Insulation Manufacturers Association

Whole-life carbon and insulation specification

A building-level approach to better carbon decisions

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Insulation Manufacturers Association (IMA) is the Trade Association that represents both the polyisocyanurate (PIR) and polyurethane (PUR) insulation industry in the UK. Its members manufacture rigid insulation that provides around 40 per cent of the total thermal insulation market into the UK. IMA's membership comprises all of the major companies in the industry, including manufacturers of finished PIR and PUR insulation products, as well as suppliers of raw materials and associated services.

IMA represents the industry's views across all government and industry stakeholders and decision makers and promotes a positive and dynamic business environment for the PIR and PUR insulation industry in the UK.

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Executive summary

Whole-life carbon (WLC) assessment is increasingly used to inform building design, procurement and policy decisions across the construction sector. In this context, insulation materials are often discussed through a carbon lens. However, many comparisons in the market still rely on isolated product-level carbon figures rather than building-level analysis.

Insulation Manufacturers Association (IMA) commissioned XCO2 to carry out a WLC assessment comparing PIR and mineral wool insulation strategies across two representative UK building archetypes: a detached dwelling and a medium-sized school. The study modelled full embodied carbon impacts across the building lifecycle using a methodology aligned with the RICS Whole Life Carbon Assessment guidance and EN 15978.

The findings highlight an important point: when insulation strategies are assessed at the level of the whole building, and when equivalent thermal performance is maintained, the resulting differences in embodied carbon outcomes are often much smaller than product-only comparisons might suggest.

This paper summarises the key findings from the assessment and outlines a framework for interpreting insulation-related whole-life carbon comparisons responsibly. The analysis presented in this paper supports the following practical conclusions:

- Whole-building comparisons should be prioritised over product-only carbon comparisons.
- Insulation strategies must be compared on the basis of equivalent thermal performance.
- Application-specific specification, including density and structural requirements, should be reflected in comparisons.
- Product-specific EPDs and comparable datasets should be used wherever possible.
- Lifecycle assumptions, particularly end-of-life scenarios, should be made transparent and realistic.
- Insulation decisions should consider both embodied carbon and operational performance over the building lifecycle.

Adopting these principles will help ensure that insulation-related carbon comparisons support robust, evidence-based decision making in building design and specification.

1. Key Findings from the Whole-Building Assessment

Whole-building carbon differences between insulation strategies are typically small

When insulation options are assessed at building level with equivalent thermal performance, the resulting differences in whole-building embodied carbon are typically very small.

The modelling undertaken for this study showed:

Detached dwelling archetype

- PIR – 811 $kgCO_2e/m^2$
- Mineral wool – 807 $kgCO_2e/m^2$

School archetype

- PIR – 1,148 $kgCO_2e/m^2$
- Mineral wool/EPS – 1,162 $kgCO_2e/m^2$

These differences represent approximately 0.5–1.2% of total building embodied carbon, indicating that insulation material substitution alone rarely drives whole-building carbon outcomes.

However, insulation choice can influence other material quantities within the building. Differences in thermal efficiency may require changes in insulation thickness, which can alter wall and roof build-ups and affect associated materials such as structure, foundations or façade elements. These knock-on impacts should therefore be considered in whole-building assessments.

Insulation typically represents a relatively small share of total building carbon

In most buildings, insulation accounts for only a small proportion of total embodied carbon, with structural elements, finishes and building services generally contributing a much larger share.

This means that comparisons focused only on insulation material carbon factors can overstate the influence of insulation choice relative to wider design decisions.

The examples in this study represent two illustrative building archetypes, and outcomes will vary on a project-by-project basis depending on design choices and modelling assumptions. Nevertheless, the analysis indicates that insulation generally contributes a relatively small proportion of whole-building embodied carbon.

In many buildings, larger contributions arise from elements such as:

- **structural materials including concrete and steel**
- **façade systems and glazing**
- **internal finishes and fit-out materials**
- **mechanical and electrical building services**

From a product specification perspective, decisions relating to these elements can often have a greater influence on overall embodied carbon outcomes than insulation selection alone.

Thermal efficiency can influence wider material use

Insulation materials with higher thermal efficiency can achieve required U-values with reduced thickness, which can help limit increases in wall depth, roof build-ups and associated structural or façade elements.

