishing coat, both mineral or organic-based kit components are used by ETICS kit manufacturers in their systems. The most used insulation materials are EPS and mineral wool. Based on values gathered by Albrecht and Schwitalla 2014 [31] concerning the area related mass of the components and the share of the specific component on the whole market, an estimation of the weighted mean area related mass for specific ETICS components was set up. The values therefore represent the share of a specific component / material of an "average ETICS kit". The values taken from Albrecht and Schwitalla 2014 are exemplary for Germany but likely to be similar across Europe. **Table 1** shows the results and also contains an allocation of the components to the waste key, as well as the total built mass of ETICS components and ETICS based on values of an EAE market survey for the year 2020 in EU-27 countries (around 230 million m^2).

According to **Table 2**, it becomes obvious that the most important groups are mixed CDW (17 09 04) with a total built mass of 2,511 kton in 2022 (69 w-% of installed ETICS) and insulation materials (17 06 04) with a total built mass of 1,073 kton (29 w-% of installed ETICS). The amount of metal (from anchors) and plastics/glass (from anchors and reinforcement mesh) are of minor relevance.

Until now the components of ETICS are not visible in the statistics, the data is aggregated according to the origin of waste (Commission Regulation 849/2010, Section 8) that specifies "Construction" and further down waste categories (Commission Regulation 849/2010, Section 2) which specifies "mineral waste from construction and demolition (12.1)". According to Eurostat (env_wasgen) the share of construction waste has increased over the last twenty years, reaching roughly 38 % of the total waste in the EU-27 in 2020 (**Figure 17**).

Figures for 2020 comprise 2,153,950 kton of total waste from which 807,170 kton represent construction waste. 286,600 kton thereof are recognized as mineral waste from construction and demolition. This means that approximately one third of the construction waste is allocated on "mineral waste from construction and demolition". In comparison the total built mass of ETICS in 2020 appears low. The estimated 3,643 kton reflect a share of only 1.3 % of mineral waste of construction and demolition and a share of 0.45 % of the total construction waste.

Mean area related mass of different components of ETICS and weighted values representing "average ETICS" including allocation to the waste key and an estimation of the yearly built mass in EU-27 based on 230 million m² of installed ETICS in 2020

ETICS kit component	Description	Area related mass	Share of specific component	Weighted area related mass	Waste key	Build mass in 2022 based on 230 mill. m² ETICS (EU27)
-	-	in kg/m²	in %	in kg/m²	-	in kton
Adhesive motar	mineral binder	4.0	80	3.2	17 09 04 17 01 07	736
	organic binder		18	0.72	17 09 04	166
Insulation (12 cm thickness)	EPS (ρ=15 kg/m³)	1.8	70	1.3	17 06 04	290
	Mineral wool (ρ=100 kg/m³)	12	26	3.1	17 06 04	717
	Others (ρ=60 kg/m³)	7.2	4	0.29	17 06 04	66
Anchors (20 g each, 6.2 /m²)	metal (87 w-%)	0.11	60	0.065	17 06 05	15
	plastics (13 w-%)	0.016		0.0097	17 06 03	2
Base coat	mineral binder	4.0	65	2.6	17 09 04 17 01 07	598
	organic binder		35	1.4	17 06 04	322
Reinforcement mesh	coated glass fibre	0.17	110	0.18	10 11 03 17 02 03	42
Finishing coat	mineral binder	3.0	65	2.0	17 09 04 17 01 07	448
	organic binder		35	1.1	17 09 04	241
Total ETICS kit	-	-	-	15.8	-	3,643

Table 1 Mean area related mass of different ETICS kit and weighted values representing an "average ETICS kit" including allocation to the waste key and an estimation of the yearly built mass in EU-27 based on 230 million m² of installed ETICS in 2020 according an EAE survey

Allocation of built mass of ETICS in 2020 in EU-27 according to waste keys

Waste key	Build mass in 2022 based on 230 mill. m^2 ETICS (EU 27)
-	in kton
Mixed CDW (17 09 04)	2,511
Insulation (17 06 04)	1,073
Metal (17 04 05)	15
Plastics (17 02 03) Glass (10 11 03)	44

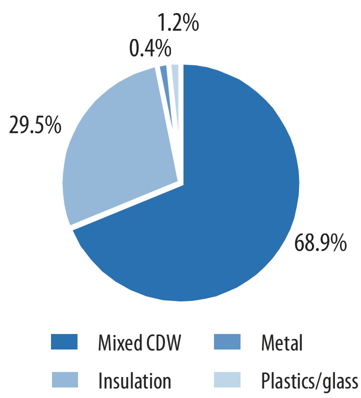


Table 2 Allocation of built mass of ETICS in 2020 in EU-27 according to waste keys

In literature so-called CDW indicators are used, that describe the CDW in mass/m^2 of built floor space. Values from several studies are summarized in Villoria-Saez et al. 2020 [33] and Malia et al. 2013 [34]. The values obtained distinguish mainly between the materials of the walls that can be concrete, masonry and timber. Minimum, maximum and mean values are summarized in **Table 3**. Depending on the material CDW indicators between 0.195 – 1.637 ton/m^2 are possible. For the following calculations the mean values were used.

An estimation of the future CDW related to ETICS depends on the installed mass of ETICS throughout the next decades and the durability of the systems. As shown in the previous clauses of this chapter the reference service life of ETICS is rather high assuming adequate maintenance. It can even be prolonged by means of ETICS-on-ETICS application. However, one day all buildings will reach their end of life – be it earlier or later. Therefore, all installed ETICS have to be deconstructed one day. To evaluate the impact of ETICS on the future CDW, a building related perspective can be chosen.

Built mass of ETICS in 2020 in relation to total CDW

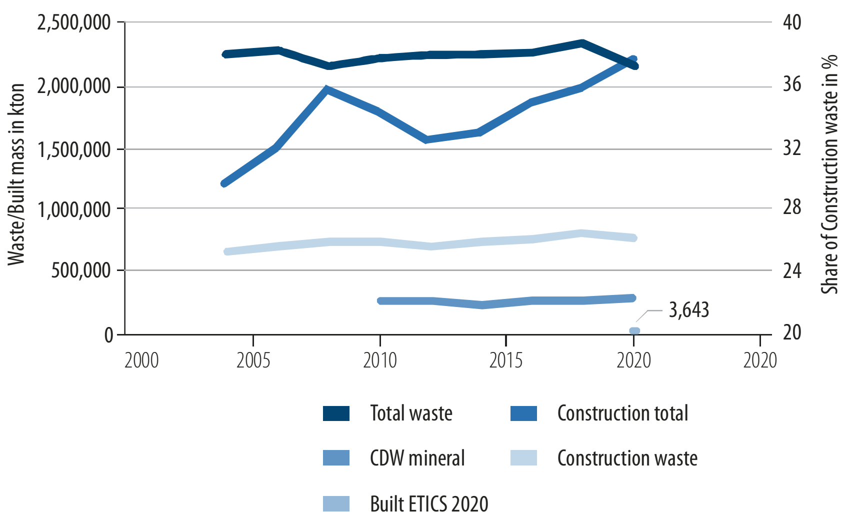


Figure 17 Total waste, construction waste, mineral waste from construction and demolition (CDW mineral) and share of construction waste in the EU-27. Source: Eurostat (env_wasgen) in relation to the built mass of ETICS in 2020

CDW indicators in ton/m²

CDW indicator in ton/m²	Residential			Non residential		
	Concrete	Masonry	Timber	Concrete	Masonry	Timber
	in ton	in ton	in ton	in ton	in ton	in ton
Min	0.805	0.302	0.195	0.742	0.664	-
Mean	1.088	0.483	0.460	1.190	0.745	-
Max	1.371	0.664	0.725	1.637	0.825	-

Table 3 CDW indicators in ton/m². Source: Summarized values taken from Malia et al. 2013 [34]

To calculate the mass-related share of ETICS on the CDW per building, assumptions about wall and floor areas are necessary. Data was taken from the AmBIENCe database [35] that refers to the TABULA and hotmaps data source. To be representative for Europe, mean values for all building types were taken over the entirety of the available construction periods and member states both for residential (R) and non-residential (NR) use. Based on the wall area and the area related mass of an average ETICS kit (**Table 1**), the mass of ETICS per building was calculated. The CDW per building was calculated accordingly, based on the floor space and the mean CDW indicators according to **Table 3**. Results are given in **Table 4**.

It becomes obvious that the mass-related share of ETICS on the building specific CDW differs depending on the building type (ratio from wall to floor area) and the construction materials (concrete, masonry, timber). In general, the ratio from wall to floor areas drops with larger buildings, thus lowering the impact of ETICS on the total CDW. For single family houses (SFH) the highest values are obtained with appr. 1.7 % in case of concrete structures to 4.1 % in case of timber structures. Vice versa, the lowest values for residential buildings are recognized for apartment blocks (ABL) with ratios of just 0.7 % - 1.8 %. Lowest ratios of wall to floor area are visible for the trade buildings and education buildings due to a rather large area of windows, respectively glass elements.

The mean mass-related ratio of ETICS related to the CDW over all evaluated scenarios is 1.3 % that is exactly the ratio that originates from the comparison of the installed mass of ETICS in 2020 (3,643 kton) in relation to the mass of mineral waste from construction and demolition in the same year (286,600 kton). Even though the share according to **Table 4** would be higher if weighted according to the distribution of the building types (e.g. > 70 % of all EU buildings are SFH), the comparison shows that the calculated values most likely reflect an upper limit.

The previous considerations aimed to compare the amount of installed ETICS in relation to other construction materials and in particular to CDW. According to the waste hierarchy (**Figure 14**), CDW can be treated in several ways. While at the product level the upmost priority must be on prevention, recycling is the preferred way of waste treatment at the waste stage.

Mean values of wall and floor area for several reference building use codes according to AmBIENCe database and calculated mass of ETICS per building in relation to the total amount of CDW

AmBIENCe database			Mass of ETICS per building	CDW per building			Share of ETICS on CDW		
Building code	Wall area	Floor area		Concrete	Masonry	Timber	Concrete	Masonry	Timber
-	in m^2	in m^2	in ton	in ton	in ton	in ton	in %	in %	in %
SFH	182	154	2.88	164	104	71	1.72	3.88	4.07
MFH	813	1,128	12.9	1,205	759	519	1.05	2.36	2.48
ABL	1,667	3,271	26.4	3,493	2,201	1,505	0.74	1.67	1.76
OFF	753	1,189	11.9	1,270	800	547	0.84	1.35	-
TRA	287	1,144	4.55	1,222	770	526	0.33	0.53	-
EDU	498	2,428	7.89	2,593	1,634	1,117	0.27	0.44	-
HEA	816	2,117	12.9	2,261	1,425	974	0.51	0.82	-
HOR	648	1,216	10.3	1,299	818	559	0.71	1.13	-
OTH	554	3,770	8.78	4,026	2,537	1,734	0.20	0.31	-

Table 4 Mean values of wall and floor area for several reference building use codes according to AmBIENCe database and calculated mass of ETICS per building in relation to the total amount of CDW

For recycling of ETICS several stages along the life-cycle can be distinguished.

- Production leftovers (providing highest degree of pureness)
- Construction leftovers (mostly high degree of pureness)
- Material from maintenance and dismantling (nowadays often polluted and mixed)

As shown in **Table 2**, 69 w-% of ETICS consist of mineral materials or mixed construction and demolition waste (mortars, renders, etc.). In case of adhesive mortar with a high pureness the waste key 17 01 01 "concrete" could be achieved, but in most cases a certain pollution with other wall building materials is likely, therefore the waste key 17 01 07 "mixtures of concrete, bricks, tiles and ceramics" or in case of a mixture with other organic components even 17 09 04 "mixed construction and demolition wastes" will apply. Recycling options for mortars and renders from dismantled ETICS are therefore limited, due to the large variation of in most cases unknown ingredients [36]. In principle, possible recycling routes could be the utilization as mineral granulates for road construction, earthworks applications such as structural backfill and noise protection walls as well as in gardening and landscaping. In case a high pureness of mineral fractions is achieved the material could also be used as aggregates for the production of concrete for concrete blocks and concrete for non-structural and structural components (Albrecht and Schwitalla 2014). However, due to the described problems of pollution, respectively unknown ingredients, a proper separation of these fractions marks a focus area to contribute improving the recycling possibilities of other mineral fractions of CDW like concrete or masonry.

Approximately 29 w-% of ETICS represent insulation materials from which EPS and mineral wool have by far the highest market share (**Table 1**). In the following, recycling procedures for both material groups are detailed exemplary.

To collect construction leftovers from the insulation, both for EPS and mineral wool, return systems are offered by manufacturers. To facilitate this, craftsmen order plastic big bags to collect the material. A prerequisite for the recycling is a high degree of pureness. Therefore, the material must be free from any other construction materials and pollution. The material is returned from the construction site by the manufacturer and enters into the recycling process.

For expanded polystyrene (EPS) several ways of recycling exist. They differ in the degree of separation of the material. Foamed beads from production and construction leftovers can be fed directly back into the production process. The possible content differs, depending on the desired intended use of the final insulation product. Another possibility is the use of foamed beads as a lightweight additive in other construction materials. A typical example would be lightweight concrete.

So-called mechanical recycling of EPS describes a process wherein the EPS waste is shred and afterwards melted in a special extruder. The re-granulate has similar properties as the

Principle of Polystyrene Loop process

Figure 18 Recycling process within the PolystyreneLoop from demolition waste to new insulation boards; principle of PolystyreneLoop with Bromine recovery unit

initial product, i.e. contains the same additives. Currently up to 10 % of such re-granulate are added to the production of new materials. At the moment, most of the re-granulate originates from packaging because construction waste streams are not sufficiently available.

