European Environment Agency

Building renovation: where circular economy and climate meet

Buildings are important in EU environmental and climate policy for several reasons, including their greenhouse gas emissions and high consumption of material resources. Improved design and building techniques will produce highly efficient new buildings, but more than 85% of today's buildings are likely to still be in use in 2050. This briefing examines potential renovation activities that could improve the sustainability of existing buildings and the implications for embedded greenhouse gas emissions and resource use.

Key messages

- The ‘renovation wave’ plays a key role in upgrading existing EU buildings and making them more energy efficient, and it will be an important element in achieving a climate-neutral EU by 2050.
- Adopting circular economy principles in building renovation can reduce the use of materials in existing buildings and minimise emissions embedded in building materials.
- By avoiding or delaying the use of new materials in buildings, circular economy-based approaches to renovation can help to reduce embedded greenhouse gas emissions. It is estimated that 20-25% of the life cycle emissions of the current EU building stock are embedded in building materials.
- The most effective circular renovation actions to reducing embedded emissions are extending the lifespan of existing buildings and increasing the intensity of building use. This reduces the demand for new construction, which consumes more materials than renovating existing buildings.
- Ambitious circular renovation strategies could save up significant amounts of greenhouse gas emissions between 2022 and 2050, depending on the scale of renovation. Building renovation based on circular principles can contribute in important ways to achieving climate neutrality.

Rationale

Transitioning to a circular economy is one of the EU’s ambitions. A circular economy calls for minimising resource use by using as few resources as possible, keeping materials and products in the economy for as long as possible and making use of generated waste so that waste materials are fed back into the economy. These resource savings may contribute to mitigating climate change by avoiding emissions associated with the extraction and processing of new resources. But how significant is this contribution?

To answer this question, this briefing looks at the EU building stock. Construction activities account for around half of the resources we consume in the EU, so buildings are a good case study for investigating the potential of increased circularity to contribute to mitigating climate change. Since 85-95% of today’s buildings will still be standing in 2050, this briefing focuses on existing buildings. Modelling the impacts of specific renovation activities on the entire EU building stock demonstrates a number of potential benefits, in terms of both buildings' circularity and their embedded emissions. It highlights the potential of what could be a circular 'renovation wave'.

The briefing is based on this background technical report.

Meeting EU climate targets will need extensive renovation of the building stock

With buildings' use accounting for 40% of annual EU energy consumption and 36% of annual EU greenhouse gas (GHG) emissions from the energy sector, improving the sustainability of the buildings sector is critical to meeting EU climate targets. To that end, the European Green Deal seeks to improve the sustainability of the building sector in mainly two ways: first, by reinforcing the legislation related to energy efficiency and the energy performance of buildings; and, second, by promoting end-user electrification in the residential sector, coupled with decarbonising the electricity sector.

Between 2005 and 2019, existing policies and warmer winters have contributed to a 29% reduction in CO_2 emissions from buildings during their use phase. However, the trend observed will need to accelerate to meet the EU's target to reduce GHG emissions by a net 55% by 2030, compared with 1990 levels. This would require a reduction in emissions from the use of buildings of 60%, as set out in the EU's renovation wave (EEA, 2021a).

To achieve this, new buildings need to be carbon neutral (EEA, 2020) and, more importantly, existing buildings need to be upgraded. The construction industry will have to implement an unprecedented acceleration in the energy renovation of the EU building stock, the characteristics of which are illustrated in Figure 1. The renovation wave aims to at least double the annual energy renovation rate (currently estimated at 1%) of residential and non-residential buildings by 2030 and to initiate deep energy renovations that could reduce buildings' energy consumption by at least 60% (EC, 2020a). The Energy Efficiency Directive, the Energy Performance of Buildings Directive and their respective 2021 recasts set out clear frameworks to achieve this.

Energy renovation of buildings is often done on top of the more 'regular' renovation of buildings. The overall quality and age of the building stock is also something to consider. Around 15% of Europeans live in dwellings with a leaking roof, damp walls, floors or foundations, and between 5% and 39% live in buildings with rot in the window frames or floors. All buildings need to be renovated regularly to address comfort, safety or maintenance issues and, in practice, energy renovation and non-energy renovation often occur together.

