Passivhaus: a route to net zero
Embodied carbon

We are in a climate crisis. When determining the most impactful way to cut emissions in the built environment, we must holistically consider embodied and operational carbon. This primer focuses on embodied carbon. Please also refer to *Passivhaus: a route to net zero - Operational carbon* and *Passivhaus: a route to net zero - Retrofit*.

Passivhaus Trust

PHT PRIMER

EFFICIENCY FIRST

Passivhaus prioritises efficiency, of both energy and material resources. Passivhaus buildings are optimised for net zero, providing the best route to minimise whole life carbon. Outstanding levels of building performance minimise operational carbon, while the Passivhaus design methodology is also found to encourage optimisation of embodied carbon through efficient use of materials and radically reducing the heating and cooling plant.

CONSIDERING CARBON

Passivhaus offers a proven route to reducing operational carbon in buildings. But what about embodied carbon?

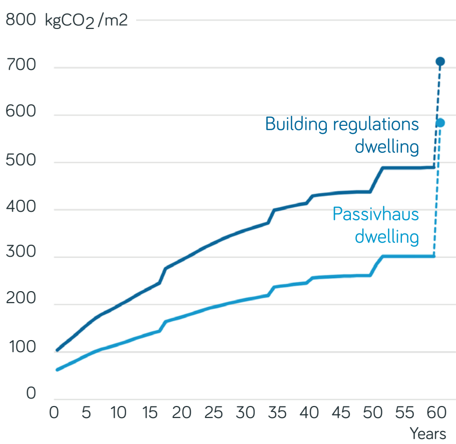
Carbon emissions caused by the manufacture and supply of building materials and in the construction process itself are locked in to the completed building, and as buildings become more energy efficient and the amount of energy required to heat them is slashed, these embodied carbon emissions start to make up a greater proportion of a building's whole life carbon footprint. The transition from gas to a decarbonising grid means that energy used now is more costly in terms of carbon emissions than is the energy that will be used to heat our buildings in the coming years, assuming that this will be sourced from a future grid supplied more and more by renewables.

Passivhaus buildings are optimised for net zero. The Passivhaus design methodology encourages optimisation of embodied carbon through efficient use of materials and radically reducing the heating and cooling plant.

It's therefore imperative that we consider the embodied carbon of our construction elements carefully.

While Passivhaus does not include an embodied carbon analysis, it was an integral part of the background that informed the Standard. However, it has sometimes been argued that designing to *decrease* operational carbon emissions *increases* embodied carbon emissions, based on the assumption that additional materials will be required, such as more insulation and a third pane of glass. Is this correct?

MODELLING



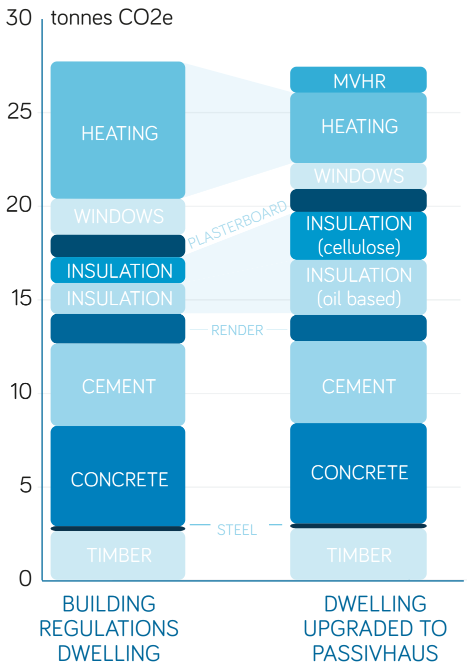
The Passivhaus Trust has undertaken modelling to interrogate this argument. The graph above compares the whole life carbon footprint (measured over 60 years) of:

- a house built to comply with building regulations
- the same house upgraded to meet the Passivhaus standard just by increasing the insulation, window specification and airtightness without any further design optimisation

The modelling shows that even with additional building elements (a heat recovery ventilation system, higher performance windows, more insulation), the Passivhaus has a *lower* initial embodied carbon and *less* operational carbon over its lifetime, leading to a smaller whole life carbon footprint, because:

1. The initial carbon footprint is smaller because the reduced heating load requires a smaller heat pump and radiators.
2. The carbon emissions accumulate more slowly over time because of the lower space heating demand (also taking into account the performance gap).