The third recycling path for EPS is called chemical recycling, wherein the EPS waste is shred, compacted and afterwards treated in a chemical process. The basis is the CreaSolv®-scheme, developed by Fraunhofer IVV (Sieber et al. 2013). Using organic solvents, the polystyrene is separated from other components like the formerly used flame retardant Hexabromocyclododecane (HBCD). HBCD can be treated in a separate process to recover elementary bromine. Through this, a safe destruction of HBCD is possible, making bromine available for the production of new flame retardants (like Polymer-FR). (**Figure 18**)

From 2017 the CreaSolv® process has been upscaled to industrial scale, funded by the EU and the industry in the PolyStyrene Loop project. The meanwhile privatised production facility is located in Terneuzen (NL). Its current capacity accounts for 3,000 ton/a and can be increased to 8,000 ton/a [37]. A comparison of GHG emissions between the current still predominant incineration process and the PolyStyreneLoop recovery process clearly demonstrates that if implemented at large industrial scale significant reduction of CO_2 equivalent is achieved, while keeping the raw materials in a closed loop.

Even though many ways of material recycling for EPS are available, it has to be pointed out, that currently still the majority of EPS construction waste is used for energy recovery. In 2018 a total of 141.7 kton of EPS/XPS pre-consumer building and construction waste was collected in EU-28+2 countries. Compared to the previous year, this marked an increase by 2.2%. From this amount around 67% are used for energy recovery, around 10% were used for material recycling and roughly 23% for landfill/disposal [38].

Figure 19 To significantly reduce the volume of insulation waste for transportation and storage before recycling treatments, mobile unites to be used at demolition sites have been developed. ©Ralf Pasker

Here the durability of ETICS turns out to be a major challenge for increasing reuse and recycling in practice. Thanks to an expected service life of several decades, the waste streams resulting from demolition are still relatively low and quite decentralised. Although technically feasible, the recycling in specific facilities is only economically feasible at large scale. Long distance transportation on the other hand results in additional carbon footprints. To minimise the problem of transportation, technologies to compact removed insulation have been developed to minimise truck loads. Some solutions already compact the insulation demolition waste on site, others in logistic hubs.

Here lies potential for future improvements. With rising amounts of ETICS demolition waste it seems interesting to establish a network of decentralised circular economy hubs. At larger scale the processes of removal, transportation and separation of waste fractions could be industrialised, offering potential to create new businesses models.

Chances are good: to guarantee an effective and economic operation of the PolyStyreneLoop and other material recycling options, the urban mining of EPS/XPS needs to be improved. The Conversio study [38] estimates that by 2050, depending on the scenario, EPS/XPS construction and demolition waste in Europe will increase to around 350-420 kton/a. From that feed stock around 60-100 kton/a qualify for treatment by the PolyStyreneLoop. The remaining amount will be treated using alternative technologies.

For mineral wool production leftovers normally are returned to the production process. For stone wool that consists of the mineral raw materials diabase, feldspar, sand and dolomite, so-called recycling stones can be added up to a share of 30 %. These recycling stones are prepared by pressing production leftovers like cutting residuals and dust together with cement as binder. The organic binder that is added for the production of the insulation slabs has to be removed in advance by thermal processes and other minerals may have to be added or removed to meet the specific formulation. For glass wool that already consists to 50 – 80 % of recycled glass, production leftovers like glass wool flocks or cutting residuals are milled and a share of up to 10 % can be added directly to the hot melt. In case of larger amounts of recycled material those have to be processed to frits. Similar to the recycling stones for stone wool, here the binder has to be removed, too, and several minerals may be added to meet the specific formulation.

A possible path for the disposal of mineral wool is backfilling. Backfilling describes the process of filling up exploited underground mines with waste from non-mining activities. Backfilling helps to stabilise the underground by avoiding settlement phenomena. In case of mineral wool e.g. the material can be stockpiled in big bags that are compacted by bulldozers. The remaining air gaps are filled with concrete. The result is a compression-proof material that also hinders the leaching of loose fibres.

To conclude, the ETICS sector takes responsibility for the circular economy and has begun to invent recycling solutions throughout the years. However, economic and ecological feasibility very much depend on the availability of ETICS waste streams. Thanks to the proven durability such waste streams are still small. This needs to be considered when setting regulatory requirements for recycled content in the future. Solutions need to be permitted that allow recycling processes mixing waste streams from different fields of application, both different uses in construction (e. g. façade insulation and roof insulation) and different sectors (e. g. construction and packaging of consumer goods) as long as the raw materials are the same. This consolidation of waste streams could help upscaling the use of recycled waste. The focus must be on minimizing the cross-sector use of virgin raw materials. This will require third-party approved calculation methods such as the mass-balance-approach to allow manufactures to declare their recycled content whilst preventing green-washing.

KEY MESSAGES - RENOVATE FOR SUSTAINABILITY AND ENVIRONMENT

- Today approximately half of all extracted materials are used by the construction sector, that also counts responsible for over one third of the total waste generation in the EU.
- The recast of the CRP will put more emphasis on recycled content, durability and circularity of construction products.
- The current and future share of ETICS on the total CDW is low.
- The ETICS sector takes responsibility for the circular economy and has begun to develop recycling solutions throughout the years.
- Economic and ecological feasibility very much depends on the availability of ETICS waste streams. Thanks to the proven ETICS durability such waste streams are still small. This needs to be considered when setting regulatory requirements for recycled content in the future.
- Solutions need to be permitted that allow recycling processes mixing waste streams from different fields of application, both different uses in construction (e. g. façade insulation and roof insulation) and different sectors (i. e. construction and packaging of consumer goods) as long as the raw materials are equal. This consolidation of waste streams could help upscaling the cross-sectoral use of recycled waste.
- Priority must be on minimizing the use of virgin raw materials across all sectors, growing the market for secondary raw materials.
- This requires third-party approved calculation methods such as the mass-balance-approach to allow manufactures to declare their recycled content whilst preventing green-washing.
- With increasing amounts of ETICS demolition waste it seems interesting to establish a network of decentralised circular economy hubs. At larger scale the processes of removal, transportation and separation of waste fractions should be industrialised, offering potential to create new businesses models.

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EAEAWARD **2021** WINNER

Category **„Residential New Built Single-family Homes"**

Project: Project VL-L in Linden/Belgium
Description: Detached single-family house (villa) on a sloping and forrested site
Architect: Niko Wauters, Niko Wauters Architecten BV
Project owner: Private
ETICS manufacturer: Willco Products

4 RENOVATE FOR THE PEOPLE

Inability to keep home adequately warm

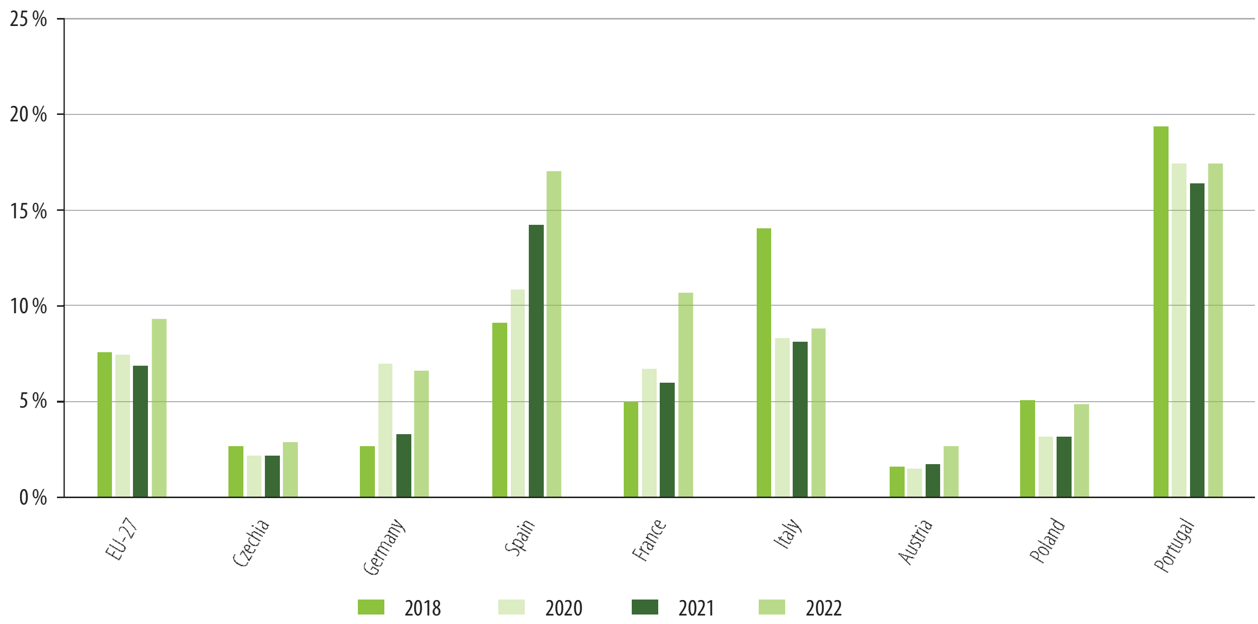


Figure 20 Inability to keep home adequately warm. Source: Eurostat (ilc_mdes01)

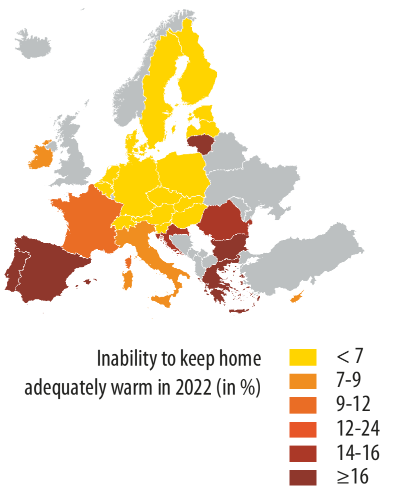
One of the focus areas of the Renovation Wave initiative [13] is fighting energy poverty. According to the European Commission's communication, nearly 34 million Europeans were living in energy poverty conditions in 2018, meaning that 7.6 % of the European population was unable to keep their homes adequately warm. Whilst this figure decreased to 6.9 % in 2021, it jumped to 9.3 % in 2022. However, as stated by the EU Commission [39] "the number of EU citizens that can be considered "energy poor" is much higher if all the different aspects around energy poverty are taken into account, such as being unable to cover basic housing costs or having inadequate comfort in the housing or work environments".

Energy poverty is a complex phenomenon linked to a combination of factors that represent the inability of households to access energy needs such as heating, cooling, lighting, and energy to power appliances as defined by the Renovation Wave communication [13]. The phenomena affect the health and the well-being of inhabitants. For vulnerable groups, extreme indoor climatic conditions can cause respiratory and cardiovascular illnesses, heat-stroke and in the worst-case death [40]. Energy poverty occurs at the domestic level and therefore it is difficult to quantify its effects. Due to its multifaced nature, energy poverty can vary even at the local level. Despite the difficulty of defining criteria for evaluating the condition of energy poverty, the causes can be traced back to three factors: low-income, high-energy prices, and low building energy efficiency [40]. As stated in the press release issued in July 2023 by the European Economic and

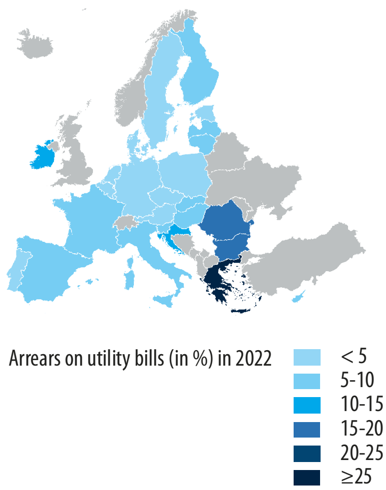
Social Committee, "over the past few months the unprecedented surge in energy prices and the Russian invasion of Ukraine have made it more difficult for even more people" [41], highlighting the great challenge energy poverty marks for Europe. In 2022, around 42 million people were unable to heat their home properly. As shown in the geographical map, the percentage is higher in the Southern and Eastern regions of Europe. The highest share is found in Bulgaria (22.5 %), Cyprus (19.2 %) and Greece (18.7 %) followed by Lithuania (17.5 %), Portugal (17.5 %) and Spain (17.1 %). People suffering from difficult financial conditions usually have problems managing their energy expenditure. This generates a vicious circle of high energy bills, arrears and problems with well-being and health. In the European panorama, the arrears on utility bills are highest in Eastern Europe and in the Balkan region, especially Greece where 34.1 % of people are unable to pay their utility bill on time.

The maps highlight the geographical differences in energy poverty. Eastern Europe and Mediterranean states generally present a higher percentage of people who cannot keep their homes adequately warm than the European average (9.3 %). In southern European Member States, this vulnerability is due to different reasons such as higher level of income poverty, governmental instability, and poor infrastructure [42, 43]. However, as stated by Stoerring et al. 2016 [44], the problem is mostly due to the lack of adequate heating systems and inefficient housing. In the Mediterranean area, energy costs are also affected by the necessity to keep the home adequately cool in summer. The vulnerability of Eastern European citizens can be linked to the liberalization of national energy markets, which led to an increase in energy tariffs, and the predominance of an unsustainable energy supply mix, in combination with the poorly insulated building properties [42, 44]. Although the indicators are below the European average value, energy poverty is also found in Northern Europe. In this case, the issue is typically confined to demographic groups with energy affordability problems and linked to poor energy efficiency of dwellings [42, 44].

