LETI Opinion Piece

Operational Carbon in Whole Life Carbon Assessments

Executive Summary

Reducing operational energy and embodied carbon are key to the reduction of the environmental impact of the built environment. As industry becomes more familiar with embodied and whole life carbon assessments, operational energy is more regularly converted to operational carbon within a whole life carbon approach. This analysis is increasingly used for scrutinising and evaluating design options, as well as quantifying the total impact of buildings.

(Operational Energy x Carbon Factor) + Embodied Carbon = Whole Life Carbon

This LETI Opinion Piece proposes a methodology for the conversion of operational energy into operational carbon, for the purpose of making design decisions. This methodology has been developed by a LETI workstream and aims to provide a basis for further analysis and discussion, through which this conclusion can be further refined.

Operational and embodied carbon emissions are interrelated, as well as varying in both numerical value and certainty over time. Central to these complexities are uncertainties around the decarbonisation of the UK electricity grid, alongside the interdependence of the amount of energy used by buildings and the ability of the UK grid to decarbonise.

The methodology proposed in this LETI Opinion Piece to convert operational energy operational carbon is a 'split carbon factor' method. In this method, a decarbonised carbon factor is applied to the electricity consumption that is below a LETI Energy Use Intensity (EUI) target, and a non decarbonised carbon factor is applied to electricity above a LETI EUI target.

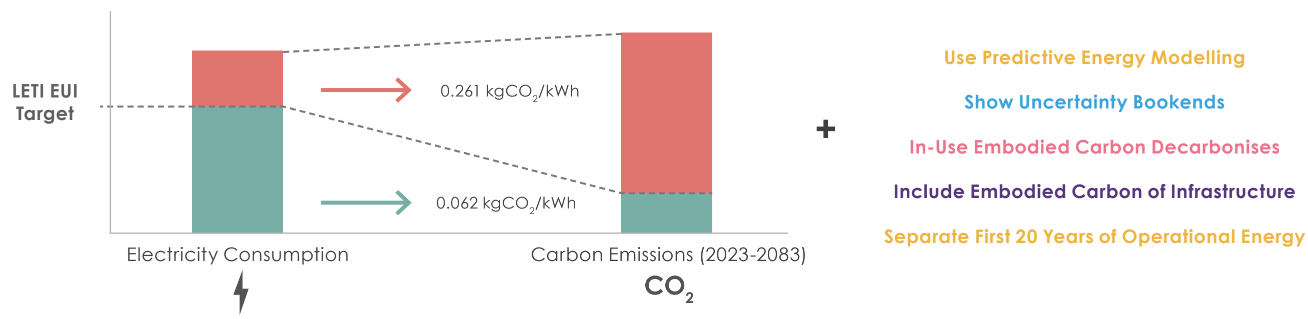


Figure 1 - Split carbon factor conversion methodology for electricity consumption

Every building must play its part and support the grid to decarbonise in an equitable way and this methodology accounts for buildings not benefiting from a decarbonised grid beyond their fair share. Further considerations include expressing uncertainty, the decarbonisation of future in-use embodied carbon emissions and inclusion of infrastructure embodied carbon which are illustrated on the dashboard below.