We can see the impact of a reduced heating system when we compare the embodied carbon breakdown of the construction elements of the two modelled houses, as in the bar chart below:



WHAT ABOUT THE WINDOWS?

Triple glazing does not necessarily result in higher embodied carbon, but does result in higher winter comfort and reduced energy costs. Over the lifespan of a window the frame material choice makes as much, if not more, difference to the overall emissions, than the glazing choice.

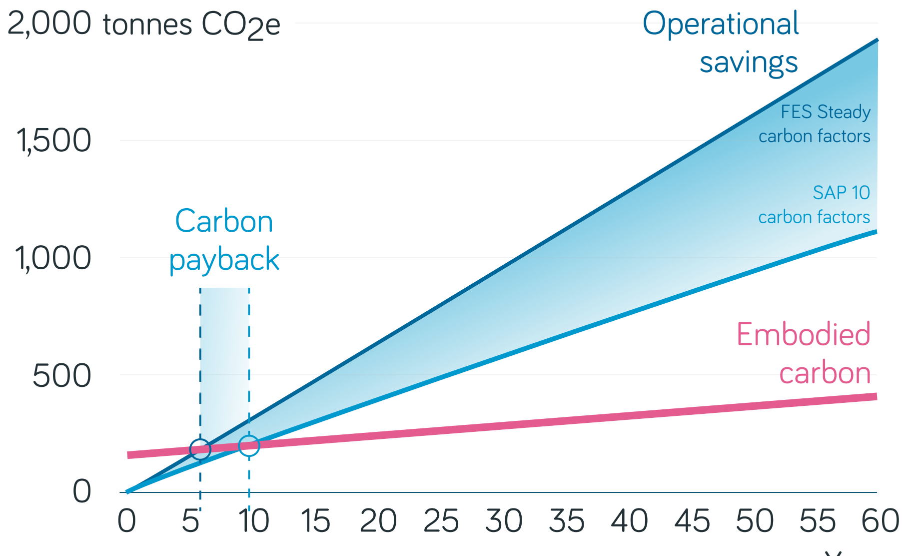
Our analysis shows that windows are an insignificant part of the challenge; the main areas to focus on are structure and services.

PASSIVHAUS BENEFITS

To compare like-for-like, the modelling has not taken into account any design optimisation and other advantages involved in delivering to the Passivhaus standard:

- Passivhaus design optimisation *(better form factor, simplified details = less material use)*
- Longer product lifespans *(certified components and quality assurance)*
- Longer fabric lifespan *(Passivhaus certification means a better quality build)*
- No need for future retrofit to meet more demanding standards

For a complete assessment of the whole life carbon footprint of the two buildings, we would need to quantify these Passivhaus advantages and their positive impact on the reduction of embodied carbon.



Carbon payback calculation for retrofit of St Sophia's Primary School

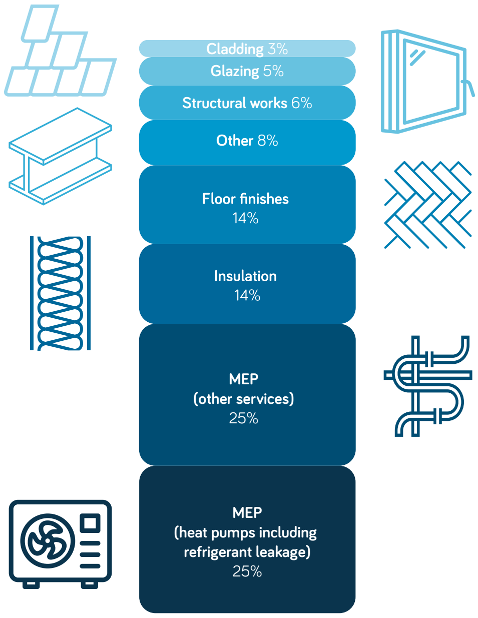
RETROFIT

Existing buildings are by far the biggest source of carbon emissions from the built environment, so pose the biggest potential for carbon savings. They also represent a massive store of embodied carbon.

