

Whole-life carbon: Retrofit vs EnerPHit

25 June 2015 | By Maiia Guermanova and Priyanka Arora of Sturgis Carbon Profiling

Assessments show retrofit to EnerPHit level, the Passivhaus retrofit standard, can reduce whole-life carbon emissions by 40% compared to typical Part L. How can EnerPHit help to deliver the government's 2050 carbon reduction targets cost effectively?



Deep retrofit project to EnerPHit standard of the 1720s terraced mews house by Grosvenor Britain and Ireland

01 / Introduction

EnerPHit is the highest energy standard for refurbishments in the UK, based on the German Passivhaus quality certification criteria. Broadly, it means the property is virtually airtight and has high insulation levels, resulting in a low heating demand, hence the term “passive”. This is achieved with limited intervention to the building and without excessive costs.

Over the last year, we have delivered a number of retrofits in London, ranging from terraces built in the 1720s, to a large-scale social housing project from the 1960s. Most of these were designed to comply with EnerPHit standards.

In this piece, we compare three scenarios from the whole-life carbon perspective: a typical un-refurbished terrace; a Part L compliant retrofit; and a deep retrofit to EnerPHit standard. We also look at the economic and carbon benefits of different types of insulation.

Whole-life carbon assessments: a brief recap

Based on BS EN 15978, carbon emissions from buildings are attributed to four main categories:

- (i) Product Manufacture
- (ii) Construction
- (iii) In Use and
- (iv) End of Life.

More detailed subcategories further classify specific sources of emissions.

The key contribution that whole-life carbon assessment makes is its ability to take account of all sources of emissions associated with the building, and not just those that arise from its use. BREEAM 2014 has also introduced up to 10 possible credits that could benefit from whole-life carbon assessment.

02 / Scenarios

Why EnerPHit?

The reason why we recommend clients undertake deep retrofit projects to EnerPHit standard are:

- Low energy bills

The average annual heating bill can be reduced by 70-95% compared to the national average of £752 (DECC 2014 data).

- Comfort

Buildings are warm, airtight and have no drafts, cold bridging or temperature stratification.

- Health benefits

Mechanical ventilation with heat recovery (MVHR) systems guarantee a clean fresh filtered air supply to all rooms (cutting out up to 80% of pollution, pollen and dust particles).

- Sound Insulation

This is achieved because of triple glazing and super insulated building envelope.

- Quality control in construction

EnerPHit is the only standard that is certified "as built" with site visits, photographic evidence, air test and product invoices, not just "on paper" calculations.

- Reduced performance gap

Co-heating test completed at Leeds Beckett University shows that Passivhaus buildings use 45W/K, which is within 5% of the predicted values, compared to the UK average of 168W/K that perform 25-150% worse than predicted.

- Other potential benefits

These include reduced arrears, low maintenance, increased rental value and market value.

Element	Scenario 1: Unrefurbished terrace	Scenario 2: Part L compliant retrofit	Scenario 3: Deep retrofit to EnerPHit standard
Building envelope	Solid brick	Solid brick with 20mm internal breathable aerogel insulation (0.50W/m2K) to front and external insulation with brick slips to rear facade (0.30W/m2K)	Solid brick with 70mm internal breathable aerogel insulation (0.15W/m2K) to front and external insulation with brick slips to rear facade (0.15W/m2K)
	Existing floor,		175mm PIR insulation (0.15W/m2K). Cellular glass insulation around steel

Ground floor	no insulation	125mm PIR insulation	beams and thresholds to avoid cold bridges.
Windows	Single glazed sash windows	Double glazed sash windows	Triple glazed mock sash windows
Roof	Existing timber roof, <100mm insulation	200mm Mineral wool insulation between rafters	200mm Mineral wool between rafters +100mm PIR insulation above
Renewables	None	None	9m2 PV panels
Heating	Old inefficient gas boiler + radiators	New efficient condensing boiler + radiators	New efficient condensing boiler (small demand) + radiators
Ventilation	Manual-opening windows	Manual-opening windows	MVHR + Manual-opening windows
Airtightness	Very poor (15-35 m3/m2h@50Pa)	Improved (15 m3/m2h@50Pa)	Very high (0.7 m3/m2h@50Pa)
DER[1] Operational (kgCO2e/m2)	94	40	12 excl. PVs (0 incl. PVs)
WLC (kgCO2e/m2)	4940	3100	1870 excl. PVs (1820 incl. PVs)