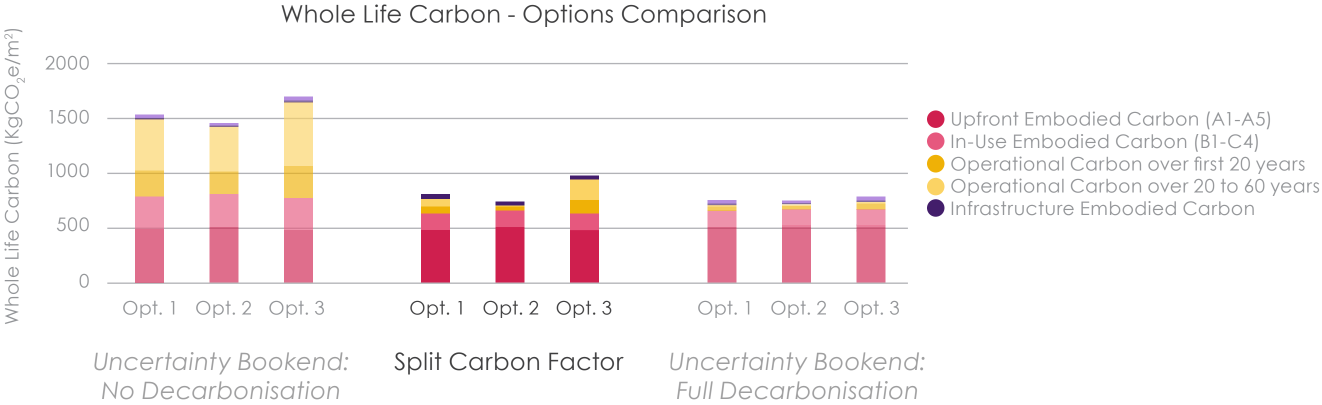


Figure 2 - Illustrative output 'dashboard' for proposed methodology. comparing three options (Opt.1, 2 and 3)

The above figure illustrates the proposed methodology reporting dashboard. Fundamental to the approach is the inclusion of two "uncertainty bookends", one showing scenario with no decarbonisation of the UK grid and the other a scenario with a fully decarbonised UK grid. Operational carbon in the next 20 years is indicated separately as this value has greater certainty than emissions over years 20 to 60 of a buildings' lifecycle. The dashboard also includes an allowance for the embodied carbon impact of the electricity grid within the whole life carbon calculations.

Operational Carbon Tool

LETI are developing a tool to carry out this analysis, which will be available through leti.uk/opinionpieces

This paper was put together by a LETI working group of about 50 built environment professionals. The group split into 5 sub working groups to explore the various methodologies which are further described in the Appendix to this study.

Explanatory notes

'***EUI***' - Energy Use Intensity (EUI, kWh/m².yr): the energy use per m² that is required by a building over a year, included regulated (i.e. domestic hot water, space heating and cooling, lighting, and ventilation) and unregulated loads (e.g. lifts, IT). It is a measure of the building's performance and therefore includes all energy supplied to the building, whether from the grid or on-site systems.

'***Carbon***' is used in this paper as a generic term to represent all GHG emissions, set out in BS EN 15978 as Global Warming Potential (kg CO_2 equivalent). GHG emissions also include methane and many refrigerants which are hugely impactful as multipliers of atmospheric warming.

'***Operational energy***' is all energy used by an asset in-use over its life cycle, which includes regulated and unregulated uses.

'***Operational carbon***' is the GHG emissions arising from energy used by an asset in-use over its life cycle.

The points raised in this piece often hold in general but may vary in differing specific contexts. The nuances underlying the impacts of many design decisions means they should, wherever possible, be supported by the calculation of carbon and WLC metrics.

It should be noted that the quantity of onsite renewables that should be installed can not be tested by the methodologies that are explored in this paper.

1.0 Introduction

1.1 Whole life carbon

'Whole life carbon' emissions are the sum total of all asset related GHG emissions and removals, both operational and embodied, over the life cycle of an asset, including its disposal (Modules: A1-A5; B1-B7 (plus B8 and B9 for Infrastructure only); C1-C4). Overall whole life carbon asset performance includes separately reporting the potential benefit from future energy recovery, reuse, and recycling (Module D).