Where insulation thickness increases, knock-on impacts may occur in:

- **foundations and excavation**
- **structural elements**
- **façade systems and interfaces**
- **wall and roof build-ups**

These impacts are often modest individually but can become visible at whole-building level.

The school archetype provides an example of how application-specific requirements, such as higher-density roof boards required to accommodate compression loads, can influence embodied carbon outcomes.

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Application and specification matter

Insulation performance and carbon outcomes depend strongly on application conditions, including:

- **structural loads and compression requirements**
- **insulation density and grade**
- **roof or façade system design**
- **detailing and build-up constraints**

The modelling results demonstrate that differences between insulation strategies can arise not only from the insulation material itself, but also from the specific product grade and specification required for the application.

During the early stages of developing the building specifications for the modelling exercise, it became clear that some application-specific requirements needed to be explicitly accounted for within the LCA model. For example, in flat roof constructions mineral wool insulation boards are typically required to have significantly higher density and compressive strength in order to accommodate installation loads, maintenance traffic and long-term service conditions.

By contrast, rigid PIR insulation boards commonly used in flat roofing applications are designed to achieve the necessary compressive strength and load-bearing performance at comparatively lower densities. As a result, different insulation materials may require different product specifications and material quantities in order to meet the same functional requirements.

When these specification requirements are correctly reflected in the model, the embodied carbon associated with the insulation layer can change materially, because higher-density roofing grades contain substantially more material per unit volume than lower-density insulation products.

In this study, adjusting the model to reflect the appropriate roofing-grade mineral wool density altered the embodied carbon associated with the flat roof build-up and contributed to the differences observed in the school archetype results.

This illustrates an important point: application-specific product grades and densities must be correctly represented in whole-life carbon assessments. Comparisons based on generic material categories or inappropriate product specifications risk producing misleading results.

For this reason, insulation comparisons should be undertaken using equivalent build-ups and application-appropriate product grades, rather than relying on simplified comparisons between generic insulation categories.

Carbon comparisons must be normalised to thermal performance

Insulation materials differ significantly in thermal conductivity (λ-value), density and required thickness. As a result, product-level carbon comparisons expressed per kilogram or per cubic metre can be misleading when used in isolation.

The purpose of insulation within a building is to provide thermal resistance, typically expressed through the U-value of the building element. Different insulation materials achieve the same thermal performance using different combinations of thickness and density.

Materials with lower thermal conductivity can achieve the same U-value with smaller material volumes, while others may require thicker layers to deliver equivalent performance.

For this reason, insulation comparisons should first be normalised to an equivalent thermal performance, typically by comparing build-ups designed to achieve the same U-value within a wall, roof or floor assembly. Only once this performance equivalence has been established can meaningful comparisons be made between the embodied carbon associated with different insulation strategies.

Density also plays an important role in many insulation applications. Certain building elements – such as flat roofs, floors or façade systems – may require insulation products with higher compressive strength or load-bearing capacity, which are typically achieved through higher-density insulation boards. These specification requirements can significantly influence the embodied carbon per unit volume of the insulation product used.

As a result, comparisons based solely on $kgCO_2$ per cubic metre without considering the density and performance requirements of the specific application may not represent a like-for-like comparison.

A fair comparison requires that insulation products being assessed:

- **meet the same thermal performance requirement**
- **are suitable for the same application and loading conditions**
- **are specified at the appropriate density and thickness for that application**

When these factors are taken into account, carbon comparisons between insulation options can more accurately reflect the real material quantities and build-up requirements used in buildings, rather than relying on simplified product-level metrics.

Robust comparisons depend on appropriate data

Whole-life carbon assessments are only as reliable as the data used.

Where possible, product-specific Environmental Product Declarations (EPDs) should be used rather than generic database values. Product EPDs provide verified data reflecting actual manufacturing processes and improvements in production efficiency. Generic datasets can be useful for early-stage modelling but may rely on sector averages or historic assumptions, which may not accurately represent current products or manufacturing practices.

Transparent reporting of data sources, lifecycle scope and modelling assumptions is therefore essential for credible comparison.