Going further: looking at circularity in building renovation

Both 'energy' and 'non-energy' renovation require materials and generate CO_2 emissions. If the EU is to achieve climate neutrality, it is necessary to further consider how to minimise emissions from the anticipated substantial renovation activities.

The EU's circular economy action plan (EC, 2020b) and resulting policy initiatives promote an increase in the circularity of the EU economy, including the built environment as a priority sector. The European Commission's proposal to revise the Construction Products Regulation (2022) will create a harmonised framework to assess and communicate the environmental and climate performance of construction products. New product requirements will ensure that the design and manufacture of construction products are state of the art, making them more durable, repairable, recyclable and easier to re-manufacture.

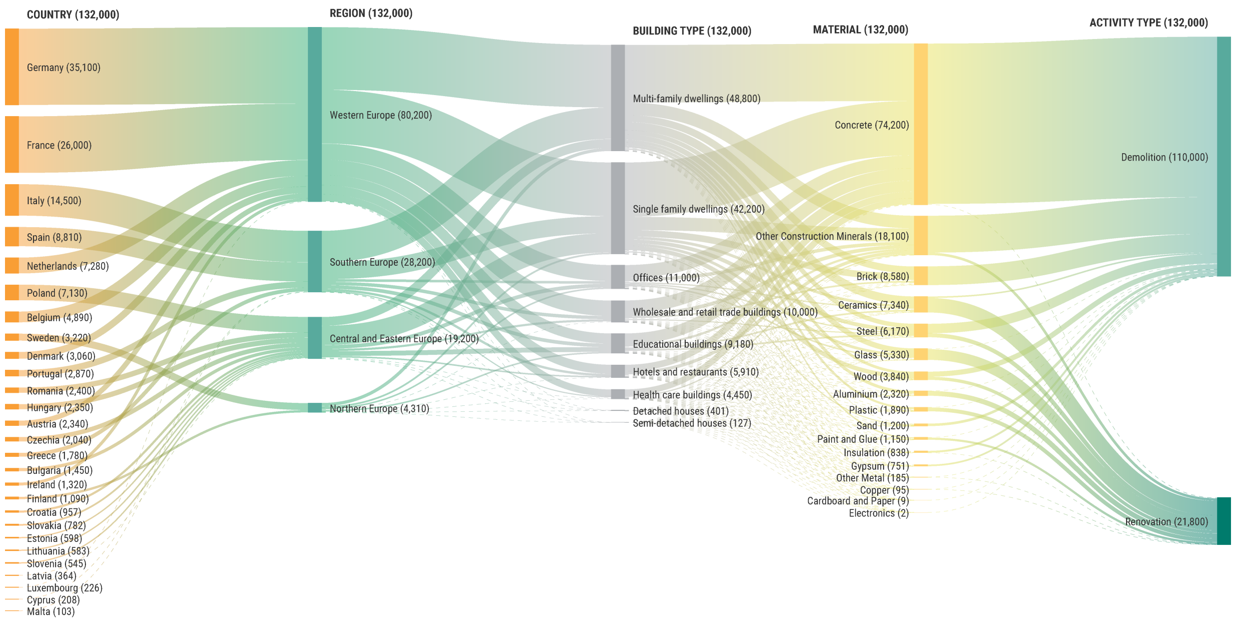
The need to move beyond the greenhouse gas emissions generated from the use of buildings and to adopt a life cycle perspective, in which emissions embedded in construction materials are addressed, is increasingly being recognised by construction sector stakeholders (World Green Building Council, 2022). Knowledge of buildings' life cycle greenhouse gas emissions is therefore important from both policy and industry perspectives.

A quantitative exploration of circular renovation

This briefing explores the potential to mitigate climate change by implementing 'circular renovation' actions on the EU's existing building stock until 2050. This involves extensive modelling of such actions on widely different building types (see Figure 1) in four distinct geographical regions spanning the EU Member States and Norway. Our modelling focuses on technical aspects and is based on mass flow modelling of renovation. This means that the socio-economic aspects of such a large-scale renovation, such as financing, skills requirements, people's preferences or economic cost are not addressed, although they are critical for the renovation wave and for circular renovation activities. This exercise is not a forecast and aims only at showcasing the potential for climate change mitigation through improving building renovation. So aspects such as availability of resources or land use for producing building materials, as well as the foreseen decarbonisation efforts in the EU, are not taken into account in the modelling. For more information about the modelling assumptions, please see the background technical report.

