eHome2

Barratt Redrow

SAINT-GOBAIN

EXECUTIVE SUMMARY

WHOLE LIFE CARBON ASSESSMENT

MAY 2025

SAINT-GOBAIN

1.0

Summary

A whole life carbon assessment (WLCA) has been carried out on a high-performance house design called eHome2, developed by Saint-Gobain, Barratt Redrow, the University of Salford and other stakeholders. The work was carried out according to the Royal Institution of Chartered Surveyors (RICS) WLCA methodology and considered three alternative construction methods representing traditional, heavy construction (masonry cavity wall with polyisocyanurate (PIR) insulation), modern methods of construction (offsite timber I-Stud panel manufacture incorporating the use of a lighter weberwall cladding) and a hybrid of the two (offsite timber I-Stud panel manufacture, with on-site brick cladding). The focus was on embodied carbon from the use of materials.

Further information about sources of data, methodology and assumptions can be found in this report. Key conclusions from the study were:

• Use of timber I-Stud with weberwall is estimated to reduce upfront carbon (comprising emissions up to and including construction) of eHome2 by 21% compared to the same house built with a traditional masonry cavity wall with PIR insulation. If biogenic carbon (ie. carbon associated with renewable materials such as timber) is included, the upfront carbon emission saving increases to 57%.

• If a brick façade is used in place of weberwall, the upfront carbon saving is reduced to 7%. If biogenic carbon is included, the carbon emission saving increases to 35%.

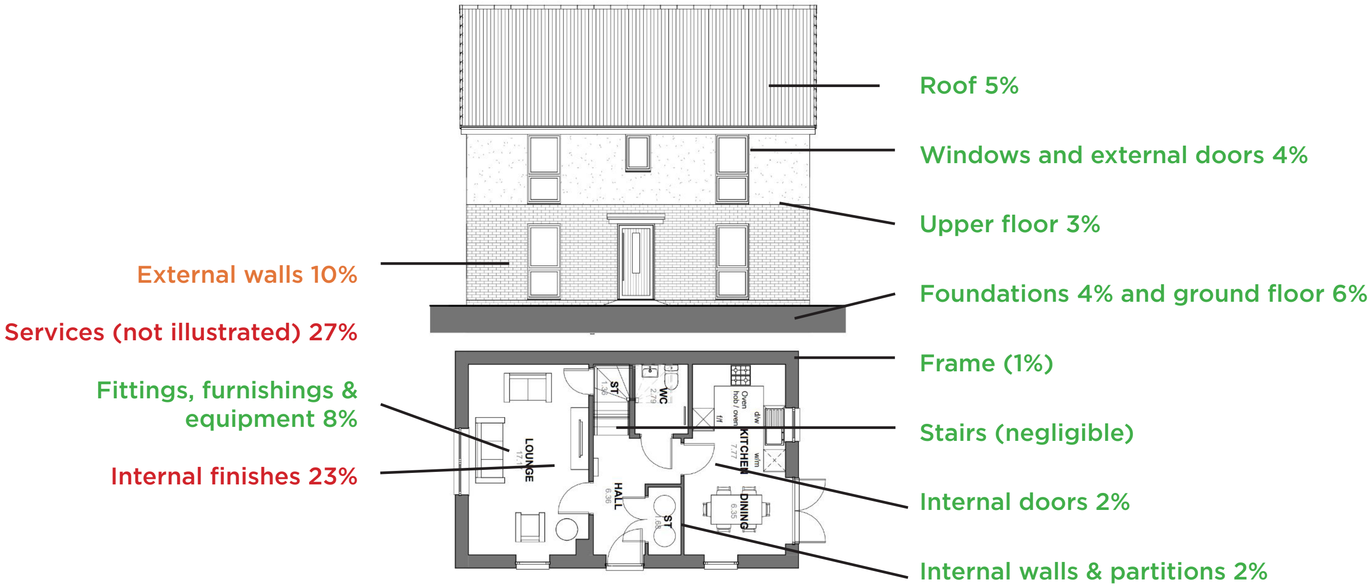
• The overall estimated carbon saving (excluding biogenic carbon) when using timber I-Stud with weberwall is 8 – 9.5 tonnes CO_2e per home compared to use of traditional masonry cavity walls with PIR insulation. The magnitude of carbon saving depends on the type of bricks being used (clay, concrete or sand lime). This saving is 2 – 3.4 tonnes CO_2e per home when timber I-Stud is used with a brick façade.

• Across the life cycle (which additionally includes maintenance and replacement of materials, when necessary, the use of the home over 60 years and its end-of-life) the timber I-Stud with weberwall combination produces an 11% life cycle embodied carbon saving compared to a traditional masonry cavity wall with PIR insulation, and 4% if the timber I-Stud is used with a brick cladding.

• Most of the calculated climate change impact of eHome2 arises from services and internal finishes common to all three options. The figure below illustrates how different elements in eHome2 contribute to life cycle embodied carbon emissions.

• The external wall construction makes the largest contribution to differences in results between the three options. The lighter timber I-Stud external wall construction also leads to a small decrease in the embodied climate change impact of the foundations, saving around 1 tonne CO_2e in absolute terms, compared to the heavier masonry external wall construction (which requires more foundations).

Where is the embodied carbon in eHome2?



*4% from construction activities not assigned to specific elements

Note 1: Based on life cycle emissions for the timber I-Stud with weberwall option.

Note 2: May not add to 100% due to rounding.

The study has enabled Saint-Gobain to understand better how its products contribute to the embodied carbon emissions of houses, and how Saint-Gobain's solution can help the industry build homes that are high-performing with a lower carbon footprint throughout the homes' life cycle.

