Adhesives and sealants' key sustainability role in the transition pathway for the construction ecosystem

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Sustainability in the construction sector is receiving substantial attention in the European Union (EU) as a consequence of both the absolute scale of this sector and its share of materials usage and greenhouse gas emissions in Europe [1], [2], [3]. Recent legislative initiatives, such as the EU Green Deal, cover the construction sector with specific provisions, addressing all levels from entire buildings to construction elements and to the materials used for their production and installation. The environmental performance of adhesives and sealants used in the construction sector is therefore of high interest.

Energy efficiency

Lifetimes of products in the construction sector are exceptionally long compared to those of other sectors. The use phase of a building or construction product, therefore, typically has a significant impact on the overall environmental footprint. Existing buildings in the EU are responsible for 36% of greenhouse gas emissions[1] whereas heating, cooling and hot water account for around 80% of the energy consumed in residential buildings[4]. Consequently, thermal insulation and efficient heat sources are essential for the *energy efficiency* of buildings.

Thermal insulation

The emissions savings potential of thermal insulation is estimated to be about 80% compared to non-insulated buildings[5]. As part of external thermal insulation systems, adhesives increase the durability and performance of insulation panels[6]. Polyurethane foams provide insulating gap filling to augment the overall insulation performance. Self-adhesive tapes and sealants provide airtightness of insulation systems and windows or glazing elements[7]. Airtightness is crucial for thermal insulation performance, as air leakage can represent up to 50% of energy losses in a building[8], [9]. Sealants are also key for the *energy efficiency* and longevity of multipaned glass elements[9].

Adhesives and sealants can provide these benefits both in new construction as well as in (energy) renovation projects. Renovation is of the highest importance as almost 75% of the current building stock in the EU is considered to be inefficient and 85-95% of these buildings are expected to be still standing in 2050[10].

Decarbonisation of heat sources

In addition to improvements in insulation value, adhesives and sealants support the transition to decarbonised heat sources, such as photovoltaic panels, which provide electrical energy for heat pumps, to batteries, which allow storing of surplus daytime electrical energy from photovoltaics, and to solar thermal collectors.

Adhesives and sealants – large benefits from small quantities

While adhesives and sealants carry a footprint of their own due to their raw materials, their production and their logistics, the amount of adhesive or sealant in a final product is very low (in construction often less than 1% by weight in a building). To understand the impact and benefits of adhesives and sealants, the focus should therefore be on the finished product[11]. Use-phase savings can rapidly offset the full footprint of adhesives and sealants[8, 12] with the 'break-even point' occurring potentially within days of installation. Model Environmental Product Declarations (EPDs) offered by FEICA[13] provide footprint information for adhesives and sealants and allow for such calculations to be performed by actors in the value chain.

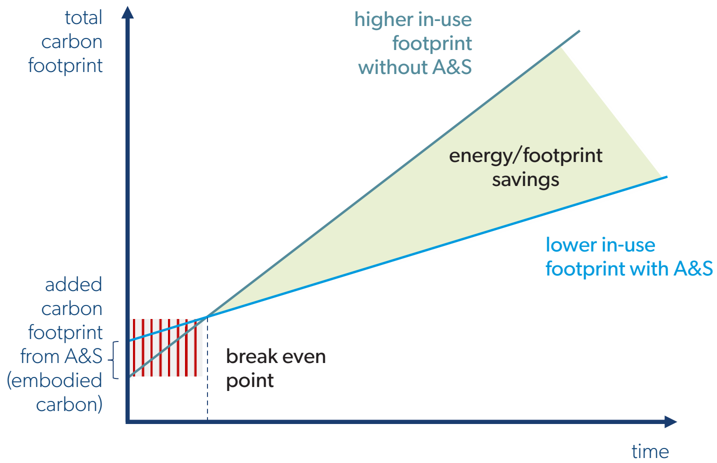


Illustration of the evolution of the total carbon footprint over time with and without adhesives and sealants.