2. Interpretation and wider considerations

End-of-life assumptions can significantly influence insulation WLC results

The study assessed embodied carbon across the full lifecycle (A1–C4), including end-of-life impacts. However, end-of-life assumptions remain one of the more uncertain aspects of whole-life carbon modelling for construction products.

In the modelling used for this assessment, PIR insulation was assumed to follow an energy-from-waste incineration route, while mineral wool was treated using the default scenario applied within the modelling tool, which broadly reflects landfill or recovery routes depending on product category. These assumptions influence the carbon reported in lifecycle stages C1–C4 and any associated benefits or burdens beyond the system boundary.

In practice, the future end-of-life pathways for insulation materials remain uncertain. Current Environmental Product Declarations (EPDs) and industry practice show a range of possible scenarios for both PIR and mineral wool, including:

- **landfill disposal**
- **incineration with energy recovery**
- **emerging recycling or recovery routes**

The relative balance between these routes may evolve over time as waste policy, recycling infrastructure and product recovery systems develop.

Because end-of-life assumptions can materially affect lifecycle module C (and module D where reported), whole-life carbon comparisons should make these assumptions transparent and interpret results with appropriate caution.

Where insulation-related carbon outcomes are close, it may be appropriate for assessments to test alternative end-of-life sensitivity scenarios, for example:

- **landfill-dominant disposal**
- **energy-from-waste recovery**
- **future recycling or recovery scenarios where credible evidence exists**

This approach can help ensure that carbon comparisons reflect the range of plausible end-of-life outcomes, rather than relying on a single assumed disposal route.

Balancing embodied carbon and operational benefits

Insulation plays a dual role in whole-life carbon performance. While insulation materials carry an embodied carbon cost at manufacture and installation, their primary purpose is to reduce operational energy demand over the lifetime of the building.

In most cases, the operational energy savings enabled by effective insulation significantly outweigh the embodied carbon associated with the insulation itself.

As electricity systems decarbonise and heating technologies shift toward lower-carbon solutions such as heat pumps, the carbon intensity of operational energy is expected to fall over time. Projections for the UK grid suggest continued reductions in emissions intensity as renewable generation expands and fossil fuel generation declines. This means that the relative carbon savings attributable to insulation may gradually diminish compared with a highly carbon-intensive energy system.

However, several factors suggest that insulation will remain a critical component of low-carbon building design.

1. Insulation reduces absolute energy demand, not only carbon emissions. Lower demand reduces the size and operating requirements of heating systems, limits peak loads on electricity networks, and improves the overall efficiency of low-carbon heating technologies.
2. While long-term projections anticipate a lower-carbon electricity system, the pace and pathway of decarbonisation remain uncertain. Energy systems are influenced by policy decisions, infrastructure investment, geopolitical factors and technological development. Temporary setbacks, slower deployment of generation or network capacity constraints could alter the trajectory of grid decarbonisation.
3. Buildings are long-lived assets. Design decisions made today will influence energy demand for many decades, often outlasting multiple generations of heating systems and energy infrastructure. Ensuring that buildings have low heat demand provides resilience against future uncertainty in energy prices, technology performance and system carbon intensity.

For these reasons, insulation should not be evaluated solely through a narrow comparison of its embodied carbon. Instead, its role should be understood in the context of whole-life performance, including:

- **reductions in operational energy demand**
- **improved performance of low-carbon heating systems**
- **resilience to future energy system uncertainties**
- **avoidance of costly or disruptive retrofit interventions later in a building's life**

Taken together, this reinforces the importance of considering insulation as part of whole-building carbon optimisation, rather than focusing exclusively on the embodied carbon of individual materials.

3. What this study does and does not show

The findings presented in this paper should be interpreted within the scope of the underlying modelling exercise.

The commissioned assessment compared PIR and mineral wool insulation strategies across two representative building archetypes under a defined set of assumptions. The purpose of the study was to examine how different insulation approaches influence the overall embodied carbon of a building, and to better understand the role that insulation plays within whole-building carbon outcomes.

The results therefore illustrate how insulation strategies can behave within whole-building carbon assessments when equivalent thermal performance is maintained.

Real-world outcomes will vary depending on building design, insulation specification, modelling assumptions and the datasets used.