2.0 Glossary

Acronym or term	Definition
Biogenic carbon	Carbon that is associated with biological materials. It may be sequestered, for example, through photosynthesis by growing trees in a sustainable forest plantation, which are subsequently harvested to manufacture construction products. Biogenic carbon may also be emitted, for example, due to combustion of waste timber, to provide heat and/or generate electricity. Including biogenic carbon sequestration has the effect of lowering upfront carbon. At end-of-life, the sequestered carbon dioxide in a material is either emitted, for example through incineration, or is accounted as returning to atmosphere if the material is reused, recycled or landfilled. When results exclude biogenic carbon, they are termed as “gross” emissions, and “net” emissions when biogenic carbon is included.
Embodied carbon (or life cycle embodied carbon)	Total greenhouse gas emissions and removals associated with materials and construction processes, throughout the whole life cycle of an asset (adapted from [1]).
Energy House 2.0	The University of Salford’s Energy House 2.0 facility was completed in February 2022 and is the largest research facility of its type. Inside, there are two environmental chambers, each able to accommodate two detached houses and under controlled conditions, recreate a wide variety of weather conditions with temperatures ranging between -20˚C to +40˚C and simulated wind, rain, snow and solar radiation. With this capability, the facility can simulate weather associated with possible future climate scenarios.
kg CO_2e	Units used to express a climate change impact or Global Warming Potential (GWP), normally over 100 years following greenhouse gas emission. May also be expressed in other units of mass such as tonnes CO_2e. Carbon dioxide (CO_2) is the reference gas used for calculating climate change impact. The impact that emissions of other greenhouse gases have on climate change in comparison with carbon dioxide, is calculated using GWPs. Thus, carbon dioxide has a GWP of 1, and other greenhouse gases may have GWPs that are higher or lower than 1, depending on their relative contribution to climate change, compared to carbon dioxide.
MMC	Modern methods of construction
Modern methods of construction	Encompasses off-construction site, near-construction site or on-site premanufacturing. It is divided into seven categories, of which Category 2 concerns structural panelised systems (based on [2]).
Operational energy	Greenhouse gas emissions arising from regulated energy use (space heating, hot water, lighting, pumps and fans) and may, additionally, include unregulated energy use (for example, cooking and plug loads).
Part L	The UK building standard focussed on energy efficiency.
Regulated energy	See Operational energy.
SAP	UK Government’s National Calculation Methodology for assessing the energy performance of dwellings [3]
Upfront carbon	Greenhouse gas emissions associated with materials and construction processes up to practical completion. Excludes the biogenic carbon sequestered in the installed products at practical completion (adapted from [1]).
WLC(A)	Whole life carbon (assessment)
Whole life carbon (assessment)	(Assessment of) the sum of all asset-related greenhouse gas emissions and removals, both operational and embodied, over the life cycle of an asset, including its disposal (adapted from [1]).

3.0

Introduction

Saint Gobain, Barratt Redrow, the University of Salford and other stakeholders developed a high-performance concept house design called eHome2. Focus Consultants and Saint Gobain have carried out a whole life carbon assessment (WLCA) of seven design alternatives based primarily on the choice of external wall build-ups. This Executive Summary focusses on three of the seven options, representing different construction methods. Since there is a negligible difference in the operational carbon performance of each of the alternatives, the WLCA study focussed on embodied carbon only, according to the RICS WLCA methodology [4].

Figure 1 Rendered image of eHome2

eHome2 (Figure 1) is a two-storey, 3 bedroom detached home with a gross internal floor area (GIA) of 92 m^2. It is the result of a collaboration between Saint-Gobain, Barratt Redrow, University of Salford and other stakeholders, which sought to design and build a home that can meet anticipated performance levels in the Future Homes Standard [5], including net zero carbon emissions from regulated energy.

Table 1 provides a summary of the home's SAP rating (based on SAP 10.2), with floor plans and elevations in Figure 2.

Table 1 eHome2 calculated Standard Assessment Procedure (SAP) performance levels.

Specification	Measure	SAP rating
Operational carbon emissions (kg CO_2eq / m² floor area)	Target Emission Rate (TER)	28.73
	Dwelling Emission Rate (DER)	-1.92 (I-Stud with brick or weberwall), -1.91 (masonry with PIR)
	% improvement	**106.7%**
Energy demand (kWh / year)	Target Fabric Energy Efficiency (TFEE)	63.5
	Dwelling Fabric Energy Efficiency (DFEE)	45 (I-Stud with weberwall), 44.9 (I-Stud with brick), 46.8 (masonry with PIR)
	% improvement	**26-29%**

eHome2 has now been built in the University of Salford's test facility called Energy House 2.0 [6], providing valuable information on measured performance under a range of controlled conditions [7] .

As a manufacturer of many of the building materials in eHome2, Saint-Gobain wants to understand better the embodied carbon of the home and compare it with alternative construction methods that meet the same operational performance in terms of energy and water use.

The three key reasons for this are:

• The significance of embodied carbon emissions increases in more energy-efficient houses that have lower operational carbon emissions.

• A large proportion of embodied carbon emissions occur early in the life cycle of a house, meaning greenhouse gases can accumulate in the atmosphere earlier, contributing to climate change.

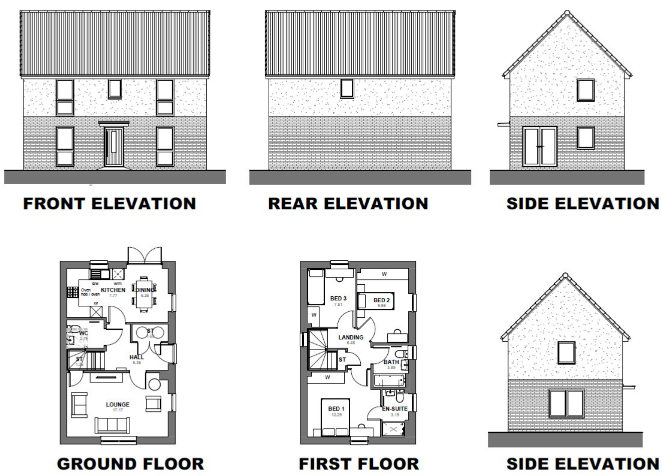


Figure 2 eHome2 floorplans and elevations

• To identify areas to improve the embodied carbon of products used in the house design.

For this reason, Saint Gobain commissioned and worked with Focus Consultants to undertake a whole life carbon assessment (WLCA). The study was carried out according to requirements set out in international life cycle assessment standards ISO 14040 [8] and ISO 14044 [9] and the RICS Whole Life Carbon Assessment methodology [4].

4.0

Goal and scope of the study

The purpose of the study was to compare life cycle embodied carbon and upfront carbon emissions as a result of materials used in eHome2 built at the Energy House 2.0 facility, and compare this with six other possible construction alternatives for the same house design. Each of the design options has the same GIA and performance characteristics (Table 1).