Inability to keep home adequately warm in 2022 (in %)



Arrears on utility bills in 2022 (in %)



Current state of the thermal transfer coefficient in W/(m² K)

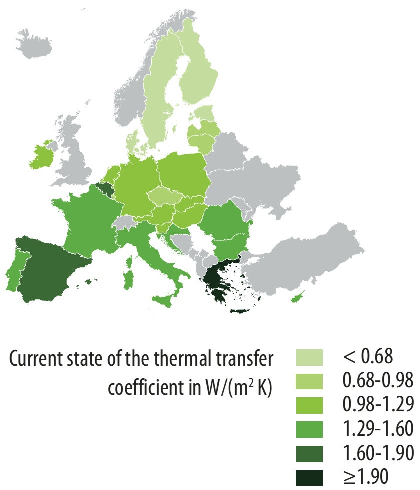


Figure 21 Left: Inability to keep home adequately warm in 2022 (in %). Source: Eurostat (ilc_mdes01); centre: Arrears on utility bills (in %) in 2022. Source: Eurostat (ilc_mdes07); right: Current state of the thermal transfer coefficient in W/(m² K). Source: Joint Research Center

Evolution of natural gas prices

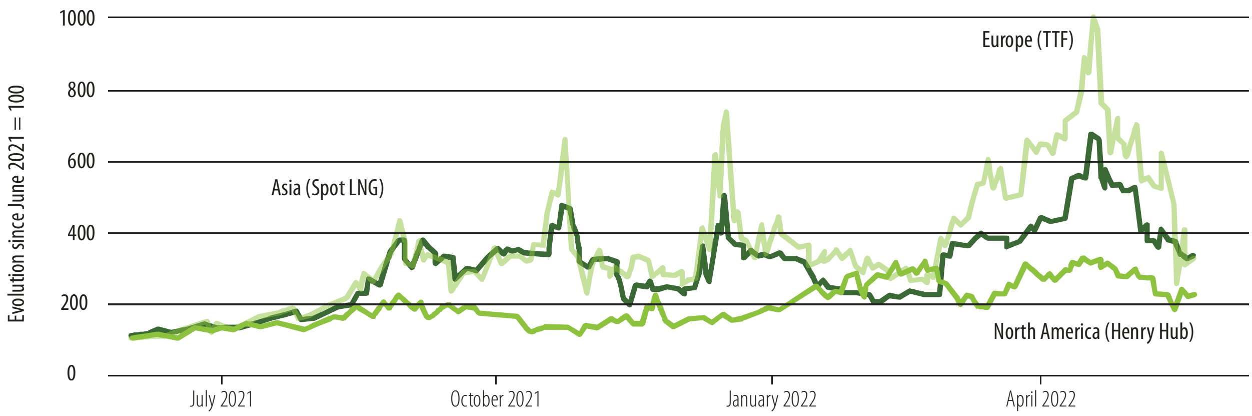


Figure 22 Evolution of natural gas prices, June 2021 - October 2022. Source: IEA [49]

Discrepancies between the inability to keep homes adequately warm and the arrears on utility bills, such as in Finland and Portugal, can be attributed mainly to government policies and support as specified by EPOV report [45].

In 2021 the gas price has risen due to multiple factors linked to the strong recovery after the pandemic, a tight supply in relation to the high demand, and due to a colder and longer winter that led to a prolonged heating season [46, 47]. In correlation with the gas price, the electricity price also increased, reaching the highest level. "In Germany and Spain, for example, prices in September have been around three or four times the averages seen in 2019 and 2020" as stated in an IAE article [47]. In 2022, Russia's invasion of Ukraine kicked energy prices to high records and, although the prices have fallen again, they have not yet reached pre-crisis values [48].

The price trend has significantly influenced the families, pushing them to cut expenses and live in conditions that are no longer comfortable. According to COM(2020) 951 [50], the poorest European households, i. e. in the lowest 10 % income bracket, spent a share of 8.3 % of their total expenditure on energy in 2018, although this number varies across countries and income levels. Indeed, the report also specifies that "northern and western European middle-income households spent 3-8 % while central and eastern Europeans with the same income level spent 10-15 %". A study carried out by the International Monetary Fund (IMF) [51] estimated an increase of 7 % of the average cost of living in 2022, with a strong impact on the poorest fifth of households. In some countries such as Estonia, the analysis estimates that 25 % of the income of the poorest families is spent on energy bills. The greatest energy expense that weighs on families is due to space heating. Indeed, the energy consumption in households with the greatest percentage is aimed at heating their home (**Figure 24**).

Due to the COVID-19 crisis, the increase in energy prices, and the Russian invasion of Ukraine, the situation has worsened for many European families, urging the European institutions to take action. Over the last few years, tackling energy poverty has returned into the

European Commission's sights. Several measures and instruments have been introduced to tackle the problem such as the Energy Poverty Advisory Hub (EPAH) [53] launched in 2021, the Recommendation on energy poverty [54] issued in 2020 as part of the Renovation Wave and specific measures to identify the key factors of energy poverty are proposed in the Fit-for-55 package [55] adopted in 2021 [56]. Nevertheless, the European strategy goes beyond the mere identification of the energy poverty condition of European citizens, including measures aimed at the energy renovation of buildings. Energy inefficiency of buildings is one of the causes for energy poverty that can be directly addressed, improving the living conditions of dwellers whilst increasing the renovation rate and energy savings to achieve the climate neutrality target in 2050. Furthermore, energy subsidy funds could be reinvested in further energy-efficiency renovations.

Refurbishment measures on buildings will have a double effect: Home renovation will improve the thermal indoor conditions contributing to the well-being and health of the people as well as increasing their control over energy expenditure. Finally, reduced energy expenditures set budgets free stimulating consumption, supporting economic growth and social participation of most vulnerable parts of societies.

Energy price rises as share of income for the poorest 20 % of households in 2022

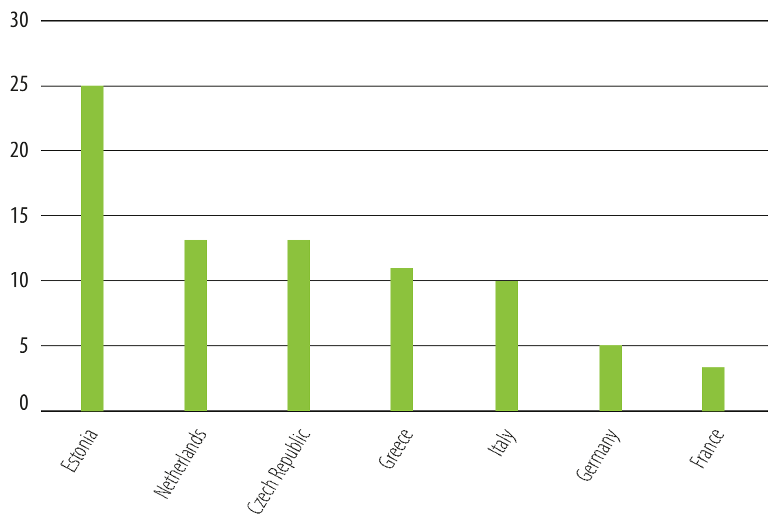


Figure 23 Energy price rises as share of income for the poorest 20 % of households in 2022. Source: Investment monitor [52]

The perception of the thermal conditions is a subjective experience influenced by several factors like gender, age, clothing, activity level as well as the time of day and season. The main physical parameters to assess thermal comfort are room air temperature, radiant temperature

Energy consumption in EU households

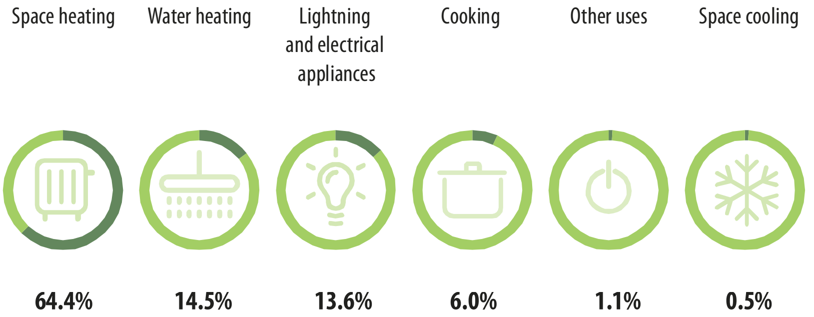


Figure 24 Energy consumption in EU households. Source: Eurostat (nrg_d_hhq)

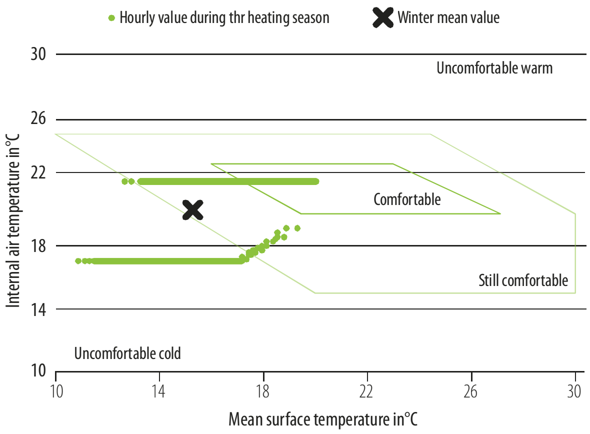
(the temperature of the surrounding surface such as walls, floors, and ceilings), relative humidity, and air velocity. Although thermal comfort is affected by multiple variables influencing the heat exchange between the person and the environment, specific environmental conditions, such as room air temperature and radiant temperature, generally define a thermal comfort range within which most people feel comfortable. These models serve as general guidelines to simplify the assessment of indoor conditions since thermal comfort varies based on individual perception.

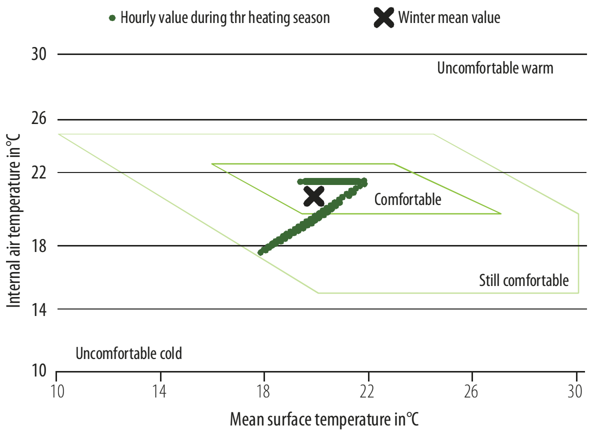
Thermal comfort is a complex subjective concept that reflects an individual's contentment with the thermal environment. Humans emit and absorb radiant heat from their surroundings due to temperature difference, making the surface temperature on the interior walls greatly important. Thermal comfort is indeed perceived not only through the air temperature of the room but also through the balance of radiant heat exchange with the surroundings. If the surface temperature of the wall is too cold, this creates a cold draught resulting in an uncomfortable cold feel. Therefore, enhanced insulation during the winter season can result in a higher inner surface temperature and a more pleasant indoor climate, minimizing in this way also the air movement or "draughts" caused by natural convection due to the temperature differences of the enclosing surfaces. Inadequate insulation can lead to discomfort since the body heat is exchanged by radiation towards the surrounding cool surfaces, requiring higher room temperatures for comfort. The ideal situation is when the temperature of the surface is uniform and the difference to the room air temperature is below 2 °C.

To show the effects of insulated building elements in relation to thermal comfort, the indoor climate was investigated through transient thermal simulation for an exemplary residential building in Holzkirchen (Germany) before and after renovation. For the calculation purpose, a small house of 100 m^2 floorspace with an unheated attic has been analysed. The building dates from the 1960s, therefore, the thermal transmittance of ceiling, wall, and floor reflects the typical values of this class of buildings. It is assumed that the windows had already been replaced by a double-glazing window with a U-value of 1.60 W/($m^2 \cdot K$). To assess the impact of building envelope renovation on the indoor climate, the simulation has been performed for the same building with improved U-values of the building envelope. The results compared the thermal conditions of the building during the heating period (from October 1st to April 30th). The indoor temperature has been held at a minimum temperature of 22 °C during the day and 17 °C during the night by a heating system. When the temperature inside the room decreased below these two desirable values of temperature, the heating system intervened to maintain the temperature at the target values.

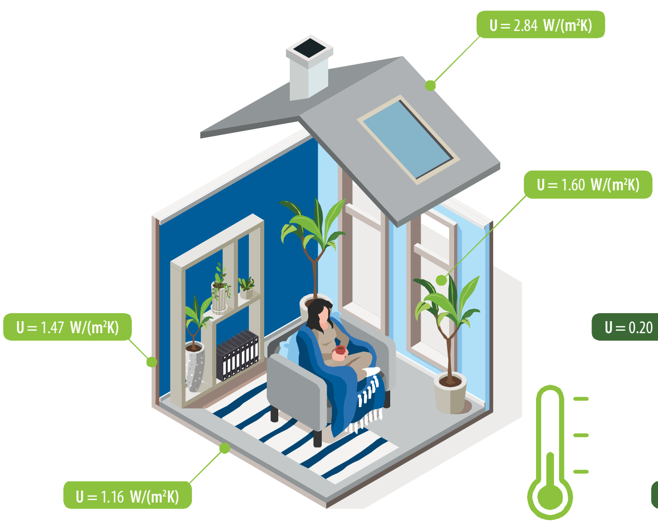
As depicted in the figure, the building before renovation required the heating system to be permanently activated both during day and night to maintain the desired indoor temperature. The indoor temperature has been constant at 22 °C respectively 17 °C. However, despite the use of the heating, the internal climate has been perceived as uncomfortably cold during the nighttime hours, dropping out of the thermal comfort range. This was due to the low temperature of the building envelope. On the inner surface temperatures down to 11 °C have been determined. As a representative value of winter conditions, the temperature mean value of the coldest months, namely January, February, and March, reveals that the thermal comfort during this winter period barely meets the lower limit of the comfort range, illustrated as black cross in the graphic (**Figure 25**). In the scenario of the renovated building, the improvement of the wall has been achieved through the application of an ETICS kit. By this, the hourly value of the temperature consistently fell within the thermal comfort range, even when considering the average values of the winter months. In comparison to the unrenovated scenario, especially the inner surface temperatures were significantly higher, reaching a minimum value barely below 18 °C. Furthermore, the intervention of the heating system to maintain the desired temperature has been limited significantly.

