# Performance of plastics building materials from a Whole Life Carbon perspective

*The European Union is embarking on a significant transformation of its building sector, with the EU ambition to achieve climate-neutral building stock in 2050. Key initiatives like the Energy Performance of Buildings Directive (EPBD), the Construction Products Regulation (CPR), the Renovation Wave and the national building renovation plans, are setting the stage for increased energy efficiency, sustainability and a shift towards renewable energy sources in buildings.*

*The latest revision of the EPBD introduces the concept of "whole life cycle Global Warming Potential", requiring the assessment and disclosure of emissions from all stages of a building's life cycle, including construction, use, and end-of-life. On the other hand, the CPR which harmonises the rules for placing construction products on the EU market will ensure reliable information on the environmental performance of those products, including their contribution to the global warming potential (GWP). The EPBD dictates what needs to be measured, while the CPR defines how to measure and declare through standardized assessments of construction products.*

*Whole life carbon (WLC) refers to the entire amount of carbon produced by any particular built asset, meaning the carbon arising from the manufacture, transportation, installation, maintenance and disposal of the infrastructure, plus the operational carbon throughout the service life of the building.*

*The building and construction sector accounts for more than 30% of the total European environmental carbon footprint [1].*

*The added value of plastics in building and construction lies in the operational life of the building. During that period, which can extend up to 50 years or more, Greenhouse Gas (GHG) emissions in the production phase are observed to involve a trade-off with emissions during the operational phase[2].*

*Over the whole service life of buildings, plastic materials show multiple benefits including GHG emission reduction due to their efficiency.*

*This paper portrays the benefits of the most used plastic materials in construction: insulation, windows frames and pipes.*

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[1] Addressing the environmental and climate footprint of buildings EEA report 09/2024

[2] Röck M. and all; *Embodied GHG emission of buildings – The hidden challenges for effective climate change mitigation*

## Contribution of plastics to reduce whole life carbon emission in Buildings

Plastics have versatile properties that make them highly suitable for a wide range of applications in the building and construction sector, particularly with regard to reducing the whole life carbon (WLC) emissions. These properties include low weight, durability and corrosion resistance, low thermal and electric conductivity and high mechanical strength. Additionally, these properties can be customised to the product requirements such as fire safety or circularity.

The whole life carbon of a building, which accounts for both embodied and operational carbon, can be reduced using plastic components. The specific properties of plastics enhance the carbon reduction primarily during the operational phase of the building, minimizing energy loss and therefore helping to mitigating GHG emissions and promoting a more sustainable built environment.

The plastics industry is actively working to reduce the embodied carbon and environmental impact of its products through various strategies and innovations like the electrification of crackers with renewable energy or the substitution of feedstocks ( biobased or recycled content). Another key approaches is the implementation of Environmental Product Declarations (EPDs), which provide transparent and standardized information about the environmental performance of plastic products throughout their life cycle. EPDs are based on life cycle inventory (LCI) data and offer insights into various environmental indicators, such as greenhouse gas emissions, energy consumption, and resource use.

## Insulating materials

Plastic insulation materials such as EPS (expanded polystyrene), XPS (extruded polystyrene), phenolic foams, PU (polyurethane) and PIR (polyisocyanurate) offer excellent properties for building insulation. Plastic insulation products save over 200 times[3] more energy over their lifetime than is used for their production. A recent investigation in the US revealed that the carbon avoidance ratio of plastic insulation (embodied carbon to carbon savings) ranges from 1kg of $CO_2$ produced for every 30kg of $CO_2$ saved to 1kg of $CO_2$ produced for every 348kg of $CO_2$ saved, depending on heating system and grid factors. This means that the carbon savings significantly compensate for the plastics embodied carbon[4] [5].

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[3] PE Sustainability Folder 6_pages.indd

[4] Schmidt, A., Chertak, A. (2023): Unlocking Carbon Savings with Plastic Insulation Materials. American Chemistry Council.