This Executive Summary focusses on three of the seven options evaluated in the full study, to illustrate results based on methods of construction, as follows:

- **Option 1** – representing traditional on-site, heavy construction.
- **Option 2** – representing a hybrid of Options 1 and 3.
- **Option 3** – representing an example of modern methods of construction (MMC), with off-site manufacture and use of lighter materials. This option was constructed at the Energy House 2.0 facility.

It is intended for those with an interest in the study outcomes, including Saint Gobain customers, designers, specifiers, builders and consumers.

The assessment is for one eHome2 dwelling over 60 years. The WLCA did not consider other important considerations when designing and building a home, such as acoustics and fire risk.

4.1

Life cycle stages within the scope of the study

The life cycle of a building is described by RICS in its WLCA methodology [1] and illustrated in Figure 3. Referring to Figure 3, several modules were omitted from the study, summarised in Table 2.

Table 2 Life cycle modules omitted from the study scope

In-Use stage life cycle module	Type of carbon	Reason for omission from study
B1	Embodied	This module concerns emissions from materials or products in-use. Options in the study were not significantly different to warrant inclusion.
B5	Embodied	This module concerns major refurbishment, for example, the addition of an extension or conservatory during the In Use phase. These events are related to occupant decisions and are uncertain, so were not included.
B6	Operational energy	Assessed options have very similar performance characteristics (Table 1) so energy use is almost identical (based on SAP calculations as required under Part L of the Building Regulations). Whilst calculated in the full report, it is omitted from this summary which focusses on embodied carbon.
B7	Operational water	This module concerns water supply and removal. Assessed options have the same water use. This was not assessed.

Percentage differences between options in this report are calculated excluding the modules listed in Table 2.

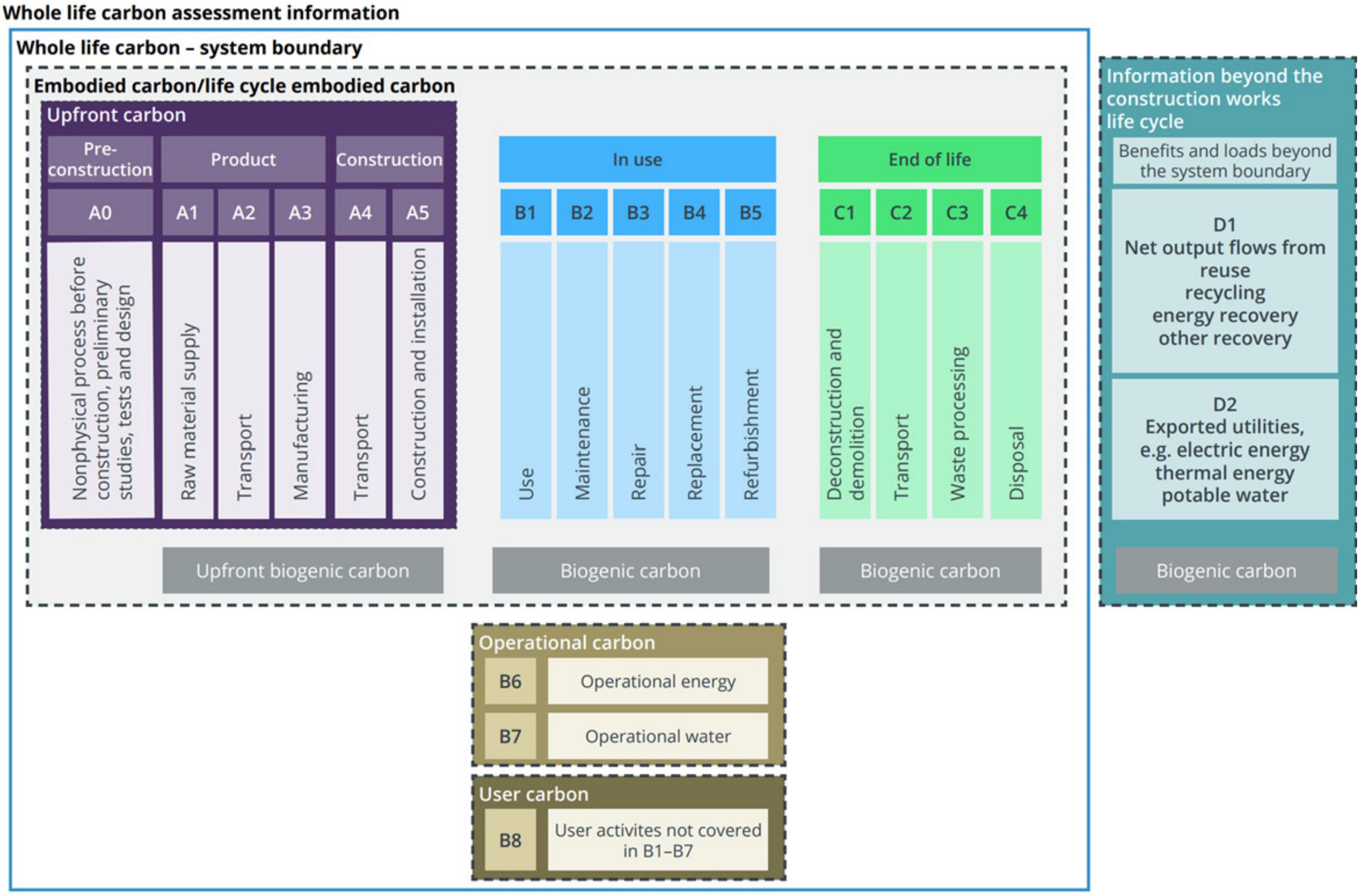


Figure 3 The building life cycle (taken from the RICS WLCA methodology)

4.2

Building elements within the scope of the study

Building elements (based on RICS building element categories [10]) included in the study are summarised in Table 3.