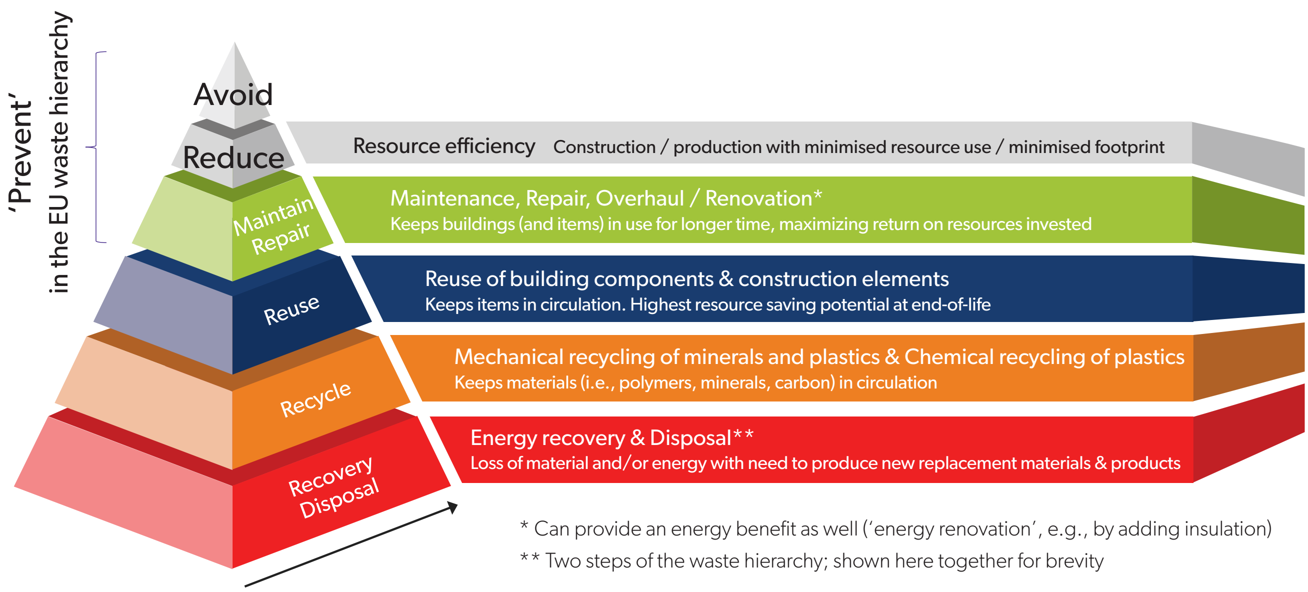
Material efficiency

In addition to use phase emissions, the total life cycle emissions of a building from construction to demolition include the footprint of the installed materials, referred to as 'embodied carbon'. In highly energy-efficient buildings, the embodied carbon can be higher than 50 years of use-phase emissions[14]. A study by the European Environment Agency[15] found that selected actions can provide a reduction of > 60% of embedded carbon during the building's lifecycle. Reducing the embodied carbon footprint is achieved through *material efficiency*.

Considering that the opposite of *material efficiency* is the creation of waste, the EU waste hierarchy[16] is a key tool with regard to *material efficiency*. When the waste hierarchy is applied, a wholistic approach is important for optimum solutions, as a sole focus on only one step of the hierarchy, e.g. recycling, may cause unwanted effects on another, e.g. reduction[11]. The hierarchy provides a preference to prevent materials from becoming waste, by avoidance, reduction and maintenance / repair. A recent study[17] identified material reduction, alternatives to cement and steel, and reuse of construction elements as high impact options.

Material use reduction

Adhesives and sealants can support *material efficiency* by allowing for the reduction of material



Visualisation of the waste hierarchy, adapted to the construction sector.

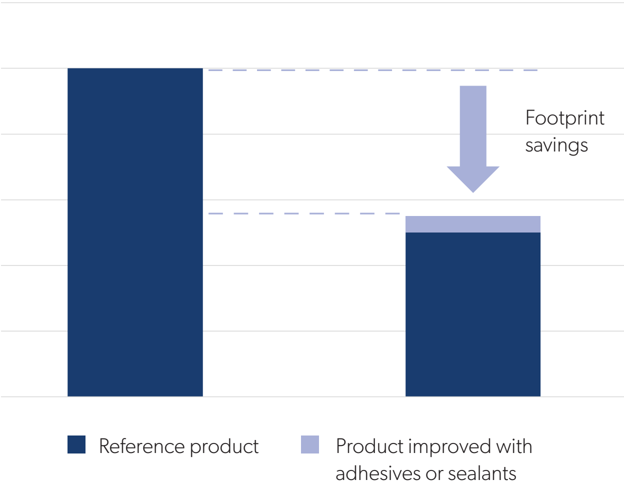


Illustration of footprint savings through material use reduction enabled by adhesives and sealants.

use, for example, by replacing window components made of steel[7] or through lightweight construction for doors[18]. They also enable the use of lower (embedded) carbon construction materials, as in engineered wood elements[19], where 1 ton of wood instead of 1 ton of concrete is estimated to yield an average reduction of 2.1 tons of CO_2[20].