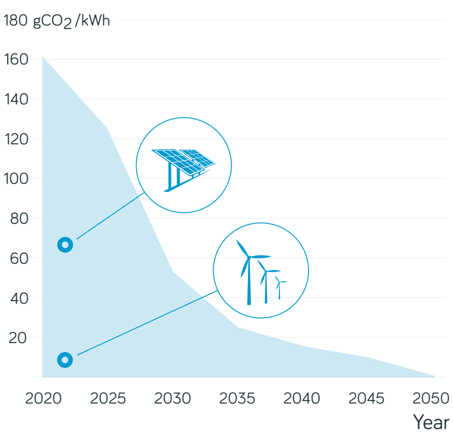
Deep retrofit of course has an embodied carbon cost, with the addition of extra insulation and new building services. But it can be quickly offset by the resultant savings in operational carbon, and must be weighed against the waste and expense in embodied carbon of the alternative option, to demolish and rebuild.

Just one example, St Sophia's primary school in East Ayrshire, showed a carbon payback time (after which the operational carbon savings outweigh the embodied carbon of the retrofit) of only 6-7 years, and an embodied carbon cost 40% less than if it had been demolished and replaced.

The new mechanical, electrical and plumbing (MEP) services contribute half the embodied carbon of the total retrofit and are equal to all of the fabric improvement measures combined - see below.



This proportion would be even higher if heating demand was not significantly reduced using the EnerPHit methodology. This reinforces that simply changing the heating systems in our existing buildings without insulating and tackling air tightness means locking in high levels of embodied carbon into equipment that needs regular replacement and relies wholly on a decarbonising grid. Investing in the building fabric means less embodied and operational carbon, which results in a faster carbon payback.