Table 3 Building elements included in the study according to RICS building element classifications

Scope	Element breakdown	Study terminology	Designation	Materials
1 Substructure	1.1 Foundations and piling	Standard foundations	Variable	Concrete strip. See Table 4
	1.2 Basement retaining walls and lowest slab		Fixed	Nuspan precast concrete insulated slab
2 Superstructure	2.1 Frame		Variable	See Table 4
	2.2 Upper floors		Fixed	Timber Posi-joists
	2.3 Roof		Fixed	Trussed pitched roof with concrete tiles
	2.4 Stairs, ramps and safety guarding		Fixed	Timber
	2.5 External envelope including roof finishes	External walls	Variable	See Table 4
	2.6 Windows and external doors		Fixed	uPVC frame, Planitherm One T low-e coated double glazing
	2.7 Internal walls		Fixed	Timber stud, British Gypsum plasterboard
	2.8 Internal doors		Fixed	Timber
3 Finishes	3.1 Wall finishes	Internal finishes	Fixed	Plaster, paint, carpet, wood flooring, tiling
	3.2 Floor finishes		Fixed	
	3.3 Ceiling finishes		Fixed	
4 Fittings, furnishings and equipment (FFE)	4.1 FFE		Fixed	Kitchen, sanitary ware
5.2 Heating, ventilation and air conditioning (HVAC)	5.2.1 Space heating and hot water	Services	Fixed	Mechanical Ventilation with Heat Recovery (MVHR), air-source heat pump (ASHP), photovoltaic panels and battery storage
	5.2.3 Air movement		Fixed	
5.4 On site renewable energy generation	5.4.1 On site renewable energy generation		Fixed	

Of the building elements shown in Table 3, only three show any variation, either with respect to amount and/or type of materials used, summarised in Table 4.

Table 4 Building elements varied in this Executive Summary

Element	Option 1: Masonry (PIR)	Option 2: I-Stud (brick)	Option 3: I-Stud (weberwall)
Frame	-	Timber frame	Timber frame
External Walls	Brick/block cavity wall with PIR insulation	MMC – Category 2 closed panel timber frame, glass wool insulation with traditional brick façade	MMC – Category 2 closed panel timber frame, glass wool insulation with lightweight façade system (weberwall [11])
Standard Foundations	Concrete strip	Concrete strip	Concrete strip

4.3 Modelling

Modelling to calculate life cycle embodied and upfront carbon emissions was undertaken in 2023 using the One Click LCA package [12]. One Click LCA provides users with access to a large database of materials, including both generic and manufacturer specific data. The calculation tool used within One Click LCA is developed for the purpose of compliance with the RICS WLCA methodology.

4.4 Assumptions

The following assumptions were used in the study:

- The home is built as specified and detailed, and based on good standards of construction.
- Occupancy and use of energy and water are the same across evaluated alternatives and are therefore excluded from the assessment.
- The home is well maintained in accordance with manufacturers' guidance.
- All timbers and engineered woods are obtained from sustainable forestry management.
- The home is not materially altered during the In-use phase e.g. addition of an extension.
- During the end-of-life stage, the RICS guidance factor of 3.4 $kgCO_2eq./m^2$ was applied to account for demolition.
- Default material end-of-life scenarios (reflecting the proportion of each material that is diverted from landfill or goes to landfill) in One Click LCA were used. The exception to this was Weber's fast-fix, lightweight brick system called weberwall. While One Click LCA deemed each of the weberwall components as being recyclable, a conservative approach was taken in which the system was assumed to be landfilled. Table 5 summarises end-of-life scenarios for a selection of materials featured in the study.

Table 5 End-of-life scenarios for a selection of materials in the study

	End-of-life module (from Figure 3)*		
Materials	**module C3**	**Module C4**	**Module D**
Bricks	Crushed to aggregate	N/A	Aggregate used in construction
Blocks	Crushed to aggregate	N/A	Aggregate used in construction
weberwall	N/A	Inert landfill	N/A
Steel	Recycling	N/A	Recycled to rebar
Timber	Incineration	N/A	Energy from waste incineration
Mineral wool	N/A	Inert landfill	N/A
PIR	N/A	Inert landfill	N/A

* In reality, end-of-life of materials is likely to be a combination of routes based on the quality of materials, the presence of contaminants etc. Hence, the modelled end-of-life routes are simplified and potential benefits (or loads) from diverting materials from landfill (Module D) are reported separately.

4.5

Data collection and data quality

The I-Stud (weberwall) version of eHome2 built at Salford University's Energy House 2.0 facility had a bill of materials, which was utilised to establish the material quantities. Material quantities for other design options were developed through a combination of material take-offs, design information, and standard industry estimations. Cost plans developed for the study were detailed, with only minor items missing, such as some fixings. The estimated total mass of materials missing from the assessment for each option has been estimated at no more than 5%.

Embodied carbon data for materials in One Click LCA can be specific e.g. from Environmental Product Declarations (EPDs) or generic e.g. ecoinvent 3.8. Data quality checks for compliance with the RICS WLCA methodology are understood to be undertaken by One Click LCA before incorporating new data into their databases.

In this study, EPD data for Saint-Gobain and partners' products were used in preference, defaulting to generic data to fill any data gaps. Table 6 summarises the sources of data used for embodied carbon calculations for the main materials in each of the variable building elements (Table 4), according to the estimated materials cost. The main difference is in the external walls/frame. This shows a higher proportion of good quality data from product-specific EPDs (11%) is used in embodied carbon calculations for the I-Stud (weberwall) option, in comparison with the Masonry (PIR) option, which uses 20% generic data.

Table 6 Analysis of the distribution of data sources for carbon emission calculations based on estimated spend (Options 1 and 3 only)

Building element (varied in study)	Source of embodied carbon data	% by estimated spend (£)	
		Option 1: Masonry (PIR)	Option 3: I-Stud (weberwall)
External wall / Frame	Product-specific EPD	0	11
	Sector average EPD	80	89
	Generic	20	0
Standard foundations	Product-specific EPD	0	0
	Sector average EPD	0	0
	Generic	100	100

When selecting data to use to represent materials in eHome2, the LCA practitioner preferred to use datapoints that were familiar, have been used previously on other projects and were known to be good quality. In the remaining cases, datapoints were checked for quality by considering the following:

- The programme operator by whose standards the EPD had been verified and published.
- The declared or functional unit of the data and its alignment with the target material or product.
- The age of the data.
- The absence or otherwise of data-quality warnings placed on a datapoint by One Click LCA through their own data quality checks.

eHome2 models were developed in One Click LCA, from which climate change impact results were extracted to Excel for analysis.