Thermal comfort in a SFH before and after thermal renovation





U-value beforrenovating in W/(m²K)	Building component	U-value after renovating in W/(m²K)
2.84	Ceiling	0.15
1.47	Wall	0.20
1.16	Floor	0.25
1.60	Window	0.90



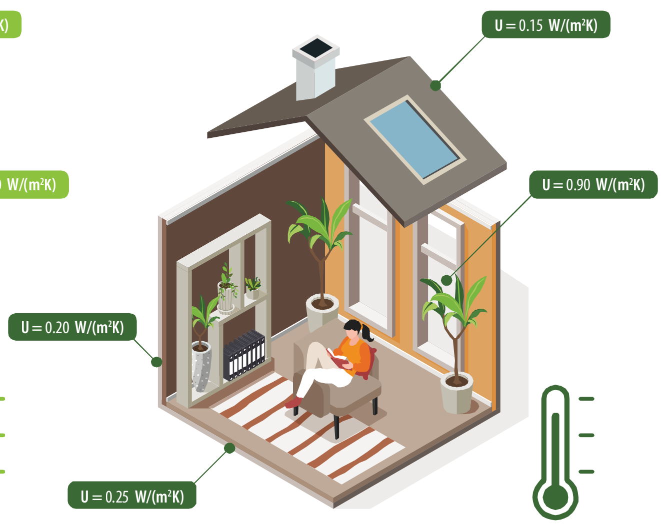


Figure 25 [1] Thermal comfort in a single-family-house built in 1960; [2] Thermal comfort in a single-family-house built in 1960 after renovation. Source: FIW

Furthermore, the combination of low temperature and high humidity conditions can cause the proliferation of mould growth. When encountering a cold surface, such as a cold wall, the warm and moist indoor air cools down rapidly. As the air temperature drops, its ability to hold moisture decreases, resulting in high relative humidity or even condensation of water vapour onto the surface which then provides the necessary water source to foster the development of mould. Mould, however, can start to grow at relative humidity at the wall surface of 80 % (some types of mould can thrive at lower values as well). This is achieved at a surface temperature of 12.6 °C or less, especially in corners and niches. People exposed to mould spore, in particular people with allergies, existing respiratory conditions or suppressed immune systems, can be susceptible to illness. Therefore, enhancing the thermal insulation of the wall to reduce the temperature differences between the indoor air and surfaces can improve the hygrothermal conditions and reduce the risk of condensation in capillaries which is a first enabler for mould formation.

The reduction of the heating load through the improvement of the thermal insulation is also highlighted by Holm et al. 2023 [57]. The report shows the crucial role of well-insulated building in lowering the heating demand and in the transition to renewable heating systems. Achieving full decarbonization necessitates the transformation of existing fossil-based heating systems into decarbonized energy sources. Since the availability of renewable energies is limited, the reduction of energy demand for heating is crucial. According to the study, insulated buildings can achieve a significant reduction of the peak load in winter compared to non-renovated buildings. In addition to the significant impact on future electricity grid, it also impacts the heating costs. The study clearly states that the synergies of the combination of thermal insulation and heat pump leads to a 18 % reduction in heating demands, resulting in a 37 % decrease in heating costs. This additional saving results from a much better efficiency of the heat pump when running at lower heating flow temperatures. Therefore, an increased energy efficiency of the building envelope enables a smaller heat pump (requiring lower investments) and makes it possible for the heat pump to be operated with a low flow temperature, which is a prerequisite for better efficiency resulting in a high COP value.

The energy renovation of the building envelope leads not only to an increase in thermal comfort but also to significant energy savings and thus to a reduction of energy costs. To demonstrate this, two single-family houses (SFH) in different initial states (built in 1960 and 1990) in Germany were examined as examples. The final energy demand was determined according to the calculation regulations currently valid in Germany (GEG and DIN V 18599). The final energy is the one the owners or tenants have to pay for. The following table shows the initial U-values of the different components of the thermal building envelope as well as the U-values assumed after the renovation.

U-values before and after energy-efficient renovation

Component	U-values initial state in W/(m²K)		U-values after refurbishment in W/(m²K)
	1960*	1990	
Basement ceiling	1.0	0.6	0.25
External wall	1.4	0.6	0.20
Window	1.6*	2.7	0.90
Roof	1.4	0.5	0.14

*Due to the average service life of windows, a replacement of the windows and thus an improved U-value was already assumed for the SFH built in 1960.

Table 5 U-values before and after energy-efficient renovation.

Energy cost savings by component-improvements compared to two initial states

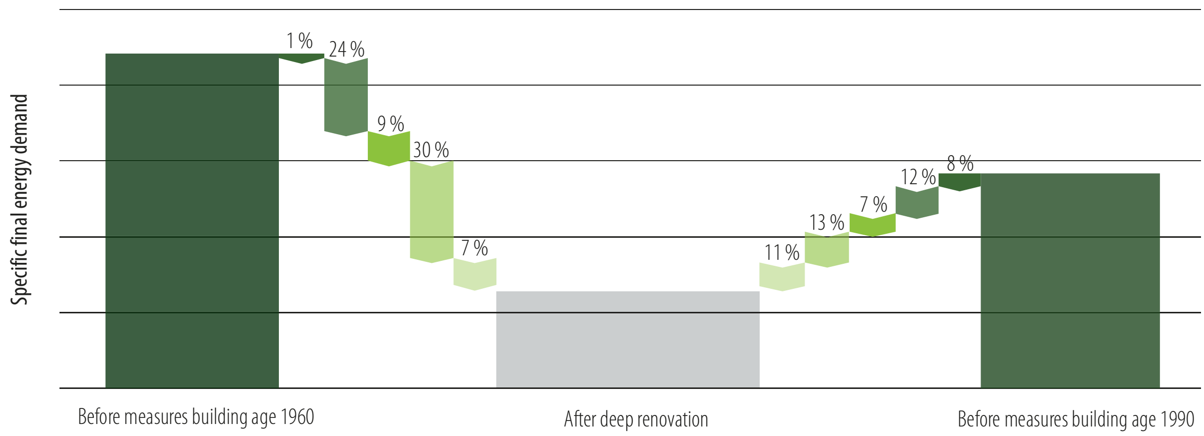


Figure 26 Energy cost savings by component-improvements compared to two examplary initial states Source: FIW

Figure 26 shows the results of the calculations. On the x-axis the three pillars show the energy performance before renovation (left for building age 1960, right for building age 1990) and after renovation (pillar in the middle). The building ages should represent two different initial efficiency states. The energy demand of a non-renovated building from the 1990s is usually significantly lower than for an (almost) unrenovated building from the 1960s. The y-axis shows the final energy demand without specific numbers because for this consideration the goal was to just show the relation of the energy cost savings in relation to a better and a worse initial state. By multiplying the final energy demand (e.g. given in kWh) with the energy costs per energy unit (e.g. €/kWh) one can calculate the total energy costs. The arrows in the figure represent the final energy savings respectively the energy cost savings in % achieved by renovating the different elements of the building envelope. The percentage represents the ratio of the difference in final energy demand/costs between the renovated and the two initial states, relative to the final energy demand/costs of the two initial states. At this point it should be mentioned that the focus of the calculations was to determine the energy savings potential of the building elements. The measures on the building envelope usually also reduce losses due to thermal bridges (especially as ETICS provide continuous insulation from the outside) and improve airtightness (especially when replacing windows). The improvement is shown separately in the graph. Improvements of the heating system were not considered.

It can easily be seen that the overall energy cost savings potential for the SFH built 1960 is higher compared to the SFH built 1990. This is not surprising considering the higher U-values of the building elements – except for the windows. Considering the average service life of windows, a replacement of the windows and thus an improved U-value was already assumed for the SFH built in 1960. This is the reason for the low energy cost savings (1 %) by improving the windows for the SFH build 1960. Due to the renovation of the building envelope the final energy demand and therefore also the energy costs of the considered SFH built 1960 can be reduced by 71 % and the one built 1990 still by 51 %. Both graphs show that the greatest savings derive from improving the walls and the roof. On one hand this is caused by the high U-values of the initial state compared to the final state and on the other hand due to the area ratios of the different building elements. At this point it is necessary to mention that for terraced houses and multi-family houses the area ratios may deviate, e.g. the area ratio of the wall becomes greater in multi-family houses whereas the area ratio of the roof or basement ceiling becomes smaller. Nevertheless, it demonstrates that renovating the building envelope, especially the walls and the roof, lead to a significant reduction of the final energy demand and therefore also to reduced heating costs.

In case the renovation work would be extended to the entire European building stock, the decrease in energy consumption and, as a residual, potential energy savings would be huge. BPIE [58] calculated that the enhancement in terms of thermal transmittance of only the roof and the walls of all European buildings could lead to an overall saving of 44 % (777 TWh which is more than the final energy consumption of households in Germany) of the energy used for heating. This also means a reduction of fossil fuel consumption such as coal (48 %), heating oil (44 %), and natural gas (46 %).

The policies aiming towards the reduction of GHG emissions by 2030 could lead to the creation of new jobs, shifting and changing the European labour market. The broad construction sector in Europe involves around 18.2 million employees that work in building construction, architecture and civil engineering, real estate and specialized construction activities which include, for example, demolition, site preparation, electrical installation, HVAC installation and plumbing.

Final energy consumption for residential space heating in current and renovated buildings (in TWh) and final energy saved in EU 27

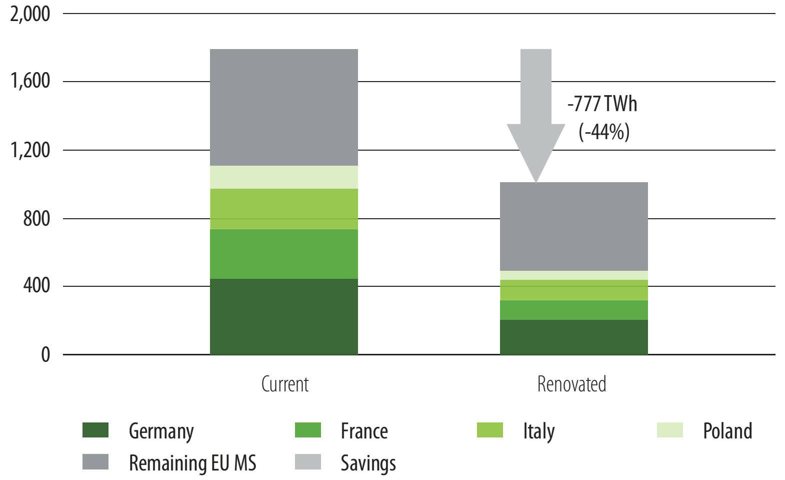


Figure 27 Final energy consumption for residential space heating in current and renovated buildings (in TWh) and final energy saved in EU-27. Source BPIE [58]

Number of European employees in the construction industry in millions of employees

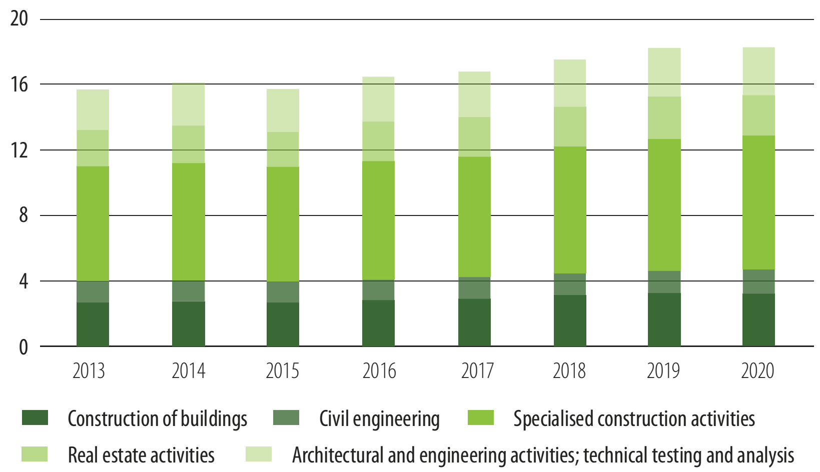


Figure 28 Number of European employees in the construction industry in millions of employees. Source: Eurostat (sbs_na_sca_r2)

Development of the EU construction production, January 2020 – January 2022

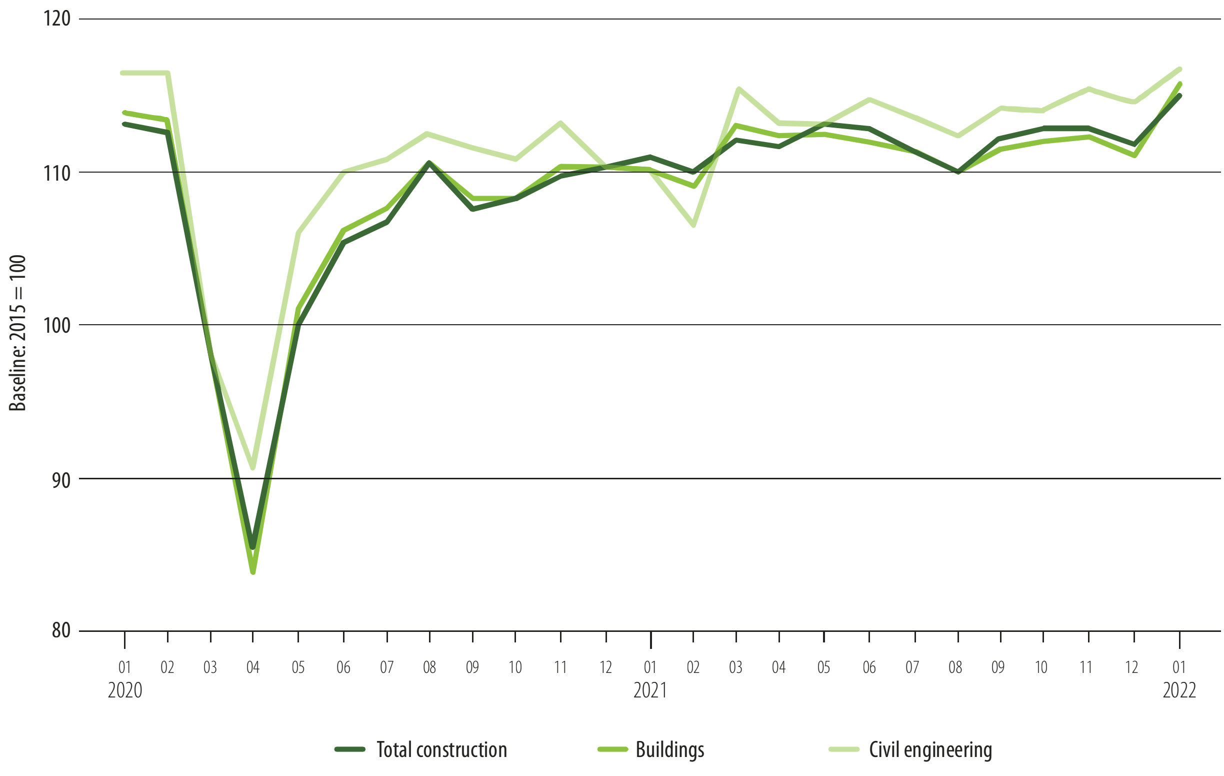


Figure 29 Development of the EU construction production, January 2020 - January 2022. Source: Eurostat [59]

The Covid-19 crisis hit the construction sector quite hard, which suffered a decline of 25.9% between March and April 2020. However, since May 2020, the construction sector has grown again by 20.4%, recovering part of the losses [59].