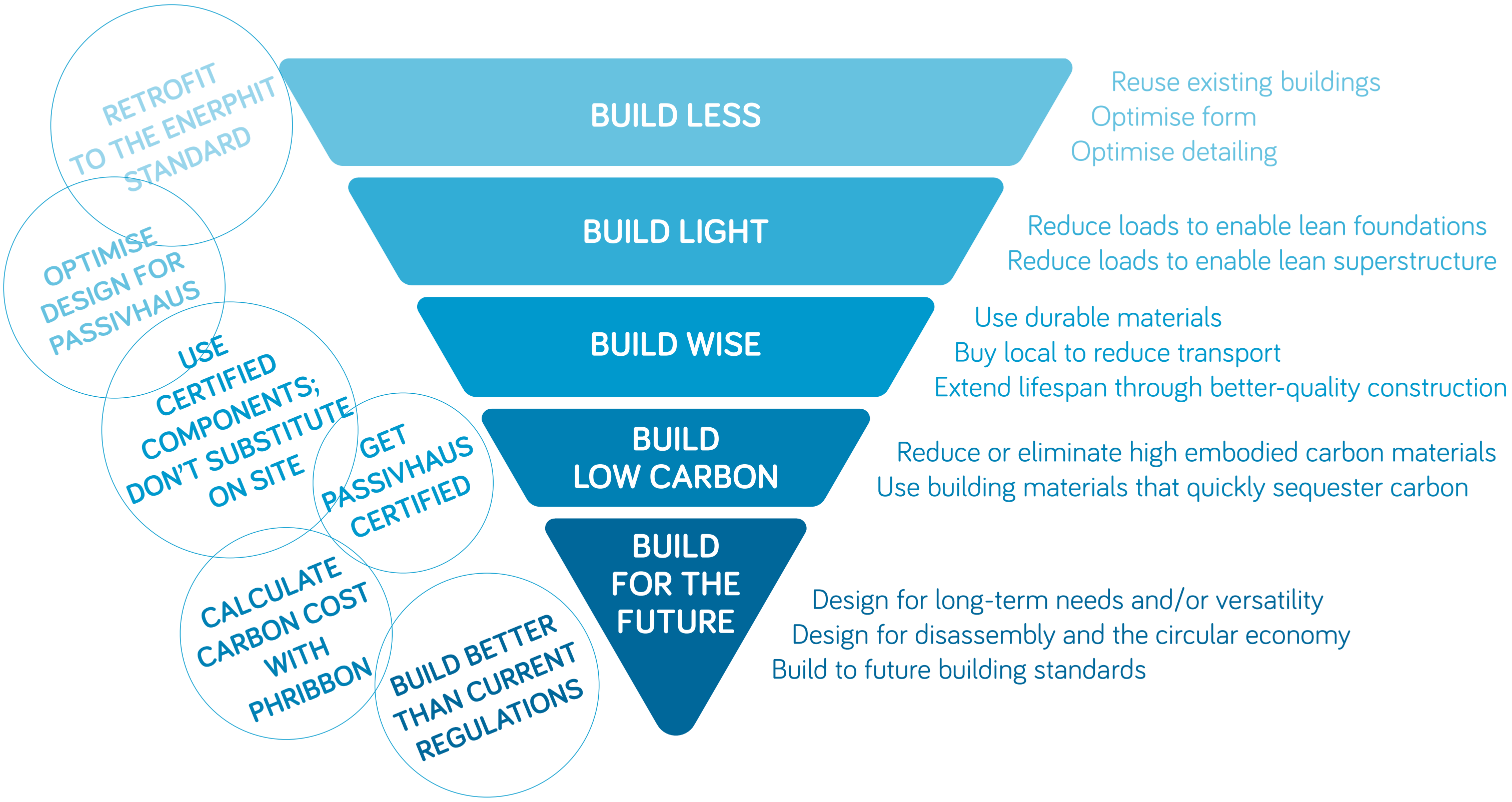


Embodied carbon of PV and offshore wind compared to grid carbon intensity

ON SITE RENEWABLE ENERGY

A rapidly decarbonising grid is also changing the embodied /operational calculations for on-site renewable technologies. If energy demand using the building fabric is not fully optimised, bolt-on technologies such as photovoltaics (PV) are often used to 'offset' carbon emissions. However, these technologies also have embodied carbon implications.

In addition, the carbon intensity of the grid does not include the embodied carbon of the infrastructure to generate electricity cleanly. To allow a true comparison, this needs to be factored into the calculations.



FURTHER STEPS TO REDUCE EMBODIED CARBON

We have seen that a certified Passivhaus building can have less embodied carbon, and will have a significantly smaller whole life carbon footprint, when compared like-for-like with one built to building regulations Is Passivhaus also compatible with additional measures taken to reduce embodied carbon, and how much difference can those measures make?

The answer is yes. The graphic above lists cradle-to-grave strategies any construction project can use to reduce embodied carbon on the right. On the left, it shows how Passivhaus helps with these., leading to the ultimate outcome of the lowest possible whole life carbon footprint.

CALCULATING CARBON COST

It's hard to reduce what you haven't counted, so accurate carbon calculations are essential. These calculations can be seamlessly integrated into the Passivhaus design process using the PHPP (Passivhaus Planning Package) add-on PHribbon. Building on the RICS Professional Statement on Whole Life Carbon, and incorporating a library of over 400 EPDs, PHribbon makes whole life carbon calculations quick to perform using the material quantities already embedded in a PHPP assessment.

CONCLUSION

The relationship between embodied and operational carbon is rapidly changing, as energy supplies decarbonise worldwide. The embodied carbon of construction materials is locked into a building, based on the energy supply conditions now, whereas operational carbon changes as energy supplies change which, at the moment, are steadily decarbonising. However, continuing to reduce energy demand is still important as it reduces peak loads which will reduce the level of future zero carbon energy infrastructure and storage needed.

Emerging research shows that designing to the Passivhaus standard, be that for new or existing buildings, does not need to result in increased embodied carbon and that choice of materials, rationalisation of build form and reduction of building services play a significant part in reducing whole-life carbon.

REDUCING OPERATIONAL AND EMBODIED CARBON IS NOT AN EITHER/OR CHOICE. WE MUST AIM TO TACKLE BOTH SIMULTANEOUSLY

Therefore, with a Passivhaus you get the multiple benefits of:

- **Reduced operational carbon**
- **Reduced whole life carbon**
- **Reduced operational and maintenance costs**
- **Increased summer and winter comfort**
- **Increased indoor air quality**

DOWNLOAD THE FULL REPORT

Other primers on operational carbon and retrofit are available to download online.