SIGNPOST *leti.uk/carbondefinitions*

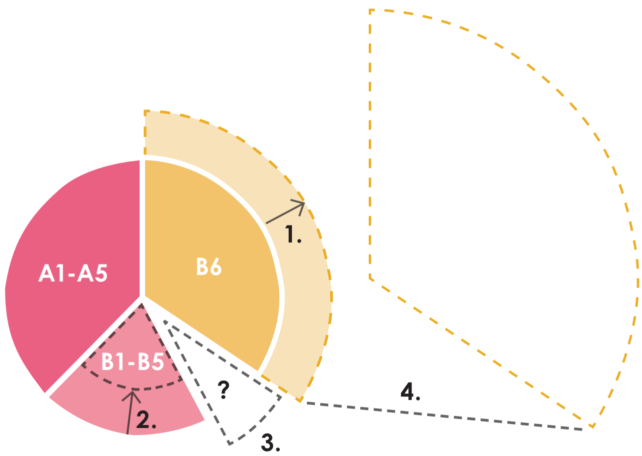
1.2 How to carry out a whole life carbon assessment

A Whole Life Carbon Assessment is an estimation of the whole life carbon associated with a building. This typically includes carrying out a Lifecycle Embodied Carbon assessment, and an assessment that predicts the energy consumption of the building (for example CIBSE TM54 or a PHPP assessment).

1.3 Outlining the problem

Part of the purpose of carrying out an embodied carbon assessment is to look at design options available that reduce the embodied carbon of a building. Similarly, part of the purpose of carrying out an operational energy assessment is to look at design options that reduce the operational energy of a building.

Bringing these two assessments together, so that the whole life carbon implications can be evaluated, is positive in principle, as unintended consequences of a design solution can be better understood. Yet, problems arise where there is a trade off between operational and embodied carbon. How do we value the potential for grid energy reduction in the future, relative to embodied carbon which we emit now?



1. **Compliance modelling underestimates energy consumption**
2. **Future decarbonisation of embodied carbon not included**
3. **Embodied carbon of energy infrastructure not included**
4. **Normally an average grid carbon factors is applied to the predicted energy consumption, that represents the average carbon emissions associated with electricity generation over the next 60 years. The RICS PS requires a decarbonised result to be presented as well, but both results are not often shown in assessments**

Figure 2 - Challenges in combining embodied and operational carbon within a whole life carbon approach

There are many related factors relevant to both the construction of the building and what a relevant carbon factor for the electricity grid would be over the next 60 years.

As we move to a lower carbon grid, we will need to construct more renewable energy, which in itself requires embodied carbon to build. Lowering the combined peak demand on the grid and increasing the ability to shift peak loads will need fewer renewables and energy storage infrastructure to be built. Thus the ability for the grid to decarbonise over the next 60 years partly depends on the energy consumption of existing buildings and new buildings that are constructed.

In addition, with a future fully decarbonised grid that is powered by renewables, (solar, wind, tidal, wave) the energy supply is inherently intermittent. The amount of electricity is governed by how much the sun is shining, whether it is windy etc. This means our future grid will need to have more storage capacity in order to deal with the peaks and troughs. However, storage is expensive (both financially and in terms of embodied carbon) and the greater the peaks and troughs, the more storage will be needed. Thus if a building is flexible in when it needs electricity, it helps the grid decarbonise. These themes are explored in more details in this paper.

Complexities and interrelationships with bringing together operational energy and embodied carbon:

→ Decarbonisation: Typically no decarbonisation is applied to embodied carbon. Installing a window in year 0 and year 30 has the same embodied carbon in a WLC assessment, even though it is much more likely that the embodied carbon relating to the window installed in 30 years time will be much lower, as fossil fuels are replaced and energy supplies and materials decarbonise. This is particularly problematic if the benefit of a design feature with additional embodied carbon reduces operational energy, but only the operational energy is subject to decarbonisation and the whole life embodied carbon is not.
→ Embodied carbon of energy infrastructure: is not usually taken into account.
→ Demand response and flexibility: carbon benefits of implementation at scale cannot be quantified, unless the embodied carbon footprint can be compared against the operational carbon benefit, which requires calculations using dynamic carbon factors with high temporal resolution.
→ Renewable procurement: how the electricity is procured will affect the carbon factors associated with the electricity consumption.