4.6 Sensitivity analysis

Given the finding in Table 6, a sensitivity analysis was carried out which used mainly generic data (from ecoInvent 3.8) instead of EPD data for materials, to understand how robust the results are to the selection of different data sources.

In this study, clay brick was used to represent masonry. A sensitivity analysis was additionally carried out to test the robustness of findings when different types of bricks are considered. This additionally included bricks made from concrete and sand lime.

5.0 Life cycle impact assessment

Climate change impacts (as $kgCO_2e$) were calculated as required by the RICS WLCA methodology. When normalised for floor area, total results are divided by 92 m^2.

5.1 Life cycle embodied and upfront embodied carbon – overall findings

Figure 4 summarises the calculated life cycle and upfront embodied carbon results for the three eHome2 options over a 60-year period, based on figures presented in Table 7. The graph on the left of Figure 4 depicts results excluding biogenic carbon, whereas the graph on the right includes biogenic carbon.

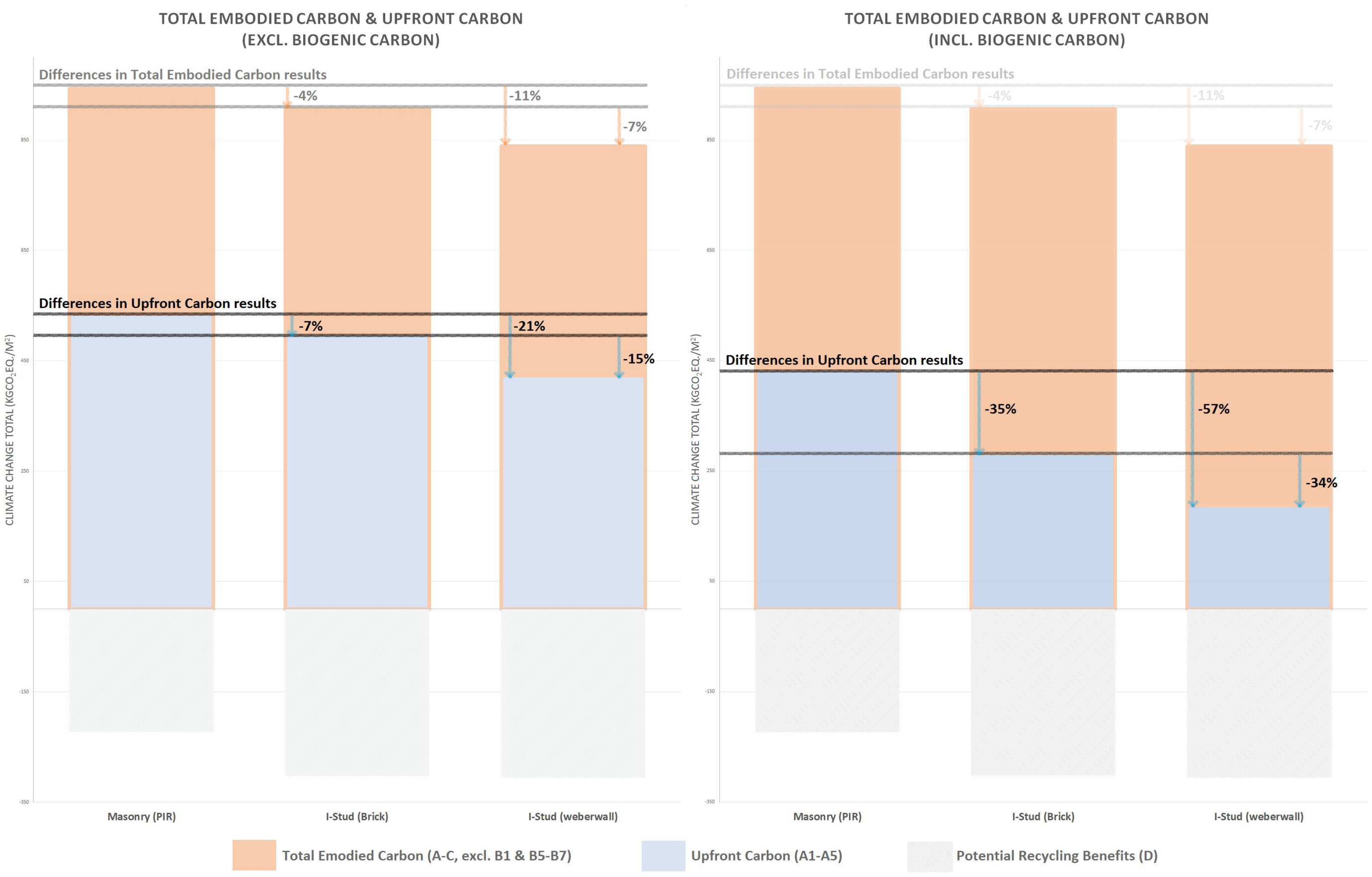
eHome2 constructed with external walls comprising the I-Stud (weberwall) system has an 11% lower life cycle embodied carbon impact compared to eHome2 constructed with traditional masonry (PIR) external walls. Furthermore, the upfront embodied carbon for the I-Stud (weberwall) system was 21% lower (excluding biogenic carbon or gross emissions) and 57% lower (including biogenic carbon or net emissions), compared to the masonry (PIR) system. The latter result is only valid when all timbers and engineered woods used in the construction of eHome2 have been sourced from sustainable forestry, evidenced by a chain of custody such as FSC (https://fsc.org/en), for example.

eHome2 built using the I-Stud system but with a brick rather than weberwall façade also produced a lower calculated climate change impact compared to masonry (PIR), being a 4% saving on a life cycle basis, 7% saving (upfront carbon, gross emissions) and 35% saving (upfront carbon, net emissions).

In absolute terms, the total WLC saving when constructing eHome2 using an I-Stud (weberwall) system is 9.5 tonnes CO_2e, compared to a traditional masonry (PIR) build. This reduces to 3.4 tonnes CO_2e, when brick is used with I-Stud.