Many studies agree on the increase of the workforce employed thanks to the green transition policies, but the determination of this numerical increase is not that simple as it depends on the factors considered in the forecast models. For example, Asikainen et al. 2021 [60] state, based on the results of different economic models, that the net increase in jobs will be up to 884,000 (+ 0.45 % of the total workforce in Europe) by 2030. Vandeplas et al. 2022 [61] argue that the green transition could create around 1 million jobs by 2030 in the EU's energy and construc-

Forecast employment impact of the European Green Deal In EU-27 (in % difference between forecast scenario and baseline of 2020)

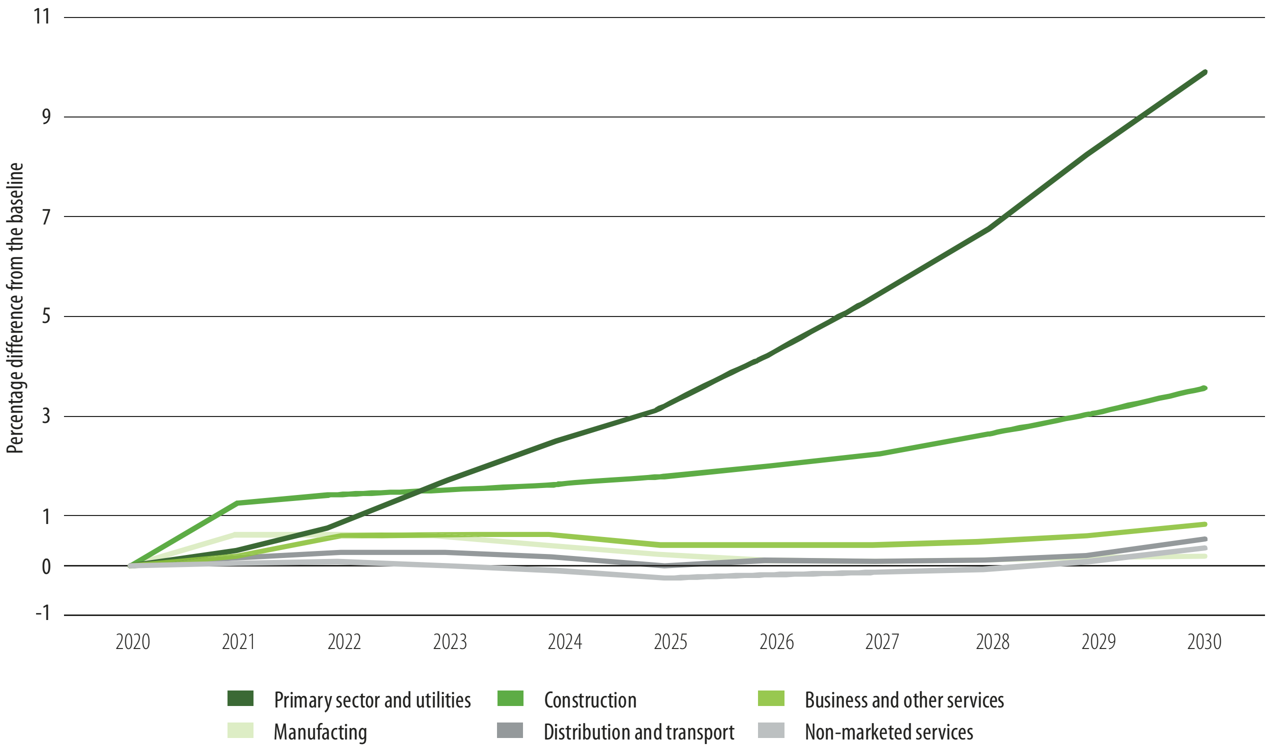


Figure 30 Forecast employment impact of the European Green Deal In EU-27 (in % difference between forecast scenario and baseline of 2020). Source: CEDEFOP [62]

tion labor market. Another study [62] predicts an increase of approximately 3.7 % in employment in the EU-27 by 2030. In particular, the construction sector will face an employment increase of 3.6 % compared to the 2020 baseline due to the Green Deal policies and especially the Renovation Wave (**Figure 30**). Mella et al. 2023 [63] studied the effect of the Renovation Wave and the Recovery and Resilience plans on the employment in the construction sector by 2030. The report found that the construction sector will need between 486,600 and 1,549,000 additional workers as effect of the Renovation Wave strategy, while the Recovery and Resilience plans will play an important role in the EU employment creating around 2 million jobs in the EU labour market.

To achieve the GHG emission reduction goal, renewables and new technologies will be deployed to improve energy efficiency. Therefore, new “green” jobs will be created as stated by several studies [60-62], however, these occupations account for only a few percent of the total EU employment [61]. The green transition will in turn entail a decrease in “brown” jobs, i. e. jobs involved in high pollution activities. Highly polluting activities represent 5 % of the total EU employment and among those jobs only around 0.1 % will be completely phased out. The greatest impact of the green transition will occur on "white" jobs, with relatively neutral impact activities on the environment. "White" jobs represent the greatest share of EU employment and these occupations will reallocate the employment from the "brown" jobs as well as will undergo a transformation that will make them more "green" by reducing the emissions of existing activities [61].

Education, training and skills policies will be needed to ensure a smooth transition. Re-skilling will be of great importance for people working in sectors strongly affected by the transition to find new occupations in greener sectors. In turn, this will help closing the gap of skilled staff in the construction sector. In addition, around 3 to 4 million construction workers such as heat pump installers, carpenters, and bricklayers will require training on energy efficiency and renewable energy resources under the Green Deal transition [62]. In view of this, the European Commission has launched the Pact for Skills [64] to help workers and learners to upskill and reskill, offering webinars, seminars, and peer learning activities.

Summary of the findings regarding the creation of jobs in the green transition

Findings	Sources
+ 160,000 jobs in the construction sector	EU Renovation Wave
+ 884,000 jobs (+ 0.45%)	The future of jobs is green (JRC) (2021)
+ 3.6 % more than baseline (2020) in the construction sector	CEDEFOP (2021)
1 million jobs in the energy and construction sector	The possible implications of the Green Transition for the EU Labour Market (Economic and Financial Affairs) (2022)
Impact of Renovation Wave: + 484,600 – 1,549,000 workers needed in the buildings and energy renovation sector Impact of the Recovery and Resilience plans: around 2 million jobs will be created in the construction sector	Skills and quality jobs in construction (2023)

Table 6 Summary of the findings regarding the creation of jobs in the green transition. Source: Renovation wave [13], JRC [60], CEDEFOP [62], EFA [61], Skills and quality jobs in construction [63]

Different impact of the green transition on the labour market

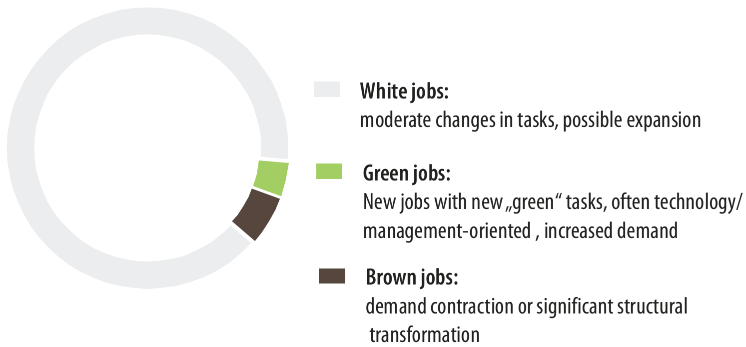


Figure 31 Different impact of the green transition on the labour market. Source: EFA [61]

KEY MESSAGES - RENOVATE FOR THE PEOPLE

- One of the key objectives of the Renovation Wave is fighting energy poverty. Nearly 34 million Europeans were living in energy poverty conditions in 2018, meaning that 7.6 % of all Europeans were unable to keep their homes adequately warm; in 2022 this figure jumped to 9.3 %.
- The number of "energy poor" citizens is even higher if broader aspects related to energy poverty are considered, i. e. being unable to cover basic housing costs or having inadequate comfort in living or work environments. People suffering from difficult financial conditions usually have problems managing their energy expenditure, generating a vicious circle of high energy bills, arrears and problems with well-being and health.
- The problem mostly starts with inadequate heating systems and poorly insulated building envelopes. Not only in Southern Member States costs of households are increasingly affected by the energy demand for cooling during summer as heat waves meanwhile affect a broader area.
- Inefficient buildings are main causes of energy poverty. They can be addressed via enhanced renovation rates, creating various co-benefits such as improved living conditions for inhabitants, energy savings and achieving the climate neutrality target by 2050. Short-term oriented energy subsidies would be far more sustainably invested when redirected to support energy-efficiency renovations, which create long-term improvements.
- Reduced energy expenditures of households release budgets stimulating consumption, supporting economic growth and social participation of most vulnerable parts of our societies.
- The availability of renewable energies is still limited; energy demand reductions for heating is crucial and leaves more renewable capacities for other sectors.
- All policies targeting the reduction of GHG emissions in the building sector by 2030 lead to the creation of new jobs, reshaping the European labour market. The broad construction sector in Europe involves around 18.2 million employees that work in building construction, architecture and civil engineering, real estate and specialized construction activities which include, for example, demolition, site preparation, electrical installation, HVAC installation and plumbing. Hence, the Renovation Wave offers the opportunity to significantly increase employment in the construction sector. These green jobs will help compensating the reduction of brown jobs as result of the green transition.

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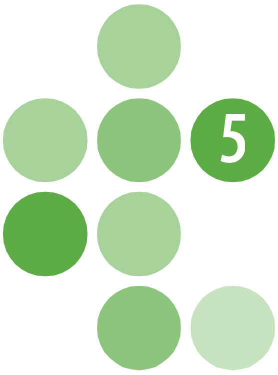
EAEAWARD
2021
WINNER

Category **„Residential buildings refurbishment"**

Project: Westend Villen in Berlin/Germany
Architect: IGS Ingenieur-Gesellschaft mbH
Project owner: Königstadt Gesellschaft für Grundstücke und Industrie mbH
Installer: Bausanierung Ralf Jahnke GmbH
ETICS manufacturer: Sto



RENOVATE TO MAKE EUROPE LESS DEPENDENT

EU's gross available energy is the amount of energy needed to serve the energy needs of all EU countries:

GROSS AVAILABLE ENERGY =
PRIMARY PRODUCTION + RECOVERED & RECYCLED PRODUCTS + IMPORTS - EXPORT + STOCK CHANGES [65]

EU's gross available energy accounted around 17 million GWh in 2021. It was 6 % higher than in 2020. The lower gross available energy in 2020 can be attributed to the COVID-19 pandemic. Since 2006, where the EU's gross available energy was around 19 million GWh, the trend has been slightly decreasing as shown in **Figure 32.**

In 2021 oil and petroleum products accounted for the largest share (34 %) of EU's gross available energy, followed by natural gas (24 %), renewables and biofuels (17 %), nuclear heat (13 %), solid fossil fuels (11 %) and non-renewable waste (1 %). As evidenced by the ratio of fossil fuels in gross available energy, the EU primarily

Gross available energy by fuel in GWh in EU-27 countries from 1990 to 2021

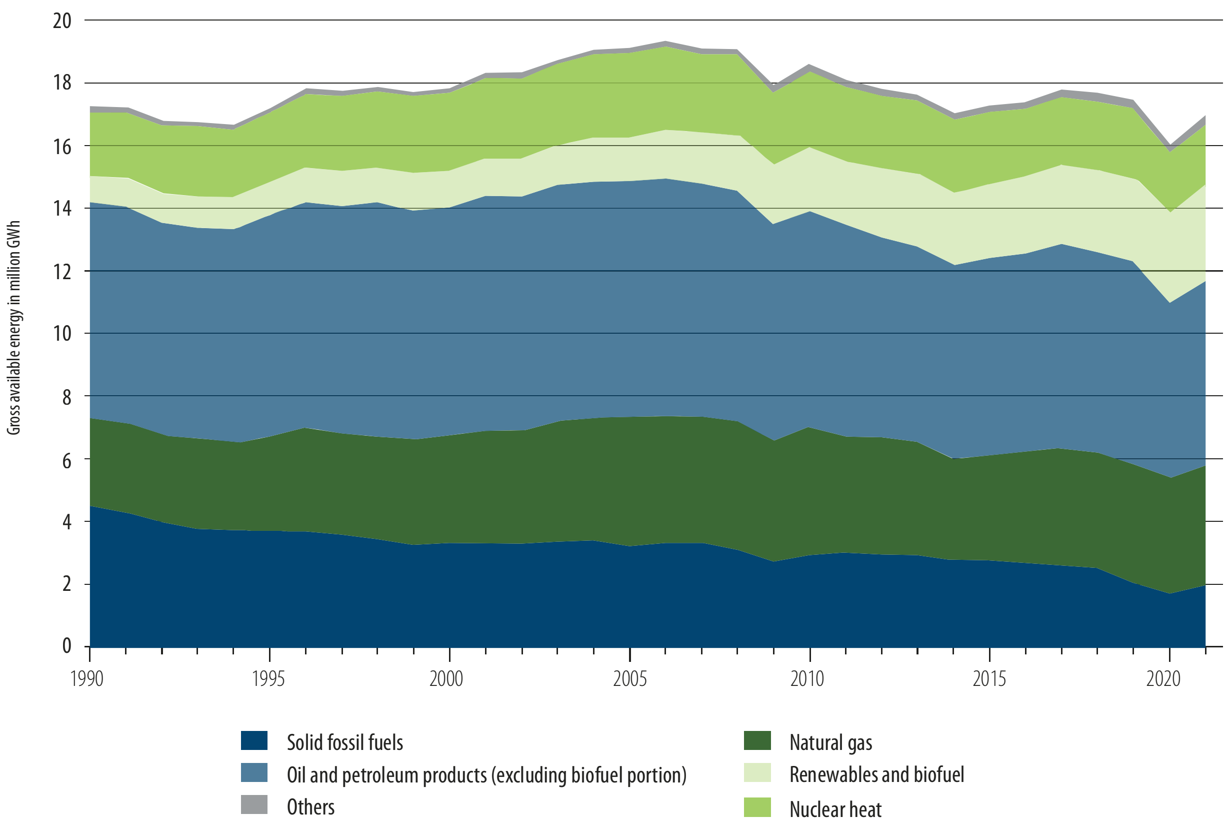


Figure 32 Gross available energy by fuel in GWh in EU - 27 countries from 1990 to 2021. Source: Eurostat (nrg_bal_c)