The different reasons for carrying out Whole Life Carbon Assessments

There are various reasons for carrying out a WLC assessment, and depending on the driving factors behind the assessment, it may be relevant to use a different method for converting operational energy to operational carbon. Reasons for carrying out a WLC assessment:

→ Making design decisions- i.e. understanding trade offs between operational energy and embodied carbon (Concept stage / Detailed design stage)
→ Comparing the whole life carbon of different projects, or a project against a benchmark (Concept stage/ Detailed design stage)
→ Predicting the whole life carbon of an asset, in order to understand the likely carbon offsetting costs in the future (Concept stage / Detailed design stage)
→ Embodied carbon assessment updated based on as built values (Practical completion)
→ Use stage: annual reporting based on metered energy consumption and embodied carbon relating to annual repair, maintenance and replacement. (Use stage)

This paper seeks to understand the most appropriate method for converting operational energy to operational carbon for the purpose of making design decisions - i.e. understanding trade offs between operational energy and embodied carbon – as noted above.

2.0 Proposed Methodology

2.1 Criteria for methodology selection

It is important that the carbon conversion methodology:

→ Can be easy to implement
→ Can be amended and adapted when carbon related to electricity grid projections are updated
→ Is based on a publicly available, regularly updated dataset
→ Drives the right outcomes
→ Doesn't create a perceived 'performance gap'
→ Can be applied to all building types
→ Can be applied to different case scenarios

2.2 Conclusions

As an industry we are still very much learning about the interrelationships between operational energy and embodied carbon and the uncertainties when bringing the two together in a Whole Life Carbon Assessment. We have explored these known uncertainties and interrelationships in this paper, however more are likely to emerge.

Bringing operational energy and carbon together is complex, and should only be carried out by those that fully understand the subject and its uncertainties. Operational energy and embodied carbon can be brought together in various ways, and can be easily 'gamified' such that the outcomes change depending on the methodologies used. It is important that the method produces the correct incentives as the grid decarbonises, ensuring it is fit for purpose to get us to net zero.

The methodology used to bring operational energy and embodied carbon together should be different depending on the purpose of the assessment. This paper focuses on the design stage, where decisions are being made on design options, where a design option increases either operational energy or embodied carbon and decreases the other.

Due to uncertainties of the decarbonisation pathway of the UK grid, and the relationship between the amount of energy used by buildings and the ability of the UK grid to decarbonise, this paper concludes that the central methodology that should be used to understand the trade offs between operational energy and embodied carbon is the 'split carbon factor' method. In this method a decarbonised carbon factor is applied to the electricity consumption that is below the LETI EUI target, and a non decarbonised carbon factor is applied to electricity above the LETI EUI target.

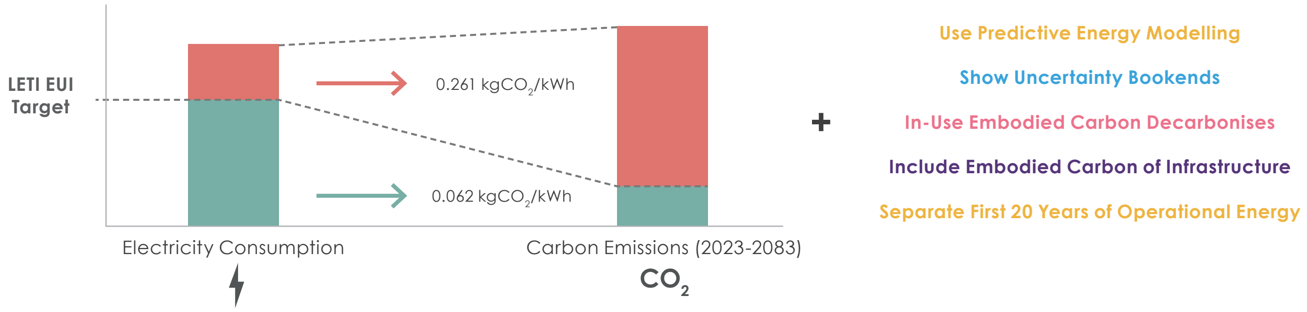


Figure 3 - Split carbon factor conversion methodology for electricity consumption