Maintenance and repair

Through maintenance and repair activities, adhesives and sealants can extend a building's life, avoid the replacement of building elements and prevent follow-on damages by making possible the mending of these damages quickly after they occur. Adhesives and sealants are also key to the maintenance and repair of machinery, about 20% of which is intended for use in construction in the EU[21]. Important applications include thread locking, retaining, gasketing and sealing.

End-of-life: reuse and recycling

When the end-of-life of parts or of the whole of a building is reached, reuse (of building components) and recycling (of materials) are preferable, circular approaches.

More standardised building design may increase the reuse potential of components, for example, via prefabricated building elements[3]. Adhesives and sealants could support prefabrication, including automation, as evident in, for example, the automotive and electronics industries.

High recycling rates have already been achieved in the EU for many construction materials, including those containing adhesives and sealants (for example, for mineral materials[24], [25], bricks and rooftiles[26], steel[27], [28], flat glass[29],[30], PVC[31], [32] and wood[33], [34]).

Adhesives and sealants in recycling processes

Due to their small weight percentage in any given product or building, adhesives and sealants are generally not the target of recycling[11]. Therefore, rather than being 'recyclable' themselves, adhesives and sealants primarily need to allow for the recycling of their substrate(s), i.e. the construction materials.

Where adhesives are used to bond two identical or similar materials together or where sealants are used, designing these products for compatibility with recycling can allow the relevant recycling processes to proceed unhindered.

Where dissimilar materials which require separate recycling processes are bonded together, large component dimensions can enable mechanical release of the adhesive joints[11], such as in the removal of floor or wall coverings. This releasability can be further improved by selective release, in which case the adhesive remains on a substrate where it is not detrimental to recycling.

Where mechanical separation is not feasible, and adhesively bonded materials must be separated before recycling, debonding can provide a solution. Debonding can be achieved, for example, by soaking the bonded area in a suitable medium to weaken or dissolve the adhesive, as has been practiced for a long time for wallpapers.

When debonding is contemplated, it is important to consider that the actual utilisation of such reversible bonds will, just as for alternatives such as screws, depend on practical and economic considerations, and alternative approaches to reversing the bond exist. For example, adhesive and sealant bonds may also be released after demolition during recycling processes, for example, by soaking, dissolution or mechanical force (crushing, milling or grinding), followed by separation, for example, by density (sink-float or wind sifting), shape, size (sieving) or sensor-based sorting[22], [23]. Further improvements both in adhesive and sealant design as well as in recycling technology will allow more material to be recycled at better quality in the future.

Material efficiency

- Material reduction and lightweightness
- Lower footprint of materials, e.g. wood-based construction
- Maintenance, e.g. façade sealants
- Repair, e.g. rain gutter sealants
- Machinery maintenance and repair

Energy efficiency

- Thermal insulation
- Insulated glazing
- Airtightness
- Photovoltaics
- Storage batteries

Examples of the contributions of adhesives and sealants to sustainability in the construction sector.

Conclusions

In conclusion, adhesives and sealants present numerous sustainability benefits to the construction sector. When used in the manufacture of construction products or in the construction of a building, they help improve *energy efficiency* and enable *material efficiency* through material reduction and the use of more sustainable materials. During the lifetime of the building, they support maintenance, repair and renovation and can thereby increase the building's life span. As evidenced by the high recycling rates already achieved for many types of demolition waste, with the right design, adhesives and sealants do also enable *circularity* at the end-of-life.

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FEICA - Association of the European Adhesive & Sealant Industry
Rue Belliard 40 box 10, 1040 Brussels, Belgium | Tel: +32 (0)2 896 96 00 | info@feica.eu

www.feica.eu

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