Primary energy production by fuel in GWh in EU-27 countries from 1990 to2021

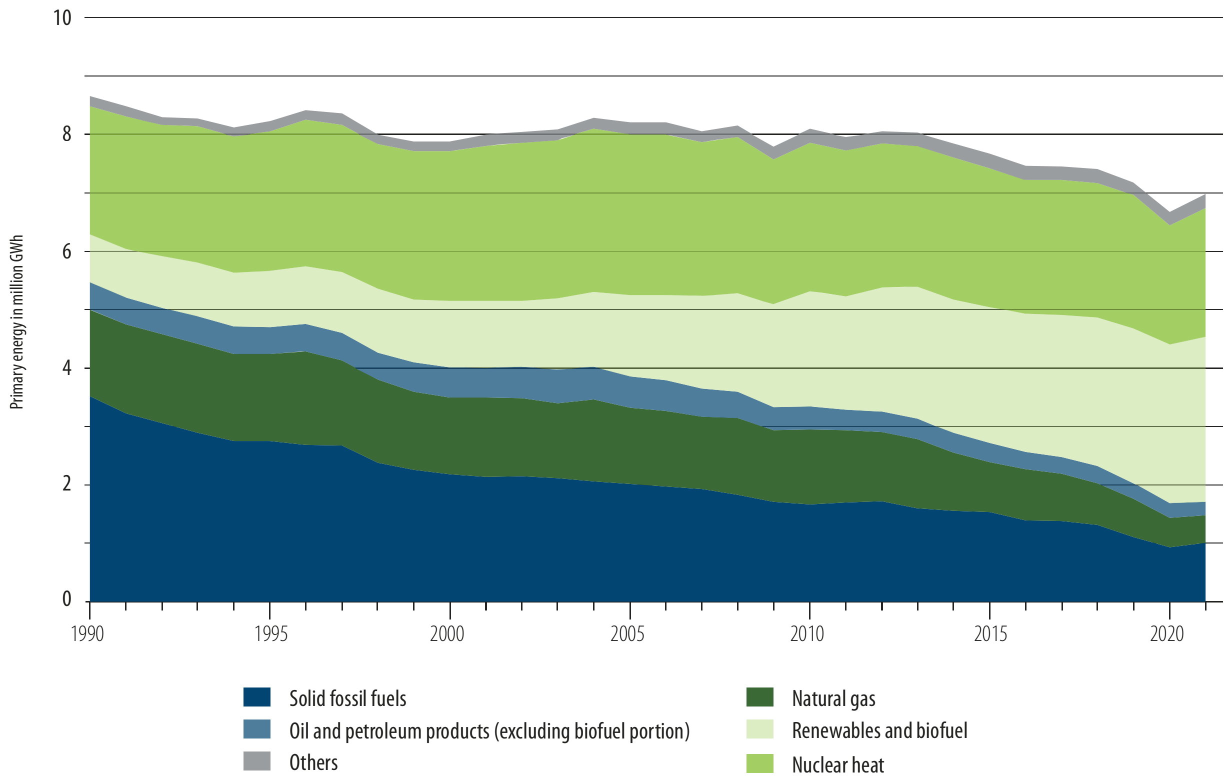


Figure 33 Primary energy production by fuel in GWh in EU - 27 countries from 1990 to 2021. Source: Eurostat (nrg_bal_c)

used fossil fuels for its overall energy supply. Nevertheless, the share of fossil fuels has decreased over the last decades from more than 80 % in 1990 to 70 % in 2021. Especially the total amount of solid fossil fuels and oil and petroleum products has decreased a lot (around 31 %). This reduction was mitigated by the increase in the amount of natural gas. In parallel, the share of renewables has increased from 5 % in 1990 to 17 % in 2021 according to Eurostat (nrg_bal_c).

The primary energy production in the EU has decreased over the past decades (see **Figure 33**) with the share of renewable energy increasing significantly. In 2021, the share of renewable energy in energy production was 41 %, making it the largest share (Eurostat (nrg_bal_c)).

However, the overall decrease in energy production led to increased imports of primary and secondary energy products. The lower demand due to the COVID-19 pandemic caused this increase to slow down in 2020 but increased again in 2021.

Energy imports by fuel in GWh in EU-27 countries from 1990 to 2021

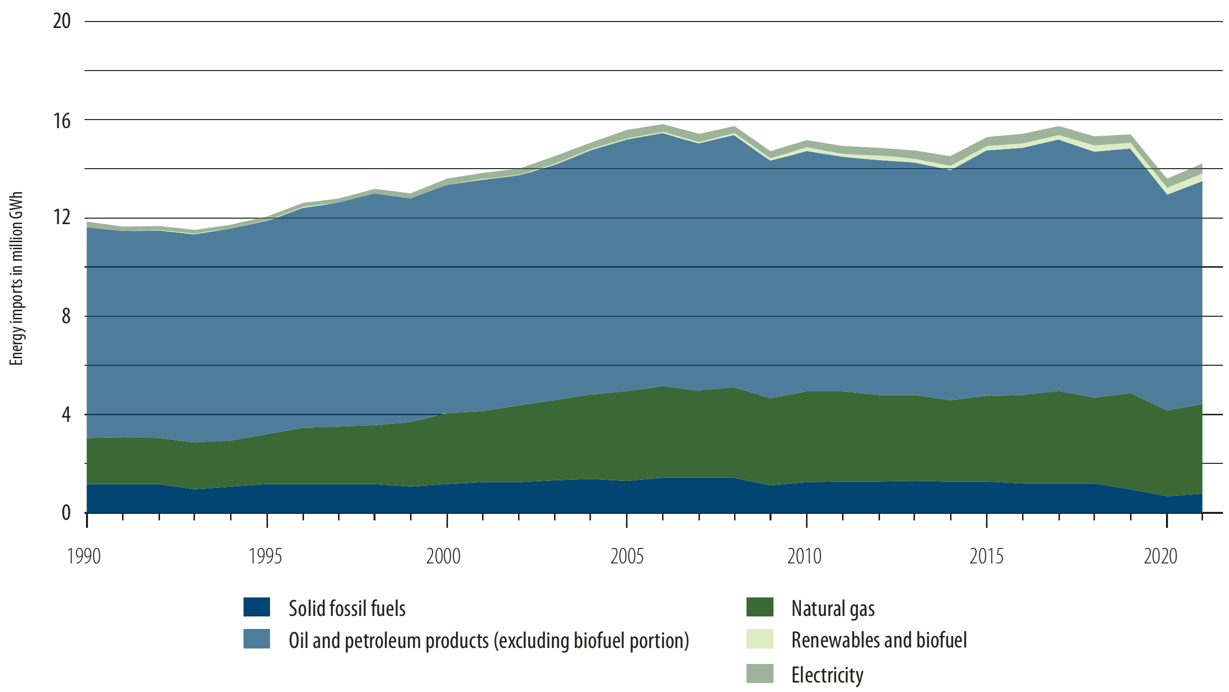


Figure 34 Energy imports by fuel in GWh in EU - 27 countries from 1990 to 2021. Source: Eurostat (nrg_bal_c)

As **Figure 34** shows, 14 million GWh energy products were imported to the EU in 2021. The most relevant imported energy products are oil and petroleum products. 9.1 million GWh, of which 5.3 million GWh stem from crude oil, were imported to the EU in 2021, accounting for 64 % of total energy imports. Natural gas is the second largest imported energy product in the EU (25 % in 2021). Its imported quantity has doubled between 1990 and 2021 and accounts for 3.6 million GWh. Imports of solid fossil fuels accounted for 6 % in energy imports in 2021. In contrast, renewables and biofuels are mainly produced in the EU. There is only a small amount of import in renewables and biofuels, which is roughly in balance with the amount of renewables and biofuels exported beyond EU borders [66].

It should be noted that the two energy products that account for the largest share of imports are also those that account for the largest share of gross available energy. It also shows how dependent Europe still is on fossil fuels – especially from non-EU countries, which will be explained in the following.

Energy dependency by fuel in % in EU-27 countries from 1990 to 2021

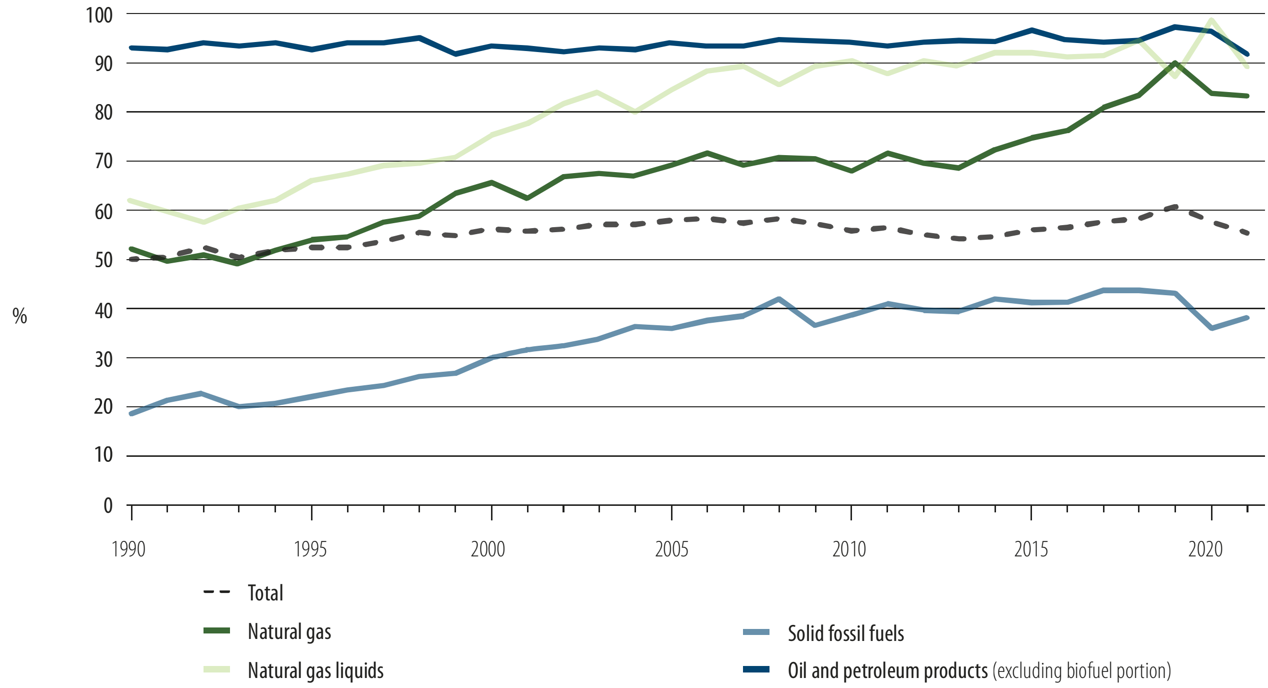


Figure 35 Energy dependency by fuel in % in EU - 27 countries from 1990 until 2021. Source: Eurostat (nrg_ind_id)

The energy dependency of a country or a region can be described as the ratio between net imports (imports – exports) and gross available energy and is an indicator for its ability to meet all the energy needs. The higher the indicator the higher the region depends on imports from other regions or countries.

Figure 35 shows the EU's energy dependency on different fossil fuels in %. In general, the energy dependency has increased over the last decades from 50 % in 1990 to over 60 % in 2019, contradicting the European Commission's objectives. Since then, the total energy dependency has decreased slightly to 56 % in 2021. The highest dependency (around 94 %) is on oil and petroleum products and has not changed much over time. Energy dependencies on other fossil fuels have increased significantly until around 2019, e. g. the energy dependency on natural gas has increased from 52 % in 1990 to 89 % in 2019. After that, the energy dependency started to decrease slightly for most fuel types.