Publications

Figure 1. Amount of building typologies in the modelled EU building stock by country, region, type of building and material, 2021



The modelling involves both energy and non-energy renovations. The energy efficiency improvement of the building stock enabled by energy renovation is not calculated but is accounted for in terms of the 'depth' and speed of the renovation. Although deep energy renovation implies increased use of insulation materials and therefore increases in embedded CO_2, it can also lead to reduced CO_2 emissions post renovation. By further increasing the recycling rate of insulation and other materials, further savings in material extraction and CO_2 can be achieved (see page 20 of the background report for more details).

Circular renovation actions

Three main circularity objectives can be addressed through circular renovation actions:

Increasing life spans, thus delaying the need for new construction and reducing the corresponding demand for new materials, or increasing the intensity of use of buildings.

Reducing the need for material consumption using resources more efficiently.

Making use of new generation materials with high circular potential.

Under these objectives, we modelled 10 circular renovation actions. These are presented in Table 1 and are clustered by objective.

Table 1. Circular renovation actions

Increase lifespans

Increasing the intensity of use

Transform existing spaces into multipurpose areas, such as using office canteens as restaurants in the evening. This reduces the need for new space in new buildings, avoiding the corresponding resources needed.

Retrofitting

When demand for a building type decreases, adapt its use. For example, if the aftermath of the COVID-19 pandemic results in a reduced need for office space, some office buildings can be converted to residential use. Such retrofitting leads to reduced demand for new residential buildings.

Choosing long-lasting building materials and products

For each building element, the component with the shortest lifespan is identified and, when renovating, that component is replaced with an alternative with a longer technical lifespan. Another strategy is to replace building elements with other technologies offering longer lifespans. This reduces the frequency of future renovation or even delays demolition with the subsequent effect of reducing the demand for new construction.

Delaying building demolition

This action is modelled by addressing the main non-economic reason for demolishing buildings: repairing the structure and foundation of aged buildings. This results in delaying the demand for new buildings.

Reduce material consumption

Using products complying with design for disassembly (DfD) principles

When renovating, use DfD products that can be reused. This action will ultimately lead to reduced demand for raw materials when these products are subsequently reused following future renovation. This reduced demand will become evident after a long time.

Maximising the recycled content of renovation materials

Assuming availability of recycled materials, this action estimates the technical maximum recycled content in all renovation materials. Savings of new (primary) materials are calculated as the difference between the current recycled content and the technical maximum assumed under this action.

Maximising reuse

Under this action, reuse optimisation strategies (e.g. removal of contamination, small repair operations to increase performance) are modelled. The increased reuse of materials from renovation undertaken saves an equivalent amount of new, virgin materials.

Use new generation materials

Using prefabricated facades

Use of prefabricated facades (including cladding and insulation) saves around 25% of material compared with non-prefabricated options. This action is modelled as all renovation of facades use the prefabricated option.

Choosing bio-based materials/products

Under this action, bio-based materials/products are used, when possible, when renovating a building element, thus saving non-renewable resources.

Using nature-based solutions

Under this action, all roof and facade renovations are assumed to include the installation of a green roof/facade.

Modelling renovation impacts on the EU building stock

The potential impacts of applying these 10 actions to the EU building stock were estimated in a modelling exercise that applies three scenarios. Based on the literature, a baseline scenario assumes a continuation, until 2050, of current renovation rates and activities, broken down into energy- and non-energy-related renovation. A second ‘policy-compliant’ scenario accelerates the renovation rate according to the aspiration of the EU’s renovation wave. A third, more ambitious, scenario further accelerates renovation, so that all buildings in the stock will have been renovated by 2050.