The study demonstrates several broader points that may be relevant across many projects:

- **insulation comparisons are most meaningful when undertaken at building level rather than through isolated product metrics**
- **thermal performance must be normalised for fair comparison**
- **application-specific specification, including density and grade, can materially affect outcomes**
- **modelling assumptions and data sources can influence results and should therefore be transparent**

The results should therefore be interpreted as evidence of comparison methodology and system behaviour, rather than as a universal rule for all projects.

4. Conclusions

The results of the commissioned whole-life carbon assessments highlight an important point for designers, policymakers and product specifiers: the way insulation comparisons are framed matters.

When insulation strategies are assessed at the level of the whole building, with equivalent thermal performance and consistent modelling assumptions, the differences in whole-life embodied carbon outcomes can be very small relative to total building impacts. In the archetypes modelled in this study, the difference between insulation strategies represented approximately 0.5–1.2% of total building embodied carbon.

This finding does not imply that insulation choices are irrelevant to carbon outcomes. Rather, it demonstrates that insulation materials must be assessed within the context of the whole building, where interactions between thermal performance, material quantities, structural requirements and specification constraints influence the final result.

Several broader conclusions emerge from the analysis.

1. **Whole-building assessment provides a more meaningful basis for decision-making than product-only comparisons.** Simplified comparisons based on isolated product carbon factors can create misleading impressions of the relative importance of different materials. In practice, insulation is only one component of the overall building carbon profile, and many other elements — including structure, façades, finishes and building services — typically contribute larger shares of embodied carbon.

2. **Thermal performance normalisation is essential for fair comparison. Insulation materials differ in thermal conductivity, density and required thickness.**
   Product-level comparisons expressed per kilogram or per cubic metre cannot capture the functional purpose of insulation, which is to provide thermal resistance within a building assembly. Meaningful comparisons therefore require insulation strategies to be assessed on the basis of equivalent thermal performance within complete building elements.

3. **Application-specific specification plays a critical role in real projects.**
   The modelling demonstrated that requirements such as compressive strength or load-bearing performance can influence the grade and density of insulation products used. These specification choices can affect both the embodied carbon of the insulation itself and the associated material quantities within the wider building structure.

4. **The quality and comparability of data are fundamental to credible carbon assessments.**
   The results of building-level life cycle assessments depend heavily on the datasets used. Product-specific Environmental Product Declarations (EPDs) can provide a more accurate representation of manufacturing processes and product characteristics than generic database averages, particularly where manufacturing practices and material compositions vary significantly between products.

5 **Lifecycle modelling assumptions remain an important source of uncertainty.**
End-of-life scenarios, replacement cycles and data selection can all influence the final outcome of a whole-life carbon assessment. Transparent reporting of these assumptions, and where appropriate sensitivity testing, should therefore be considered good practice when carbon comparisons inform design or procurement decisions.

6 **Insulation must be considered in the context of whole-life building performance, not solely through embodied carbon metrics.**
Insulation reduces operational energy demand, improves the performance of low-carbon heating systems and provides resilience against future uncertainty in energy systems and energy prices. These long-term benefits remain central to the role of insulation in delivering low-energy buildings.

Whole-life carbon decisions require like-for-like comparisons at a building level.

When insulation strategies are evaluated at the building level, with equivalent thermal performance, appropriate specification and transparent assumptions, the resulting comparisons become more credible and more useful to project teams.

The challenge for the industry is therefore not simply to compare materials, but to ensure that those comparisons are undertaken consistently, transparently and within the context of the whole building.

An important implication of this analysis is that insulation performance characteristics can influence building design efficiency as well as carbon outcomes. Materials with higher thermal efficiency can achieve required U-values with reduced thickness, which may help limit increases in wall depth, roof build-ups and associated structural elements. In some applications this can reduce material quantities elsewhere in the building envelope and minimise dimensional knock-on effects. As building standards continue to tighten and space efficiency becomes an increasingly important design constraint, these system-level interactions are likely to become more significant. Considering insulation performance within the context of the whole building system therefore remains essential to making informed and balanced carbon decisions.

For more details on the benefits of PIR insulation please visit: insulationmanufacturers.org.uk

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