European energy imports by main supply countries of oil and petroleum products in 2021 and in the first quarter of 2023

European energy imports by main supply countries of natural gas in 2021 and in the first quarter of 2023

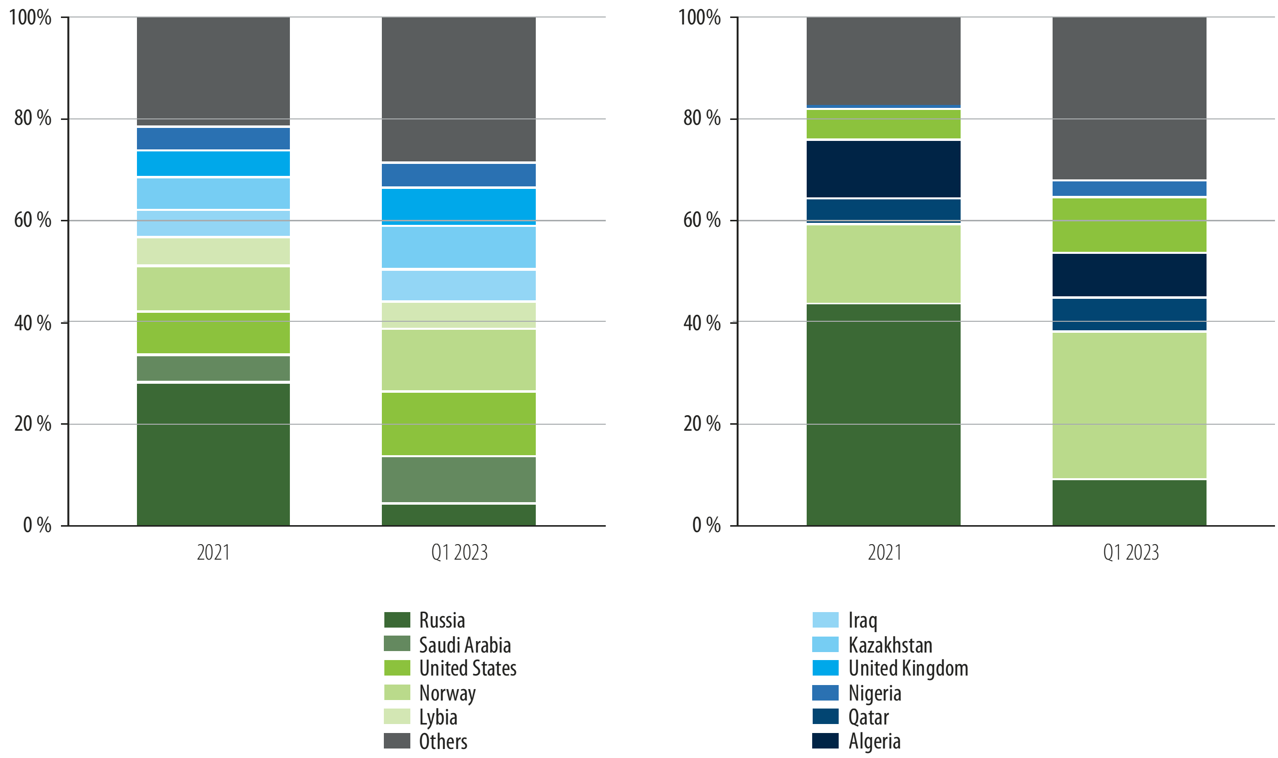


Figure 36 European energy imports by main supply countries of oil and petroleum products (left), and natural gas (right) in 2021 and in the first quarter of 2023. Source: Eurostat (nrg_ti_oil, nrg_ti_gas, nrg_ti_m)

The energy crisis resulting from the Russian invasion of Ukraine has brought challenges regarding energy security and affordability in Europe. Russia played a crucial role when it came to the EU's energy supply with fossil fuels. In 2021, the EU received around 45 % of its gas imports from Russia, which accounted almost 40 % of the EU's total gas consumption. At the same time, 29% of oil and petroleum products and 52 % of solid fossil fuels came from Russia. Following Russia's invasion of Ukraine, the EU leaders agreed to phase out the EU's dependency on Russian fossil fuels. In turn, the European Commission implemented the REPowerEU plan [4] to diversify the energy supplies whilst reducing energy consumption and increasing the deployment of renewables. To accelerate the transition, governments urged their populations to save energy during winter 2022/2023 by reducing indoor temperatures. Simultaneously, the EU actively sought new partner countries capable of supplying energy sources in the near future. Some of the supplier countries are indeed characterized by non-democratic regimes or located in regions fraught with political tensions, regional conflicts, and geopolitical risks such as Libya, Iraq, or Algeria. Consequently, the lineup of countries from which imports were sourced underwent dynamic changes since 2022 and is still ongoing. As shown in figure **Figure 35**, imports from Russia have experienced a significant decline over the past two years, while imports from other nations have surged. For example, the imports of natural gas from Norway notably have doubled, increasing from a 16% to a 30% share. Similarly, the import from United States have increased from 6% to 11% for natural gas and from 9% to 13% for petroleum products. Despite the efforts and the measures applied, the EU is still dependent on external supplies for its energy security.

IEA emphasizes the need for energy efficiency [67], stating that, "The cleanest, cheapest, most reliable source of energy is what countries can avoid using […]" [67]. A quick rise in energy efficiency would also make the EU less dependent on fossil energy imports from outside the EU. Therefore, a focus on energy efficiency is crucial to reduce final energy demand and make Europe less dependent. Energy efficiency must be Europe's primary source of fuel. As a major energy consumer, the building sector is one of the key areas to apply the energy efficiency first principle.

The residential sector, representing approximately one third (27.9% in 2021) of the total energy consumption in Europe, predominantly relies on fossil fuels (see **Figure 37**). Natural gas accounts for 33.5 %, oil and petroleum products for 9.5 % and solid fossil fuels for 2.6% of the energy consumption in EU-27 households. Renewable energy sources on the other hand only cover a minor portion of 21%, although the share of renewable energy in space heating and cooling has doubled between 2004 and 2021 (Eurostat (nrg_ind_ren)). All these energy sources are essential for various purposes, but first of all for space heating, which constitutes the largest portion of energy consumption in the residential sector (64.4%).

Figure 37, based on the BPIE calculation [58], also shows the energy consumption by fuel in a proposed renovation scenario that focuses on the refurbishment of the building envelope (only walls and roofs) of EU residential buildings. The assessment, specifically targeted at space heating, shows how the insulation of the building envelope can significantly decrease energy consumption with a notable reduction in the overall energy sources required to heat the indoor space. Therefore, the dependency on fossil fuels from extra-EU countries would decrease. The renovation scenario does not account for any change in the heating system and energy source. Consequently, both the demand for fossil energy and the utilization of renewable energy decrease in this scenario.

According to the savings shown in the figure natural gas imports could be decreased at least by 9%, oil & petroleum imports by 1% and solid fossil fuel imports by 5%. Therefore, the improvement of the insulation of existing buildings plays a crucial role to make Europe less dependent.

To achieve a complete decarbonization of the building stock and to make the EU even less dependent from fossil energy imports, the switch from fossil fuel to decarbonized energy sources such as electricity must be prioritised. ETICS could help to make old buildings ready for low temperature heating systems, which are necessary to decarbonize the building sector. They not only contribute to the reduction of the final energy demand and the heat load itself by thermally improving the building envelope but also effectively support the fuel switch from fossil fuels to electricity. By reducing the heat load, several other boundary conditions (e.g. lower supply temperature in the heating system, no need to

Energy consumption in EU household by fuel, 2021

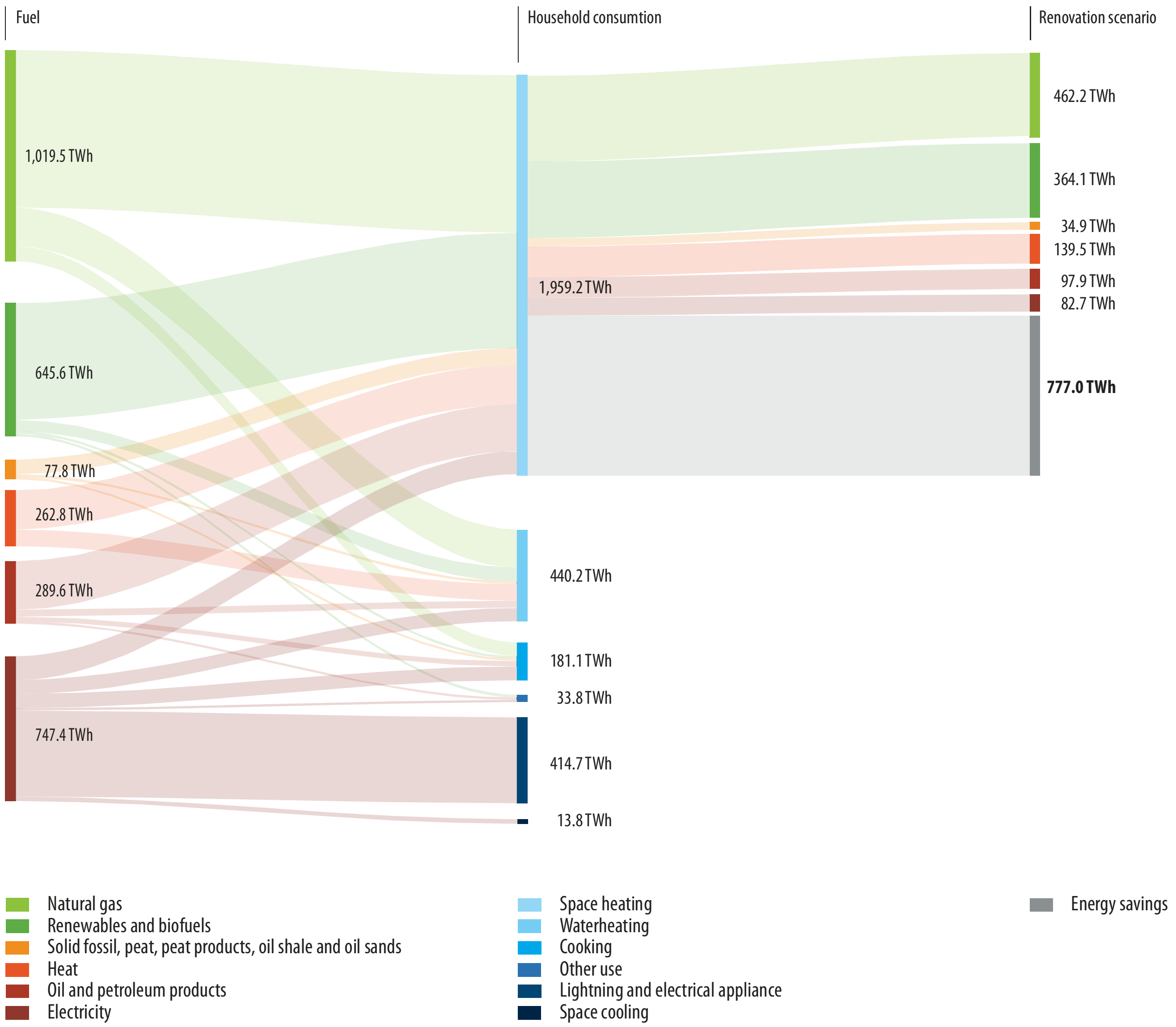


Figure 37 Energy consumption in EU household by fuel, 2021. *Renovation of walls and roofs of EU's residential buildings. Source: Eurostat (nrg_d_hhq) and BPIE [58]

Net electricity production in EU in % by fuel type in 2022

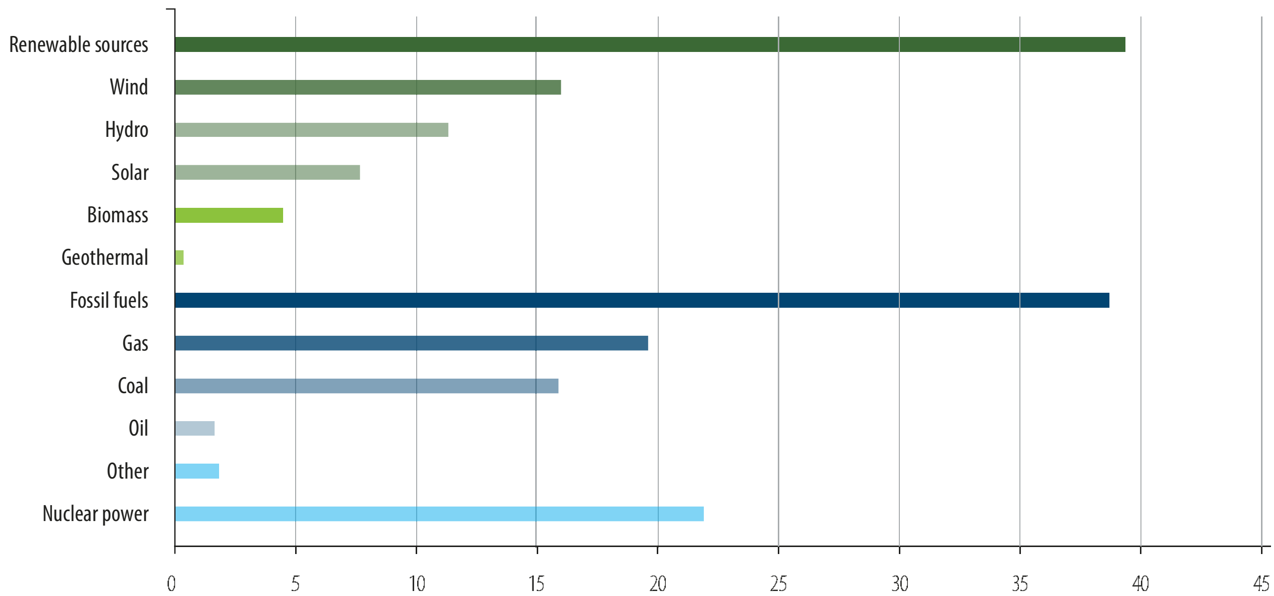


Figure 38 Net electricity production in EU in % by fuel type in 2022. Source: EU Council [68]

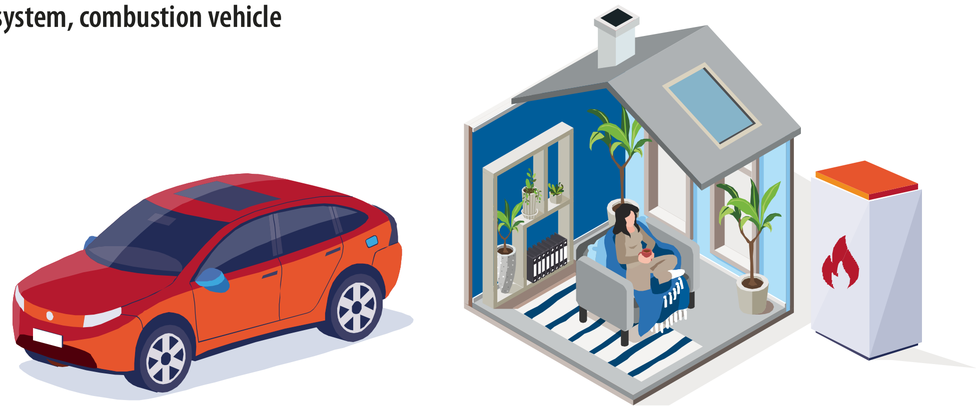
change the radiators, etc.) can be reached which are essential for the building to become "heat-pump ready". This means, that the heat load can be covered by the heat pump, whilst performing with high efficiency rates. High efficiency rates on the other hand contribute to lower electricity demands and reduced peak loads. Consequently, less energy is needed to serve the same needs, leading to a potential decrease in the demand of energy sources. ETICS and other insulation measures help to limit the necessary network expansion, the expansion of renewable energies, which would be immense otherwise, and guarantee electricity grid stability (**Figure 39**).