[1] DER based on SAP calculations from real project data from Grosvenor Britain and Ireland

03 / Findings

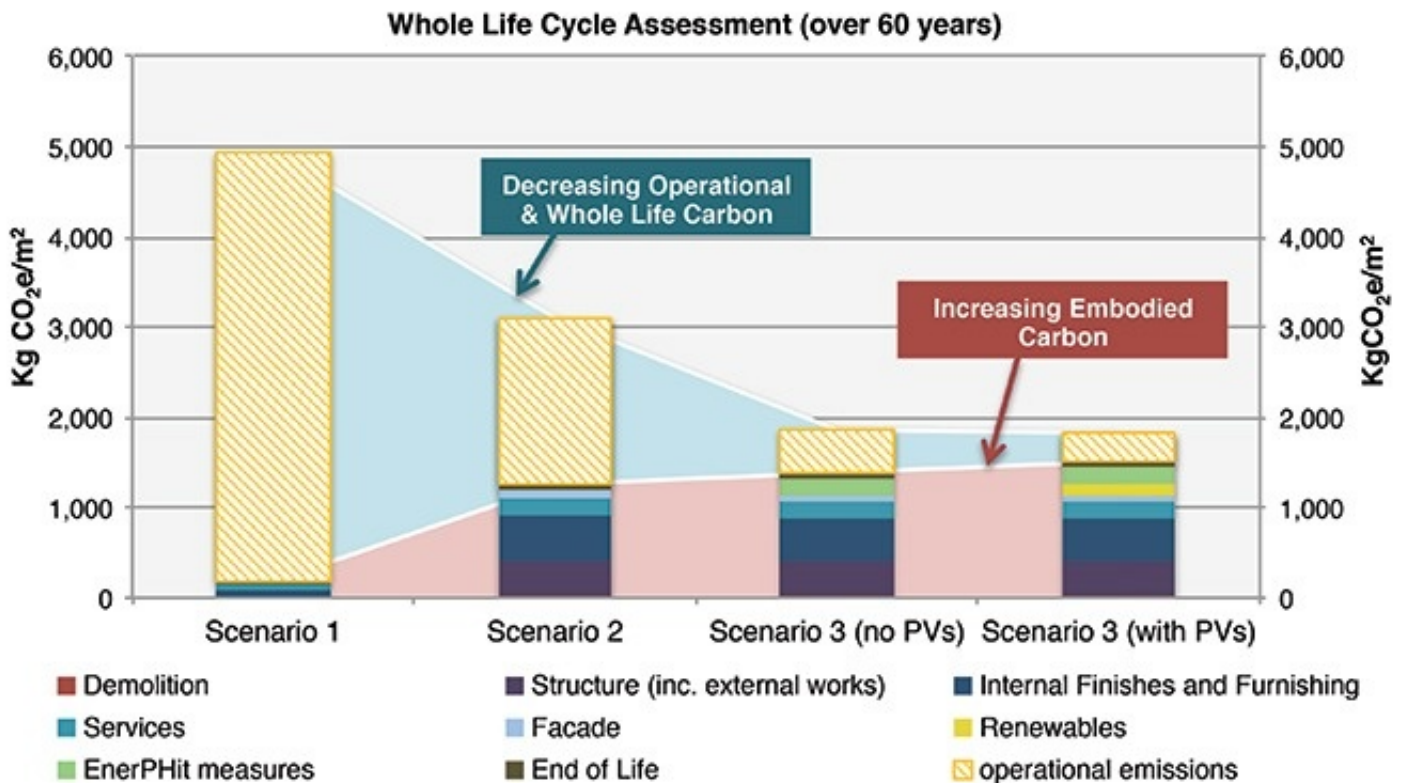


Figure 1: Whole-life cycle assessment (over 60 years)

We made the following assumptions when completing the whole-life carbon assessment:

- **Demolition Waste:** That no site waste was sent to landfill and about 50% was recycled on site
- **Timber:** Sequestration for timber in the project excluded as per CEN TC 350 and BS EN 15978
- **Grid decarbonisation:** Allowance for grid decarbonisation of 92% by 2045. Plant efficiency assumed to improve 20% at each replacement taken at 25 years. (Ref: Embodied carbon: A Look Forward by C Jones-Sustain 2011)
- **Unregulated Operational emissions:** Considered as constant across all scenarios
- **Impact of projected climate change on heating demand:** Has not been included to avoid complexity
- **The project life span:** This has been considered at 60 years, with regular maintenance to internal finishes and furnishing every 10-15 years.