The calculated potential benefit arising from the diversion of waste materials from landfill (module D) is shown separately below the X axis in Figure 4. Both I-Stud options show a slightly larger potential benefit compared to the masonry (PIR) option. This is due to incineration of the timber I-Stud frames once the house has reached its end-of-life, providing heat energy which is assumed to substitute for heat supplied by natural gas. Alternatively, this heat may be used to generate electricity, in which case the calculated benefit would be less. Estimated potential environmental benefits resulting from activities that divert waste from landfill decades in the future are highly uncertain, and therefore not considered further in this report.

Figure 4 Summary of whole life embodied carbon and upfront carbon results for the three options



5.2 Life cycle embodied carbon by life cycle stage

Table 7 shows how different stages/modules (from Figure 3) in the eHome2 life cycle contribute to total embodied carbon results. Of particular note, is the dominance of modules A1 – A3 and module B4, which collectively contribute 82 – 84% to life cycle embodied carbon (excluding biogenic carbon) across the three options. Modules A1 – A3 and, separately, module B4, each constitute about half to this.

Module B4 reflects future replacement of materials with a shorter service life than the building service life of 60 years. Finishes and services are the building elements contributing most to module B4, comprising primarily replacement of carpets and mechanical ventilation equipment respectively. It is worth noting that there are limitations to the way module B4 is calculated, discussed further in Section 6.

Modules C1 – C4 (building end-of-life) and modules B2 and B3 (maintenance and repair, comprising activities such as painting internal walls and ceilings, and repointing mortar) collectively contribute less than 5% to overall results, so can be considered minor. Transport of materials to the construction site (module A4) and construction (module A5) provide 12 – 15% of the life cycle embodied carbon impacts.

Looking at results inclusive of biogenic carbon, the eHome2 upfront embodied carbon saving built with I-Stud (weberwall) increases to over 22 tonnes CO_2 compared to the masonry (PIR) option. This is due to the additional sequestered carbon dioxide in the closed panels using I-Studs (weberwall) which is not present in the masonry (PIR) option.

This early additional carbon dioxide sequestration is balanced later in the life cycle, when the I-Stud options feature more significant carbon emissions in modules C1 – C4, in comparison with the masonry (PIR) option. For example, from Table 7, modules C1 – C4 emissions (including biogenic carbon) for the I-Stud (weberwall) option are more than double the emissions for the same modules for the masonry (PIR) option.

Table 7 Summary of results, broken down by life cycle stage, for the three options (kg CO_2eq / m²)

Life cycle stage (module)	Masonry PIR		I-Stud (Brick)		I-Stud (weberwall)	
	Excl. biogenic carbon	Incl. biogenic carbon	Excl. biogenic carbon	Incl. biogenic carbon	Excl. biogenic carbon	Incl. biogenic carbon
Product (A1 – A3)	400	298	375	159	320	84
Transport (A4)	72		66		51	
Construction / installation (A5)	63		57		52	
Upfront carbon (A1 – A5)	**535**	**433**	**498**	**282**	**423**	**187**
Maintenance / repair (B2, B3)	15		15		10	
Replacement (B4)	378		375		388	
End-of-life (C1 – C4)	17	118	19	235	18	254
Life cycle embodied carbon (A1 – C4, excl. B1, B5, B6, B7)	**944**		**907**		**839**	
Potential benefits/loads beyond building life cycle (D)	-223		-302		-306	

5.3
Life cycle embodied carbon by building element

Results presented in this section exclude biogenic carbon and module D. Figure 5 summarises the life cycle embodied carbon results divided into the different building elements.

Most building elements in Figure 5 (those designated as “Fixed” in Table 3) are shaded in greys and black. Building elements where quantities and/or types of materials vary (designated as “Variable” in Table 3 and summarised in Table 4) are coloured. The non-material specific category in the legend refers to embodied carbon emissions not specifically associated with materials, for example, operating a construction site and demolishing a building at its end-of-life. This is also fixed across the three options (although it would be reasonable to assume that employing MMC (per the I-Stud options) should provide lower construction site emissions due to quicker installation).

The masonry (PIR) option does not have a separate frame since the masonry provides the structural support for the external walls as well as the façade.

Fixed building elements contribute 75% (masonry (PIR)) to 84% (I-Stud (weberwall)) of the life cycle embodied carbon results. Internal finishes and services are the most significant contributors to the fixed building elements, contributing around 60% to the life cycle embodied carbon impacts.

Of the variable building elements, the external walls show the greatest range of results, comprising the difference between the weberwall system and a traditional brick façade. An external wall with weberwall is calculated to have less than half the life cycle embodied carbon impact of a traditional brick wall. If bricks are used as a façade rather than weberwall, then the calculated life cycle embodied carbon reduction for the external walls only is 26% compared to the masonry wall.

The weberwall facade is used with a closed panel I-stud frame which is not needed for a traditional masonry wall. However, the contribution of this frame (excluding biogenic carbon) is less than 2% to overall results.

The lighter construction of the I-Stud (weberwall) external wall provides an additional climate change benefit in comparison with the heavier traditional masonry wall construction, as smaller concrete strip foundations are required. This means that the I-Stud (weberwall) option is calculated to yield an additional 25% saving on the foundation impact only, or 7% when clad with brick, relative to the traditional masonry (PIR) external wall.

Figure 5 Life cycle embodied-carbon results (excluding biogenic carbon and module D) by building element