Nevertheless, the fuel switch will require a large amount of additional electricity and huge efforts to achieve a renewable energy share of (almost) 100% in 2050. Today (2022) more than half of the electricity is generated by fossil fuels and nuclear power – 38.7% and 21.9% respectively – while renewable energy sources account for 39.4 % of the gross electricity consumption in Europe [68].

The gap accounts 60.4%, but is even higher considering the additional electricity/energy demand needed to meet the electricity needs in the future.

To make the EU less dependent from fossil fuel imports, renewable energies must be expanded quickly within EU borders. Lower energy demands of EU buildings help to reach the objective much quicker. The renovation of Europe's building stock is crucial, especially when considering that the majority of today's buildings will still exist in 2050.

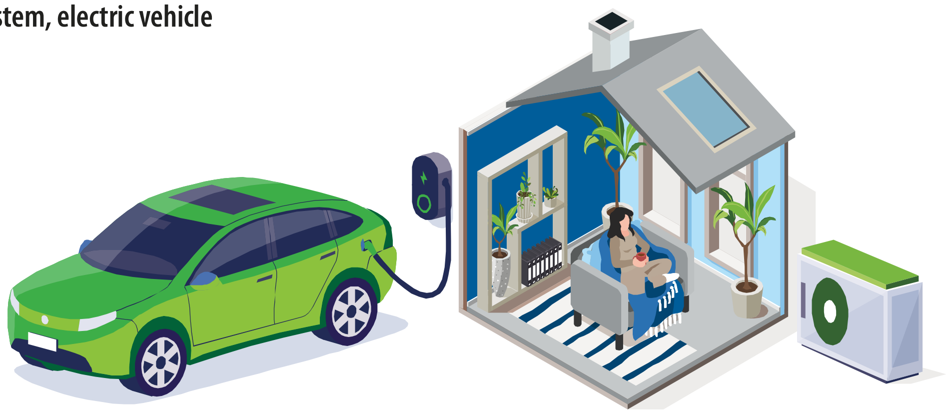
Current state
No insulation, fossil heating system, combustion vehicle



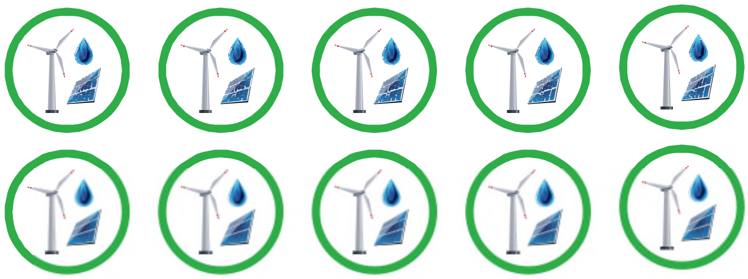
- Electricity demand of both traffic and buildings still relies largely on fossil fuels and nuclear power.
- The share of renewables (wind, hydro, PV) is already increasing.
- Many buildings are not sufficiently energy-efficient, associated with lower living comfort and the risk of energy poverty and health problems.

Figure 39 Energy needs in different scenarios. Source: FIW own calculation, Eurostat (nrg_bal_s), ENER/C1/2018-494 [69]

2050 - Climate neutral building stock
No insulation, changed heating system, electric vehicle

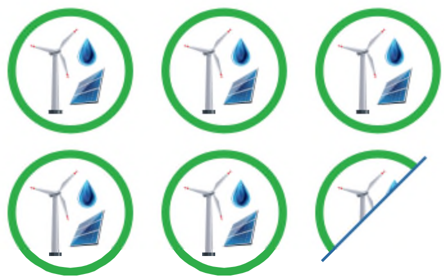


- Electricity demand of traffic and buildings will significantly increase in parallel due to the shift to BEVs and electrification of heating devices.
- To achieve decarbonization, huge investments in renewables and grids are needed to both compensate fossil and nuclear power and the further increasing electricity demand of the transportation and building sector.
- Many buildings remain not sufficiently energy-efficient, associated with lower living comfort and the risk of energy poverty and health problems.



2050 - Climate neutral building stock
Insulted building, changed heating system, electric vehicle

- Electricity demand of traffic and buildings will increase due to the shift to BEVs and electrification of heating/cooling systems. Thanks to thermal insulation the energy consumption to heat and cool buildings is significantly reduced.
- To achieve decarbonization, investments in renewables and grids can be limited as the total energy demand is significantly lower.
- Buildings are energy-efficient, providing higher living comfort and reduce the risk of energy poverty and health problems.
- Insulated buildings as part of an integrated energy system can buffer peak loads as they can remain comfortably warm for several hours even if not heated.



KEY MESSAGES - RENOVATE TO MAKE EUROPE LESS DEPENDENT

- Despite all political objectives, Europe's energy dependency has increased over decades. This applies especially to fossil fuels where the dependency in case of oil and petroleum and natural gas still exceeds 80%.
- The Russian aggression to Ukraine highlighted these dependencies and Europe's vulnerability in terms of energy security.
- Immediate action helped replacing Russia as key supplier via diversification of energy supplies. However, Europe's energy dependency remains high.
- The focus on energy efficiency is crucial to reduce our final energy demand. It will in turn make Europe less dependent. Energy efficiency must become Europe's primary fuel.
- Building renovation plays a key role. The residential sector accounts for one third of Europe's total energy consumption, two thirds of it spent for space heating alone. It still predominantly relies on fossil fuels.
- Insulating buildings' envelopes significantly decreases energy consumption by reducing the energy demand. The dependency on fossil fuels would already decrease significantly without additional measures. This eases the shift to renewable energy. Reducing the demand together with the shift to electrification boosts the process to become less dependent from imports.
- ETICS and other insulation measures make investments in network expansion and accelerated deployment of renewable energies affordable as needed to achieve electricity grid stability.
- The thermal renovation of Europe's building stock is crucial, especially when considering that most today's buildings will still exist in 2050.

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EAEAWARD
2021
WINNER

Category **„Residential buildings New built - multi-family home"**

Project:	Matadorka in Bratislava/Slovakia
Description:	New construction of apartment building with 335 dwellings and 15 retail spaces
Architect:	VI Group a.s.,
Installer:	Assyx spol. s r.o.
ETICS manufacturer:	Baumit

A

ABOUT OUR ASSOCIATION

EAE – PARTNERS FOR SUSTAINABLE CONSTRUCTION AND RENOVATION IN EUROPE

EAE
European Association for
External Thermal Insulation Composite Systems

WHO WE ARE

- EAE is the voice of ETICS in Europe, representing more than 80 per cent of Europe's revenue from ETICS.
- EAE's common aim is to improve the energy efficiency of Europe's huge building stock, working towards a "culture of sustainability" in the construction sector.
- EAE supports technical developments in the systems, products and technologies, sharing experience and keeping ongoing dialogue with European institutions and stakeholders.

OUR VISION

- EAE is the voice of ETICS in Europe.
- EAE is an active topic driver and acts as the first point of contact for third parties.
- EAE sets its own topics in the climate protection debate, which are considered in European legislation.
- EAE communicates the central importance of the building envelope as a trailblazer for other industries in achieving the climate goals.
- EAE is up-to-date and well informed, early communicator and reliable contact for politics and administration. It focuses on topics relevant to the building envelope.
- EAE's self-image is achieved through the active formation of opinions in the interaction of the actors and products related to the building envelope.

OUR MISSION

- EAE creates unique experience and a powerful network aiming for a level playing field in the Single European Market for ETICS.
- EAE successfully represents the political interests of its members to seize reliable framework conditions for their businesses.
- EAE promotes that energy-efficient building envelopes using ETICS are substantial to contribute to achieve climate targets.
- EAE supports the establishment and control of quality measures along the value chain (designers, suppliers, applicators) at European and member state level.
- EAE shapes developments in the field of energy-efficient building envelopes.

OUR ACTIVITIES

- EAE promotes the multifold benefits and the variety of ETICS via common public relations; transfer is improved by networking.
- EAE initiates joint projects to create technical standards and common solutions improving the economic and life-cycle-performances of ETICS.
- EAE operates the lobbying proactively, pointedly and where necessary in association with political partners to create majorities for its concerns.
- EAE defines its positions by forming opinions within the association, sharing national and international best practice examples.

MEMBERS AND PARTNERS

ORDINARY MEMBERS

AUSTRIA

ARGE Qualitätsgruppe Wärmedämmsysteme

www.waermedaemmsysteme.at

BELGIUM

Xthermo.be
Façade Insulating System Association

www.xthermo.be

CZECH REPUBLIC

Cech pro Zateplovani Budov
Ceska Republika

www.czb.cz

FRANCE

Groupement du Mur Manteau

www.mur-manteau.fr

GERMANY

Verband für
Dämmsysteme, Putz und Mörtel e. V.

www.vdpm.info

IRELAND

National Insulation Association of Ireland

www.niai.ie

ITALY

Cortexa Consortium per la cultura del Sitema a Cappotto

www.cortexa.it

NETHERLANDS

Bond voor Pleisterbouw

www.bondvoorpleisterbouw.nl

POLAND

Stowarzyszenie na Rzecz Systemow Ocieplen (SSO)

www.systemyocieplen.pl

ROMANIA

QETICS - Grupul Pentru Calitatea Sistemelor Termoizolante „ETICS“

www.qetics.ro

SLOVAKIA

Obcianske Zdruzenie - Zdruzenie Pre Zateplovanie Budov

www.zpzb.sk

SPAIN

ANFAPA

www.anfapa.com

EXTRAORDINARY MEMBERS

Supporting Members

Wienerberger Building Solutions (WBS)

www.wienerberger.com

Baumit Beteiligungen GmbH

www.baumit.com

Willco Products NV

www.willcoproducts.be

BSTB E-CONSULT BV

www.bstb-proattikasystems.com

Saint Gobain

www.saint-gobain.com

DAW SE

www.daw.de

EJOT SE & Co. KG

www.ejot.com

HECK Wall Systems GmbH

www.wall-systems.com

KEIMFARBEN GmbH

www.keim.com

Paroc GmbH

www.paroc.com

Sto SE & Co. KG aA

www.sto.com

Forschungsinstitut für Wärmeschutz e.V. München

www.fiw-muenchen.de

BASF SE

www.basf.com

fischerwerke

www.fischer-international.com

Baukom Bauprodukte GmbH

www.baukom-group.de

EXTRAORDINARY MEMBER

Supporting Members

Dosteba GmbH

www.dosteba.eu

IVAS Industria Vernici Spa

www.gruppoivas.com

ICL IP Europe Cooperatief U.A.

www.icl-ip.com

KLIMAS

www.klimas.com

Henkel Polska Sp. z o.o.

www.henkel.pl

APU AG

www.apu.ch

ASCHEM Petrokimya Sanayi A.S.

www.aschem.com.tr

Betek Boya ve Kimya Sanayi A.Ş.

www.betek.com.tr

Terraco Group

www.terraco.com

Mapei SpA

www.mapei.com

EXTRAORDINARY MEMBER

SECTOR ASSOCIATIONS

PU Europe - European Association of the polyurethane (PUR/PIR) insulation industry

www.pu-europe.eu

EURIMA - European Insulation Manufactures Association

www.eurima.org

EUMEPS - European Manufacturers of Expanded Polystyrene

www.eumeps.org

EUROPROFILES - The European Association of Bead and Lath Producers

www.europrofiles.com

EPFA
European Phenolic Foam Association

www.epfa.org.uk

PARTNERS

MEMBERSHIPS

European Committee for Standardization (CEN)

www.cencenelec.eu

Construction Products Europe

www.construction-products.eu

Construction 2050 Alliance

www.euconstruction2050.eu

European Council for Construction Research, Development and Innovation (ECCREDI)

www.eccredi.org

Renovate Europe Campaign

www.renovate-europe.eu

Forschungsinstitut für Wärmeschutz e.V. München

www.fiw-muenchen.de

LIAISONS

European Organisation for Technical Assessment (EOTA)

www.eota.eu

Japanese Association for Housing Thermal Insulation Technology (JATI)

EIFS Council of Canada

www.eifscouncil.org

China Association of Building Energy Efficiency (CABEE)

www.cabee.org

EIFS Industry Members Association (EIMA)

www.eima.com

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APPENDIX

List of Figures

List of Tables

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European Association for
External Thermal Insulation Composite Systems

Office
Friedhofstrasse 3
76530 Baden-Baden
Germany

Phone: +49 (0) 7221-94477-40

E-Mail: info@ea-etics.com
Internet: www.ea-etics.com

Brussels office
Bld Reyerslaan 80
1030 Bruxelles/Brussel
Belgium

Phone: +32 2 416 21 74