The graph above shows considerable differences between the whole-life carbon footprints of the three scenarios. The operational emissions decrease steeply with each successive measure, however, the increase in embodied carbon is relatively gradual. Looking closely:

- Whole-life emissions 40% less than Part L

The whole-life carbon footprint at 60 years of the Scenario 2 (Part L compliant Retrofit) is at least 35% better than that of the Scenario 1 (unrefurbished Victorian terrace); the footprint of the Scenario 3 with PVs (deep retrofit to EnerPHit standard with renewables) is a further 40% better, due to the 75% reduction in operational energy demand.

- Operational Emissions 80% less than Part L

The embodied carbon increases by only about 11% to upgrade Scenario 2 (Part L compliant retrofit) to Scenario 3 (deep retrofit to EnerPHit standard), but effectively reduces the operational emissions to less than a third without PV's; and to less than a fifth with PV's installed.

In the Scenario 3 with PVs, the operational carbon accounts for only 18% of the carbon footprint, while a typical Part L compliant retrofit in the UK has operational emissions in the range of 50%-70% over the whole-life cycle.

- Potential for further carbon reduction

The additional EnerPHit measures account for 11% of the carbon footprint at 60 years. Of this 75% comes from high efficiency insulation like PU, PIR and aerogel, and remaining 25% come from MVHR and airtightness materials. It would be possible to reduce these emissions by a further 50% by specifying low embodied and natural insulation materials in the future.

A deep retrofit to EnerPHit standards with renewables can reduce the overall operational energy demand to a minimum, possibly paving a way to zero-carbon future.

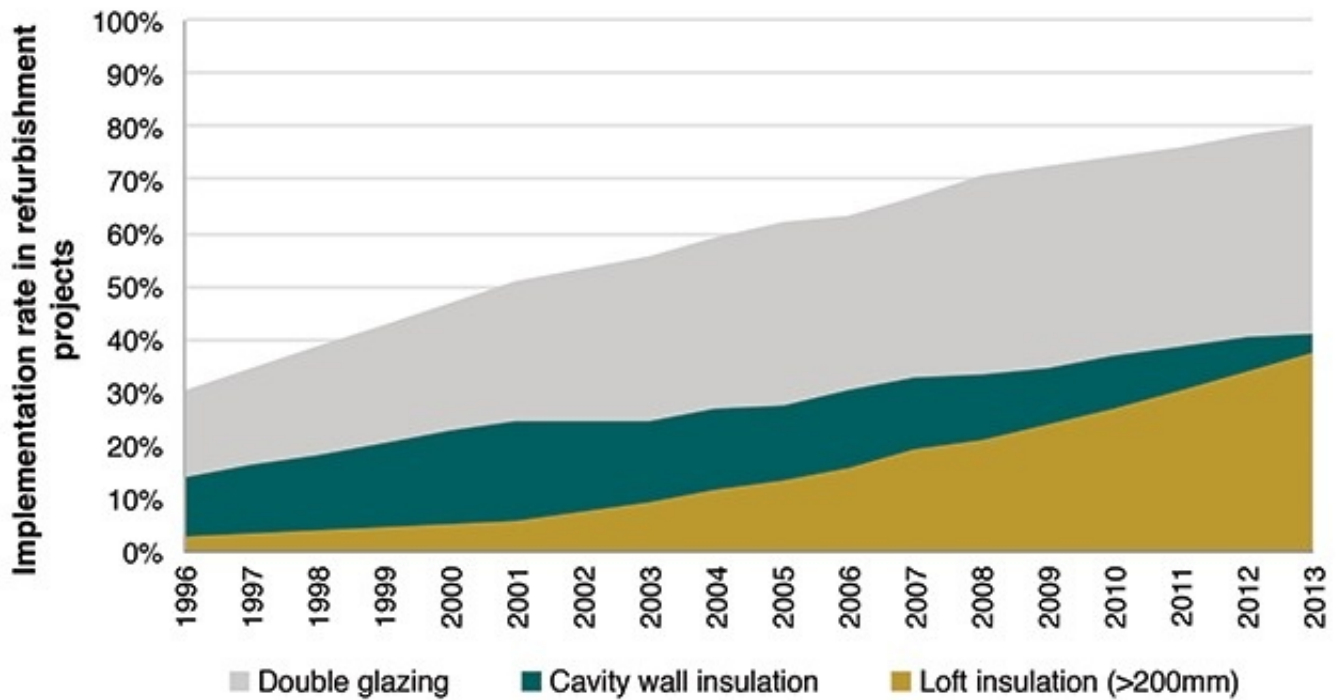
04 / Carbon economics of deep retrofit insulation

Emissions from residential buildings contribute 12% towards greenhouse emissions. The government Carbon Plan committed to reducing carbon emissions by 34% by 2020 and 80% by 2050 below the 1990 baseline. It states that what will make the most impact, most quickly, is retrofit work to existing housing, prioritising the most cost effective measures such as cavity wall and loft insulation.