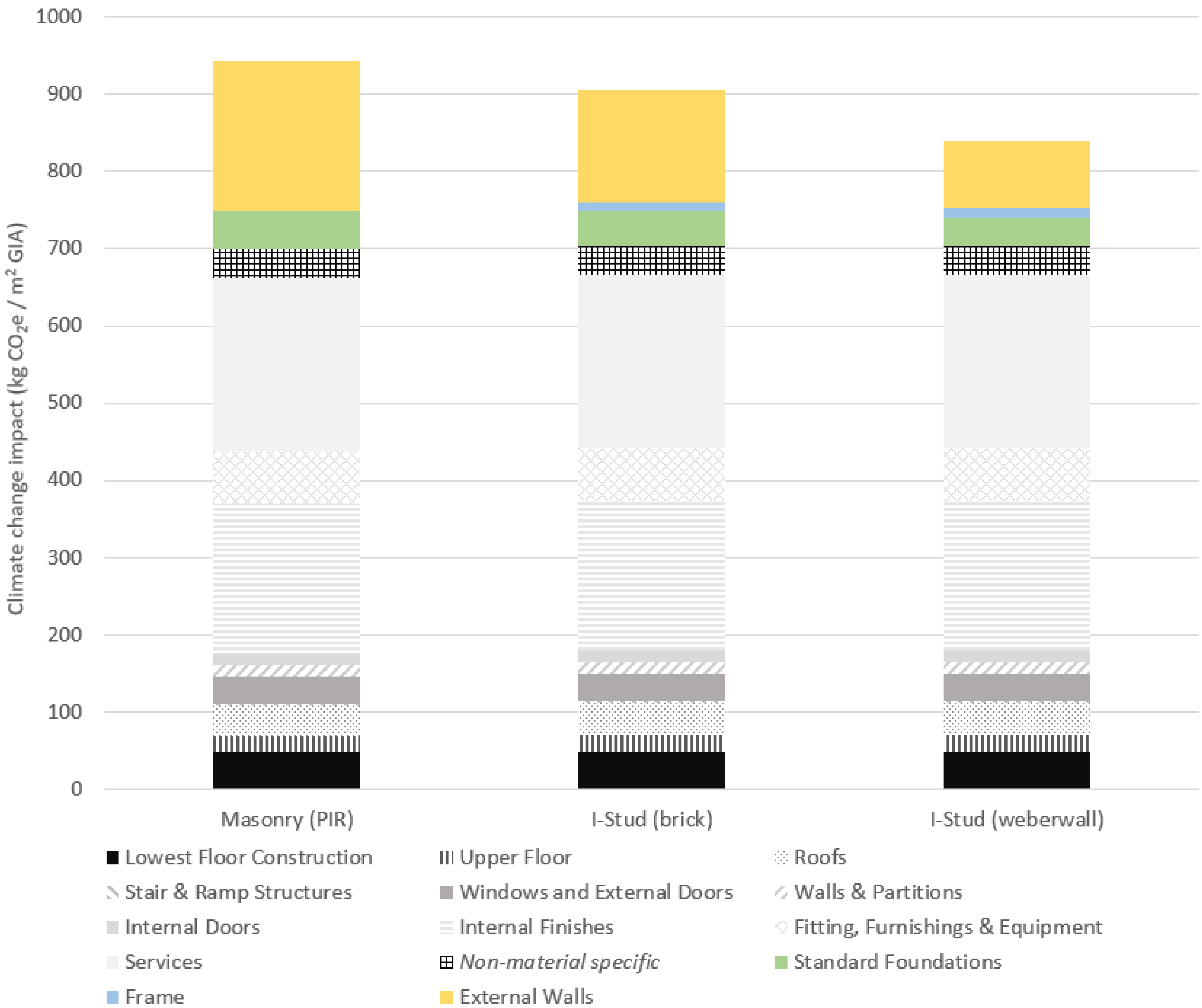
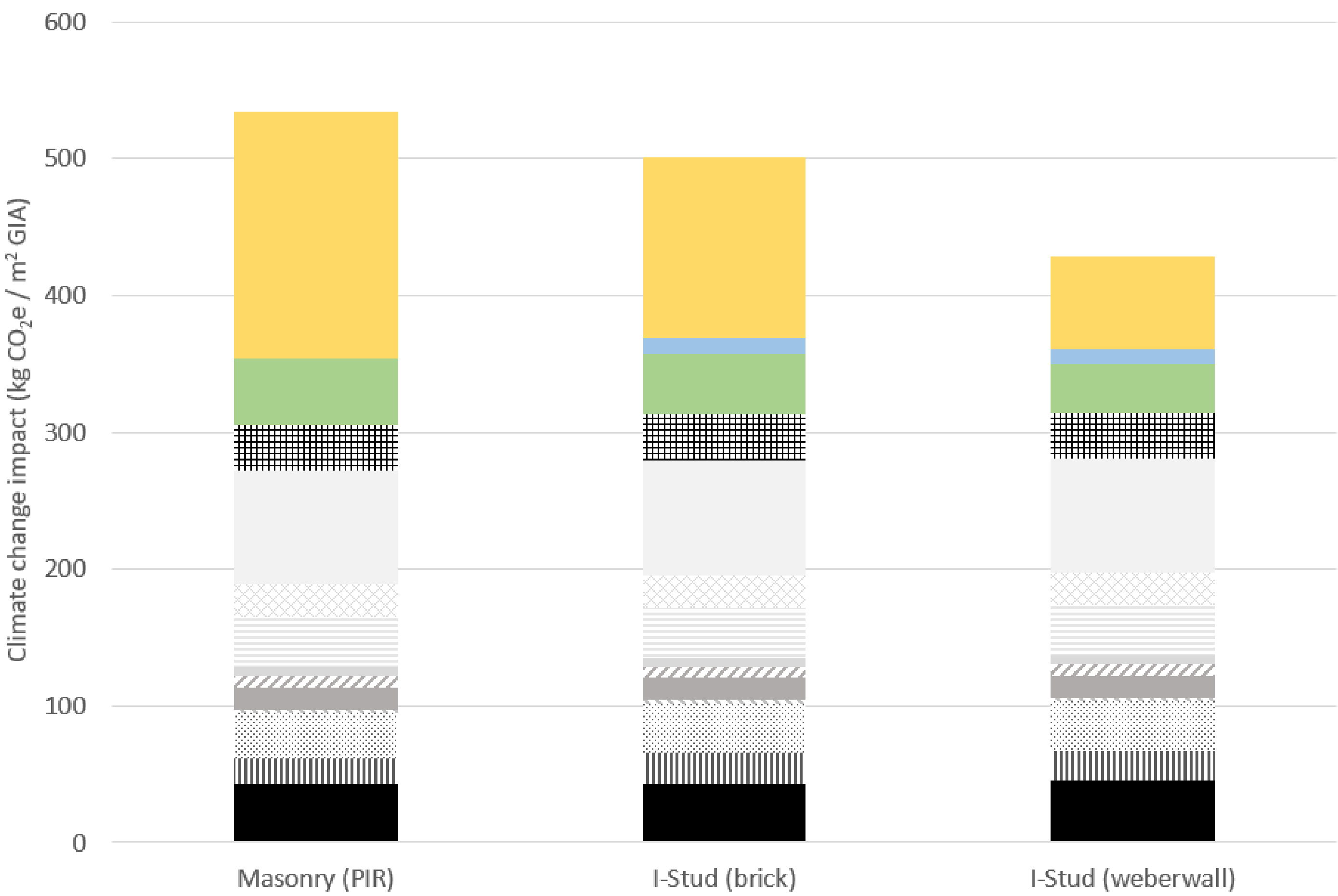


Figure 6 Upfront embodied carbon results (excluding biogenic carbon and module D) by building element



5.4

Upfront embodied carbon by building element

Results presented in this section exclude biogenic carbon and module D. Figure 6 has the same structure as Figure 5, but focuses on upfront embodied carbon emissions only (modules A1 – A5 from Figure 3).