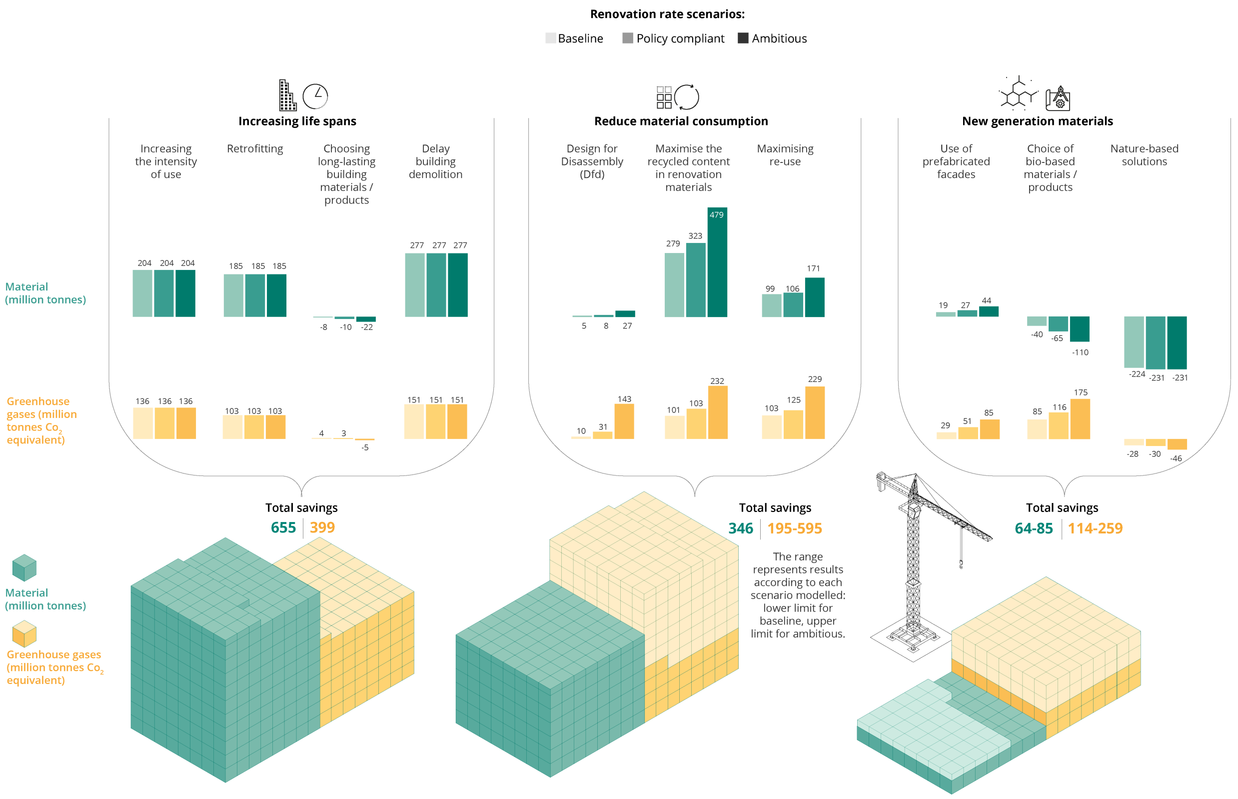
The results are shown in Figure 2, in which the annual cumulative savings of materials and GHG emissions are shown for each of the 10 modelled circular renovation actions.

Figure 2. Cumulative savings of materials and GHG emissions for each circular renovation action from 2022 to 2050

Note: Carbon storage is not taken into account.

Table 2 shows the cumulative savings of materials and GHG emissions over the entire modelled period of 2022-2050 for each circular renovation action and also for each cluster/circularity objective (see Table 1). The results for each cluster cannot be obtained by simply summing the results of individual actions, as the actions can overlap. A negative value indicates a higher cost (of materials or emissions) than the foreseen benefit.

Table 2. Material and GHG emissions savings from implementing circular renovation actions on the EU building stock



Notes: Adding together the results of each circular renovation action is not possible because of overlaps in the activities included in each action. The sum of results by cluster takes these overlaps into account.

(*) The range represents results according to each scenario modelled: lower limit for baseline, upper limit for ambitious.

CO_2e, carbon dioxide equivalent.