[5] Meng, F. (2024). *Replacing plastics with alternatives is worse for greenhouse gas emissions in most cases*; *Environmental Science & Technology*. https://pubs.acs.org/doi/full/10.1021/acs.est.3c05191

The advantage of plastics lies in their lower weight and low thermal conductivity. The thermal conductivity (lambda) of plastic insulation is generally lower than that of more traditional materials, which means that thinner insulation boards are required for plastic insulation to achieve the same insulating effect as with conventional materials. These dependencies are shown in Figure 1.

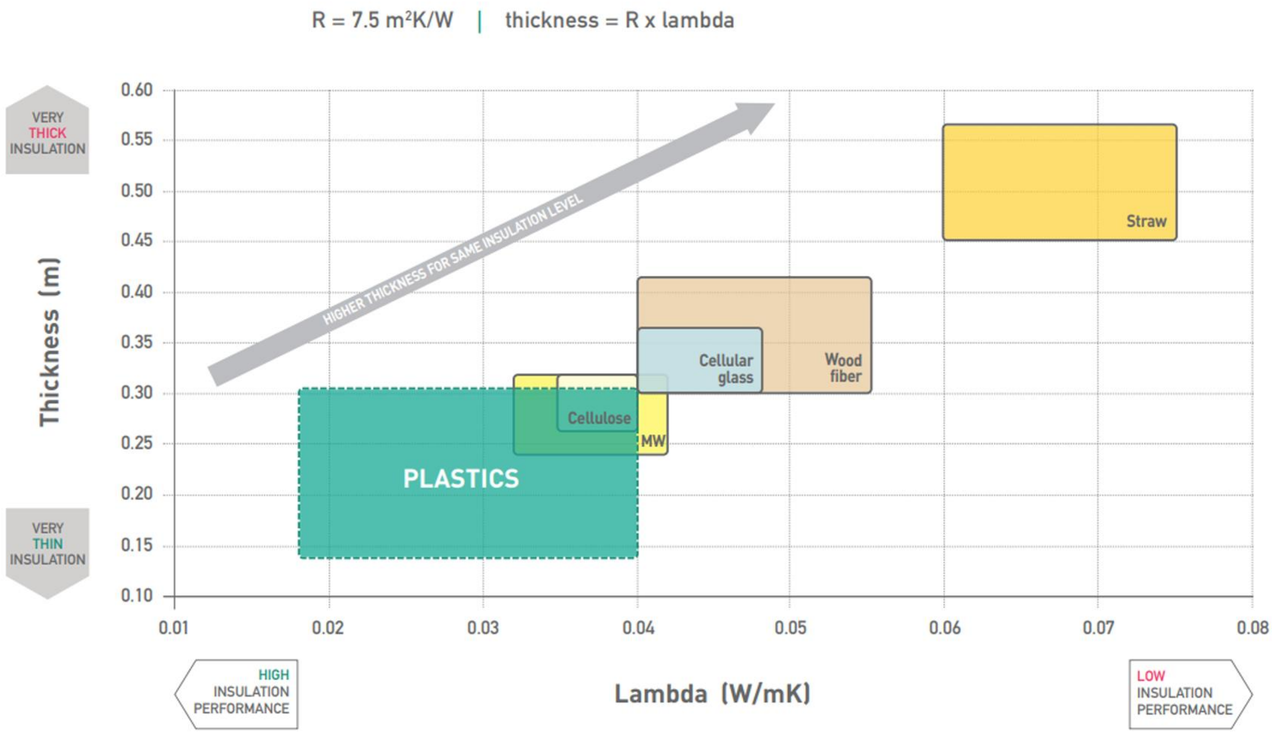


**Figure 1**. Insulation thickness to achieve the same insulation effectiveness (thermal resistance R= 7.5 $m^2K/W$), Source: Modern Building Alliance, 2021.

Insulating buildings is considered to be the most cost-effective measure for significantly reducing operational emissions of buildings. It optimizes heating and cooling costs by reducing the energy loss.

## Windows

### Window frames

Windows are a major source of heat gain and heat loss in both residential and commercial buildings.