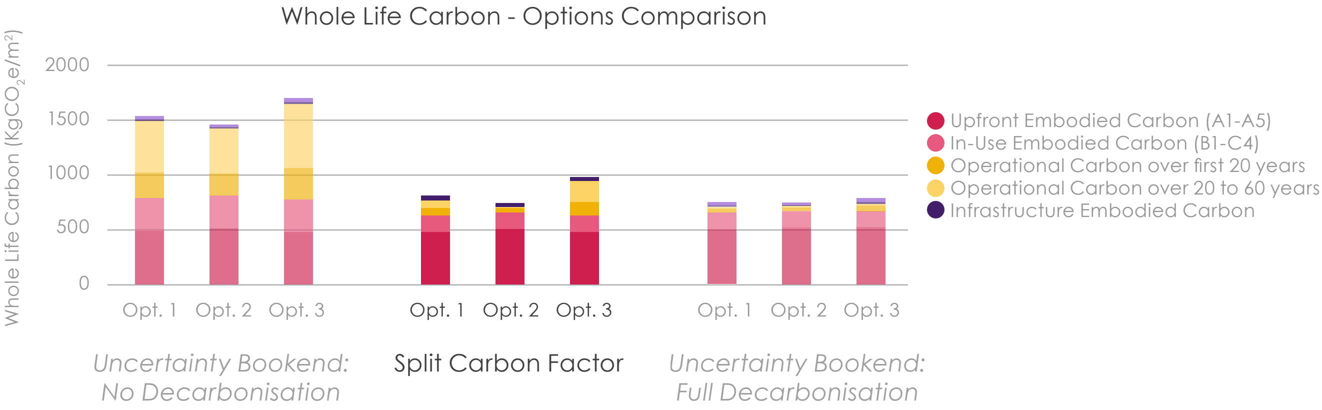


Figure 4 - Illustrative output 'dashboard' for proposed methodology. comparing three options (Opt.1, 2 and 3)

Our solution recognises that every building must play its part and support the grid to decarbonise in an equitable way, and thus buildings that use more energy than their fair share cannot use the benefit of the decarbonised grid as they don't actively support the grid to decarbonise.

The method also includes the embodied impact of the electricity grid within the whole life carbon calculations.

Fundamental to the approach is that, when whole life carbon results are presented, they must be shown in the context of 'uncertainty analysis' book ends, one showing a non decarbonised grid, and the other showing a fully decarbonised grid.

Items to note:

LETI provides EUI target for homes, offices and schools only, thus this method is only applicable to these typologies. However it is important to note that the UK Net Zero Buildings Standard, which is currently being developed, will produce Net Zero aligned EUI targets for a larger variety of building typologies.

This 'split carbon factor' methodology requires a bit of refinement. It is suggested that decarbonisation factors should be applied to module B and C embodied carbon (this could be at a flat rate, or could be used only for the embodied carbon that is below the net zero embodied carbon limit).

3.0 Next Steps

This LETI opinion piece sets out how the 'operational carbon in whole life carbon' working group believes that operational energy should be converted in operational carbon for use in whole life carbon assessments, for the purpose of making design decisions.

The next steps are to gain wider consensus on this topic, and look to establish this methodology more widely by engaging with RICS, UKGBC and others.

Actions for LETI

→ **Option B - the hourly approach**, was not explored fully in this paper, due to availability of case studies. In order for this approach to be further explored, we need to understand how to assess the benefits of thermal and battery storage and energy flexibility. This will be the subject of a separate LETI Opinion Piece.

→ LETI is developing a **guide to operational energy modelling** which will provide advice on how to carry out performance/predicted modelling, (often called TM54 or EUI modelling). This new guide will provide support on why and when this type of modelling is needed, how to carry out the required modelling and how to get maximum value for the project out of this modelling exercise.

Actions for Industry

→ Establish realistic **energy profiles for regulated and unregulated energy**. Access to current profiles of actual energy use in operation will support realistic performance energy modelling.