From Table 2, it becomes evident that focusing on renovation actions that aim to directly increase buildings' lifespans has the greatest potential for both material and GHG savings in the period modelled. This is because increasing lifespans is translated into lower demand for new construction, which is very material and GHG intensive. Increasing the intensity of use also brings substantial CO_2 savings. This action can be attributed to considering energy sufficiency, which is a crucial topic in reducing emissions from buildings (IPCC, 2022).

Meanwhile, investing in long-lasting materials presents a different picture: the results for this action demonstrate a net consumption of materials and a cost in terms of GHG emissions in the baseline scenario. This is because most of the long-lasting materials are heavier and more GHG-intensive during production than traditional materials. However, their long-lasting nature means that renovation will be needed less frequently in the future, thus avoiding the use of renovation materials and the associated embedded GHG emissions. This action demonstrates that, in some cases, circularity demands investment in materials now to harness benefits in the very long term, because of buildings' inherently long lifespans. For example, if the period modelled is extended to 2070, the scenario results for GHG emissions become net savings of between 19 and 38 million tonnes CO_2e. These results also illustrate the different strategic choices possible: if achieving rapid emissions reductions in the short term leads to the underuse of long-lasting materials, this will be at the cost of lower long-term reductions in emissions.

The second cluster in terms of material and GHG savings consists of actions that focus on reduced material consumption, mainly by boosting high-quality recycling of materials. Benefits come from the fact that almost no new resources are needed when recycled material is used, which is also much less GHG intensive to produce than materials using extracted new natural resources. Especially in the ambitious scenario, in which renovation is significantly accelerated, using materials with a high recycled content in renovation is the circular action with the highest potential for achieving savings in GHG emissions.

The more experimental circular renovation actions in the last cluster demonstrate the lowest, but not insignificant, potential for savings in GHG emissions. However, in terms of material savings, using bio-based materials and green solutions requires a greater material mass than the current conventional alternatives. This is because bio-based materials are either heavier or have shorter lifespans (which means they need to be replaced sooner in a subsequent renovation) than their alternatives. However, because these bio-based and green materials are renewable, the issue of resource depletion becomes less important if they are used — assuming that sustainable production is ensured. Interestingly, installing green facades and roofs during building renovation would mean that the balance of GHG emissions becomes negative, as green elements are heavier than existing alternatives and thus more GHG intensive to produce per unit. However, the GHG emissions cost is low, and they offer a wide range of benefits: for example, installing green facades and roofs in most of the buildings in Europe offers recreational opportunities, climate adaptation to heat stress, cooling the air temperature, carbon sequestration, storm water treatment and management, and increased biodiversity (EEA, 2021b).

Conclusions

Buildings feature strongly in both climate and circular economy policymaking in the EU. Achieving climate neutrality implies not only reducing buildings' energy demands and decarbonising the energy used but also reducing emissions from a life cycle perspective. Embodied GHG emissions account for on average 20-25% of the total life cycle emissions from buildings and will become increasingly important as the building stock becomes more energy efficient (Röck et al., 2020). In new constructions, many circularity benefits will often be realised far into the future. Increasing the lifespans of buildings and design-for-disassembly are examples of circular measures that will confer benefits once new buildings reach the end of their life, many decades from today. It is important, therefore, to also focus on the way we renovate our existing building stock, so that the benefits are harnessed in the shorter term.

The modelling presented demonstrates that applying a more 'circular renovation wave' in Europe could have a synergetic effect in both minimising resource use and avoiding GHG emissions. The 10 actions modelled offer diverse renovation activities and could also offer substantial savings in GHG emissions[1].

Recognising the climate mitigation potential of embedded greenhouse gas in buildings, the EU is already planning a whole life cycle performance roadmap to reduce greenhouse gas emissions from buildings by 2050. Similar initiatives by construction sector stakeholders (World Green Building Council, 2022) indicate a demand for decarbonisation in the sector that adopts a life cycle perspective.

The EEA will continue to invest in producing policy-relevant knowledge on buildings.

Notes

[1]Cumulative GHG savings between 2022 and 2050 from the first cluster of actions modelled in this study could reach a level approximately equal to the annual direct GHG emissions of the entire EU building stock in 2020 (431 million tonnes CO_2e) (EEA, 2021c).

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