Free insulation initiatives by utility providers have been relatively successful. These are funded by a government-backed scheme called the Carbon Emissions Reduction Targets (CERT), where consumers pay for the scheme through a levy on energy bills.

Figure 2: Retrofit measures trends in the UK

Retrofit Measures Trends in the UK



Application of EPS external wall insulation with brick slips on EnerPHit project by Grosvenor Britain and Ireland

Figure 2, from the English Housing Survey 2013, demonstrates that since 1996 the number of dwellings with insulation increased by 27% and 34% with cavity wall and loft insulation respectively compared to the 1996 figures. In the last few years the figures have started to plateau as the number of uninsulated households with cavity walls and lofts are decreasing. As this trend progresses, to achieve further carbon reductions, more homes will need to undergo deeper retrofits.

The whole-life carbon findings confirm that deep retrofit measures achieve better operational savings. Having worked with some of the largest private estates in central London, we think it is only a matter of time before the market moves toward deep retrofit measures as cost-effective retrofit measures and “easy wins” become exhausted.

The answer to optimum insulation depends not only on energy efficiency but also type of property (age and historic

value), location and economy of scale. For example, using 40mm aerogel that may cost £150/m² to supply only, is still a cost effective solution in central London, where the value of floor area is above £5,000/m². The study below looks at carbon economics of different insulation types.