Help LETI develop this topic further by submitting case study information

Limited case studies were available that had assessed both operational energy and embodied carbon and looked at design options that explore trade offs between operational carbon and embodied carbon.

LETI is keen to explore this further and develop a deeper understanding of the design decisions that are taken due to trade offs in whole life carbon, and what the different methodologies that are explored in this paper incentives.

Download the data input spreadsheet here and submit to admin@leti.uk

Your comments

This is an evolving topic, and LETI are interested in your views on this paper. Please submit your comments by emailing admin@leti.uk, and to register your interest to support LETI with further work in this field.

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Notes and references

[1] LETI EUI/New Zero EUI targets: Energy Use Intensity (EUI, kWh/m2 .yr): the energy use per m2 that is required by a building over a year, included regulated (i.e. domestic hot water, space heating and cooling, lighting, and ventilation) and unregulated loads (e.g. lifts, IT). It is a measure of the building's performance and therefore includes all energy supplied to the building, whether from the grid or on-site systems. The UK Net Zero Buildings Standard, being developed, will produce Net Zero aligned EUI targets for a large variety of building typologies

[2] Life Cycle Modules definitions set out in BS EN 15978.

Upfront embodied carbon covers modules A0-A5 and excludes the biogenic carbon sequestered in the installed products at practical completion.

Life cycle embodied carbon covers modules A1-A5, B1-B5, C1-C4.

Operational energy covers module B6.

[3] GHG - Greenhouse Gasses are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the Earth's surface, the atmosphere itself and by clouds. This property causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary GHGs in the Earth's atmosphere. Moreover, there are a number of entirely human-made GHGs in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances, dealt with under the Montreal Protocol. Beside CO_2, N_2O and CH_4, the Kyoto Protocol deals with the GHGs sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). See also Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O) and Ozone (O_3).

[4] Whole Life Carbon Assessment, methodology as defined in the RICS "Whole Life Carbon Assessmnent for the Built Environment", 1st Edition, November 2017.

[5] PHPP - the PassivHaus Planning Package is a planning tool for calculating buildings energy efficiency.

[6] CISBE TM54: methodology for evaluating operational energy performance of buildings at the design stage.

[7] SAP - Standard Assessment Procedures, is the government's method for calculating the energy performance of dwellings. These calculations are only necessary for residential properties.

[8] DUKES Table 1.14 - Estimated carbon dioxide emissions from electricity supplied [https://www.gov.uk/government/statistics/electricity-chapter-5-digest-of-united-kingdom-energy-statistics-dukes].

[9] DEC - Display Energy Certificate [https://www.gov.uk/government/publications/display-energy-certificates-and-advisory-reports-for-public-buildings/a-guide-to-display-energy-certificates-and-advisory-reports-for-public-buildings],

[10] NABERS - National Australian Built Environment Rating System, administred by BRE, provides reliable, and comparable sustainability measurement for offices only at this stage and it is expected to be expanded to other sectors.

[11] UK Net Zero Carbon Buildings Standard is being developed by leading industry organisations: BBP, BRE, the Carbon Trust, CIBSE, IStructE, LETI, RIBA, RICS, and UKGBC, who have joined forces to champion this initiative.

[12] UKGBC Renewable Energy Procurement and Carbon Offsetting Guidance for Net Zero Carbon Buildings [https://www.ukgbc.org/ukgbc-work/renewable-energy-procurement-carbon-offsetting-guidance-for-net-zero-carbon-buildings/]

[13] IPPC Climate Change 2022: Mitigation of Climate Change [https://www.ipcc.ch/report/ar6/wg3/].

[14] Nature Energy - Understanding future emissions from low-carbon power systems by integration of life-cycle assessment and integrated energy modelling [https://www.nature.com/articles/s41560-017-0032-9].

[15] Department for Business, Energy & Industrial Strategy (2022) Fuel Mix Disclosure Data Table.