For window frames, unplasticized Polyvinyl Chloride (uPVC), aluminium and wood are very common. Aluminium frames have much higher thermal conductivity, meaning that it causes heat loss in winter or heat gain in summer, reducing energy efficiency. Insulation performance of aluminium window frames require plastics thermal breaks (Polyurethanes (PU), Polyamide (PA), Polybutylene Terephthalate (PBT) or Polyphenylene Oxide (PPO)), which separate the window frame in an inner and outer section. In contrast, uPVC has a low thermal conductivity providing sufficient insulation without requiring additional measures. Modern wooden window frames with advanced glazing can keep heat inside very effectively, making them comparable to PVC[6].

The use of plastics for windows frames is a light weight, low maintenance and a durable choice. uPVC windows frame is cost effective, highly durable and weather resistant. In term of durability, we can use uPVC windows frame for more 40-50 years, before being recycled into new windows frames by different recycling methods, mechanical, thermal and chemical recycling[7].

### 2.2 Glazing

Glass is the traditional material for fenestration. Two conceivable, one on one, plastic alternatives are acrylic (PMMA) and Polycarbonate (PC). PMMA and PC can withstand greater force and is less likely to shatter or break upon impact compared to glass[8]. Both provide excellent optical properties; the optical transmission is also higher compared to glass. It is considerably lighter than glass and easier to install, maintain and allows for a highly flexible design.

It has been shown that under certain conditions UV-coated acrylics can reduce heat gain and loss in buildings compared to generic glass and consequently to lower operational carbon emissions[9]. The polycarbonate is an appropriate substitute, when requiring high mechanical strength. Polycarbonate impact resistant is greater than PMMA's. PC is a preferable choice when impact performance is a concern, e.g. for transparent roofing.

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[6] GUA, *The Contribution of Plastic Products to Resource Efficiency*
[7] Zouhair Ait-Touchente, Maya Khellaf, Guy Raffin, Noureddine Lebaz, Abdelhamid Elaissari. *Recent advances in polyvinyl chloride (PVC) recycling*. Polymers for Advanced Technologies, 2024, 35 (1), ff10.1002/pat.6228ff. ffhal-04267777
[8] Eshwar P. A *Review Article on Acrylic PMMA*; IOSR Journal of Mechanical and Civil Engineering Volume 13, Issue 2 Ver. I (Mar. - Apr. 2016), PP 01-04; e-ISSN: 2278-1684,p-ISSN: 2320-334X
[9] Manduru, V.R. et al (2022): UV coated acrylics as a substitute for generic glazing in buildings of Indian climatic conditions: Prospective for energy savings, CO2 abatement, and visual acceptability, Energy and Buildings, Volume 268, 1 August 2022, 11223.

## Pipes

There is an increased demand for pipes in Europe[10] for infrastructure projects and residential buildings. Plastic pipes made of PE (polyethylene), PVC (polyvinyl chloride), PP (polypropylene) or PEX (crosslinked polyethylene) show significant advantages in terms of easy handling, flexibility to withstand ground movements and resistance to corrosion compared to traditional concrete or metal pipes (ductile iron or copper), which are still widely used in the construction sector.

Concerning GHG emissions, it has been shown that plastics pipes emit between 25-45% less emissions over their whole lifetime compared to alternatives[11]. When PEX pipes are used for underfloor heating, the heat loss is significantly lower compared to metal pipes, leading to a lower operational carbon footprint in a building. Depending on the application, non-pressure pipes can contain high amounts of mechanically recycled content, without losing their key physical properties[12]. Therefore, plastic pipes are a sustainable option, with an expected life-time of 100 years[13] and can be recycled at the end of their service life, reducing their environmental impact even further.

[10] Benefits-of-plastic-pipes-brochure_digital.pdf (TEPPFA)
[11] Meng F and all; Replacing Plastics with Alternatives Is Worse for Greenhouse Gas Emissions in Most Cases, Environ. Sci. Technol. 2024, 58, 2716−2727
[12] Thomas R, and all; Performance of corrugated pipe manufactured with recycled polyethylene content ; NCHRP report 696.
[13]Pinter G and all; *100 years lifetime of plastic pipes* (commissioned by the European plastic pipes and fittings association)