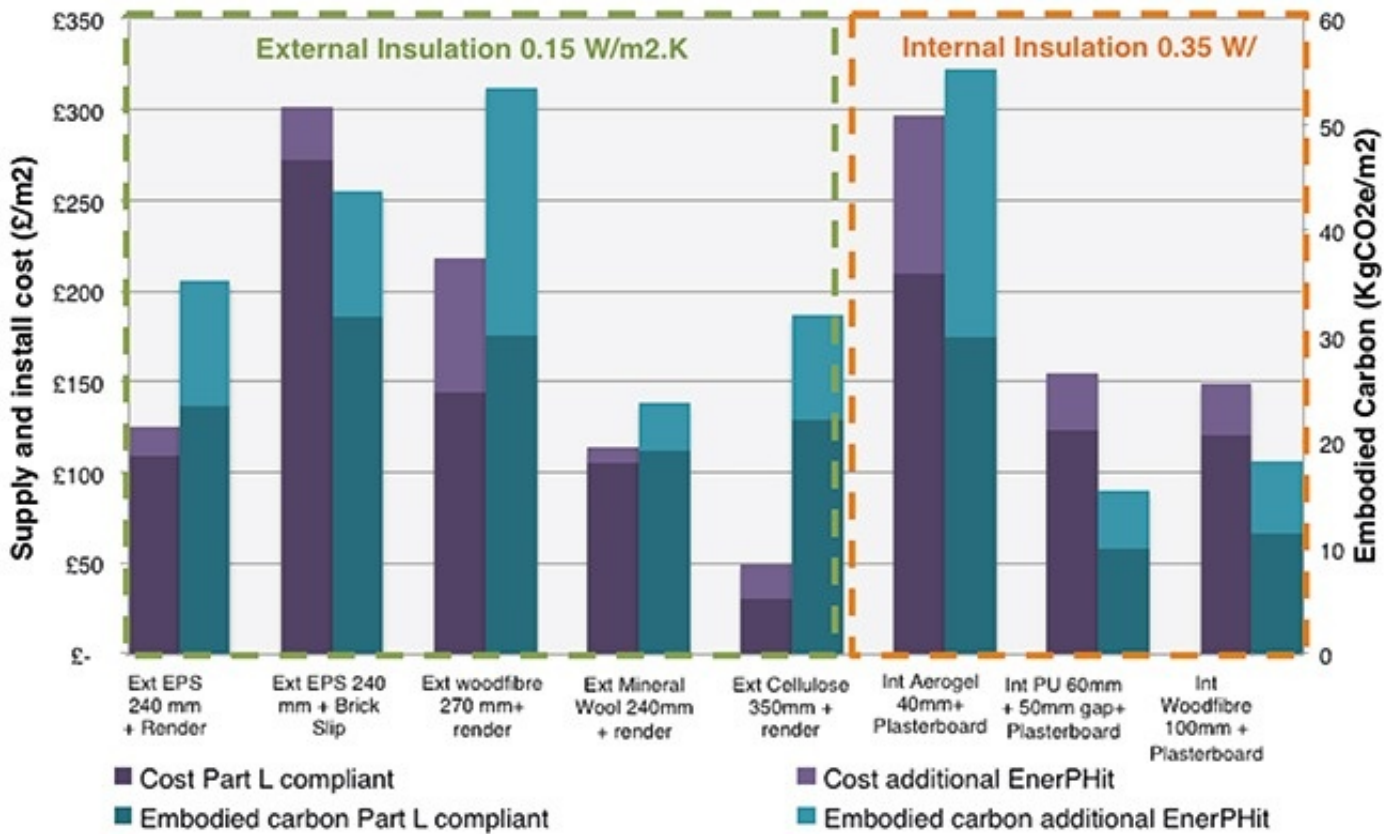


Figure 3: Deep retrofit insulation types

Based on the English Housing Survey (2013) 31% of dwellings do not have cavity walls and 22% have no loft. These will require more intrusive retrofit measures, such as internal/external wall insulation.

To compare eight insulation systems from the point of view of investment cost and embodied carbon the following assumptions were made:

- The data is based on construction projects completed by Sturgis Carbon Profiling in London so cost can be considerably higher than some of the other parts of the UK
- The additional insulation cost and embodied carbon emissions are calculated based on assumption that retrofitting work would already be taking place, and hence exclude workmanship and finishes
- The estimated thickness of insulation for requisite U-values to upgrade standards from Part L typical to EnerPHit were calculated using PHPP as below:
 External wall insulation: 0.15W/m²K for EnerPHit compared to 0.30W/m²K for Part L
 Internal wall insulation: 0.35W/m²K for EnerPHit compared to 0.50W/m²K for Part L

The graph above compares deep retrofit insulation systems that achieve EnerPHit standard over and above the Part L from the point of view of cost and embodied carbon. The study shows the following trends:

- Prefabricated timber frame with Cellulose blow-in insulation is one of the cheapest on the market; however, it is least suitable for historic properties.
- Extruded Polystyrene (EPS) and Mineral Wool are the most common in-situ external insulation types and are relatively comparable. Looking more closely, the additional cost uplift required to achieve EnerPHit standard

with EPS insulation is 13% whilst the embodied carbon increases by 34%.

- Using render is 19% more energy efficient than using brick slips because there is more cement used to bind and point the bricks; it is also about half as expensive.
- Using internal insulation is the least cost effective solution for the u-values achieved (0.35W/m2.K compared to 0.15W/m2.K of external insulation systems). However, the internal insulation systems have the least embodied carbon emissions, as no additional external finishes are required. The additional cost of thinner internal systems can be justified in high value areas due to reduced impact on floor areas.
- Because of the high-efficiency and low density PU insulation has the lowest embodied carbon – 15% less than wood fiber insulation (because carbon sequestration is not taken into account) and it is nearly a third of aerogel. However, non-breathable insulation like PU takes up more space inside the property because of the requirement to have a ventilated air gap due to the risk of moisture building up in the fabric.
- The difference in additional investment cost between Part L and EnerPHit retrofit varies between 8% and 38%, and embodied carbon varies between 20% and 46%, depending on the insulation type.

05 / Conclusions

In summary, based on the findings presented above:

- Deep retrofit to EnerPHit standard offers better energy efficiency over the Part L retrofit, achieving 40% whole-life carbon savings. Increasing embodied carbon costs can be justified by greater operational carbon savings in this study.
- How this is achieved economically depends on locational value and the appropriate options chosen to achieve high quality retrofit up to EnerPHit standard.
- Thin, expensive internal insulation systems may be justifiable in high value heritage buildings whereas less expensive external systems are likely to be more appropriate for upgrading, say, 1960s estates.
- As much as 75% improvement in operational energy performance can be achieved by as little as an 8% increase in insulation costs to upgrade from Part L compliance to EnerPHit standards.
- Our experience shows that achieving EnerPHit standard upgrades to many property types, including heritage assets, is a carbon efficient way forward.



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