The variable elements – standard foundations, frame and external walls – make a larger contribution to the upfront embodied carbon impact of the house in comparison with the life cycle carbon results, ranging from 27% (I-Stud (weberwall)) up to 43% (masonry (PIR)).

Amongst the fixed elements, services continue to be the most significant, with internal finishes also prominent, together with the lowest floor construction and roof. Construction site activities (covered in the non-material specific category) are also worth noting.

As observed in Figure 4, eHome2 built with the I-Stud (weberwall) external wall system has been calculated to provide a 21% saving in gross (excluding biogenic carbon) upfront embodied carbon emissions compared to the same home built using traditional masonry (PIR) construction, and a 57% saving in net upfront emissions (which additionally includes carbon dioxide sequestered into timbers and engineered woods used in the build). When a brick façade is used instead of weberwall, the gross and net savings in comparison with the use of masonry (PIR) in external walls, reduces to 7% and 35% respectively.

These savings reduce the magnitude of emissions early in the life cycle (which occur before eHome2 occupiers would obtain the keys to their property). With an I-Stud (weberwall) system, the gross saving is almost 10 tonnes CO_2e compared to the same home built using traditional masonry (PIR), and just over 3 tonnes CO_2e if brick is used for the façade, rather than weberwall. Therefore, it is reasonable to conclude that almost all of the life cycle embodied carbon savings achieved using I-Stud (with weberwall or brick) occur early in the life cycle (before the In-use phase).

6.0

Conclusions and Interpretation

This eHome2 Executive Summary compares three alternative methods of constructing the same house design. Most building elements are the same between options – for example the upper floor, roof, windows, internal walls, finishes and services. The three areas of difference comprise the standard foundations, frame and external walls.

A version of eHome2 with a masonry (PIR) external wall was developed to replicate a traditional, on-site build. The I-Stud (weberwall) option represents MMC, with an external wall system manufactured off-site and with a lighter façade. The I-Stud (with brick facade) option represents a hybrid of the other two options, featuring an offsite manufactured I-Stud wall system, but with a brick façade applied on the construction site.

Where possible, EPD data were used to represent products used in eHome2. For building elements that are the same between options, the data used to represent materials in these elements are identical, and therefore do not represent a point of difference. Where the data are not entirely representative of the materials actually used in eHome2, this may have an impact on the absolute calculated results.

For building elements that are different between the options, the choice of data used to represent the materials in each construction has the potential to influence the findings relative to each other. However, given the contribution made by the variable elements to the life cycle carbon results (up to 25%), this is likely to be limited (but more significant for the upfront embodied carbon results, in which the variable elements can contribute up to 43%). A sensitivity analysis has been carried out, which looks at how the selection of embodied carbon data for materials may influence conclusions.

Similarly, a sensitivity analysis has been carried out which considers use of different types of bricks in the masonry (PIR) option, to ascertain how this may affect the study findings.
The conclusions from the study are:

• Use of I-Stud with weberwall is estimated to reduce upfront carbon (comprising emissions up to and including construction) of eHome2 by 21% compared to the same house built with traditional masonry (PIR) external walls. If biogenic carbon is included, the upfront carbon emission saving increases to 57%.

• If a brick façade is used in place of weberwall, the upfront carbon saving is reduced to 7%. If biogenic carbon is included, the carbon emission saving increases to 35%.

• The overall estimated carbon saving (excluding biogenic carbon) when using I-Stud with weberwall is 8 – 9.5 tonnes CO_2e per home compared to use of masonry, with PIR. The magnitude of carbon saving depends on the type of bricks being used (clay, concrete or sand lime). This saving is 2 – 3.4 tonnes CO_2e per home when I-Stud is used with a brick façade.

• Across the life cycle (which additionally includes use of the home over 60 years and its end-of-life) the I-Stud with weberwall combination produces an 11% carbon saving compared to masonry with PIR, and 4% if the I-Stud is used with a brick cladding.

• In absolute terms, the calculated life cycle savings are very similar to the upfront embodied carbon savings. So almost all of the calculated embodied carbon savings for the I-Stud options arise before the house is occupied.

• Most of the calculated climate change impact of eHome2 arises from the fixed building elements, particularly services and internal finishes (life cycle carbon).

• Of the three building elements that were varied for this study, the external wall construction makes the largest contribution to calculated climate change impact results (both life cycle and upfront embodied). The closed panel timber frame (used in both I-Stud options) contributes little (up to 2% of overall life cycle embodied carbon) to the results. The lighter I-Stud external wall construction also produces a small decrease in the foundation climate change impact, saving around 1 tonne CO_2e in absolute terms, compared to the heavier masonry external wall construction which requires more foundations.

The calculated saving in upfront embodied carbon emissions is important, as these are more certain than future emissions which can be influenced by changes in policy, rate of development and investment in new decarbonising technology, and adoption of new lower-carbon practices. They are also important because earlier emissions savings mean less greenhouse gases are accumulating in the atmosphere in the short term, contributing to climate change. Once emitted, carbon dioxide can remain in the atmosphere for hundreds of years.

As with any study of this type, the selection and use of underlying data is important. Where possible, EPD data were used to represent the embodied carbon of materials used in eHome2. A sensitivity analysis was carried out, in which the modelling of these materials was undertaken using primarily generic data (from ecoinvent 3.8). This sensitivity analysis found that, in general, the use of generic data resulted in an increase in calculated climate change impacts. However, this increase was not significant to reported results, being less than 1% at the building level overall. Importantly, results between options did not change significantly.

Similarly, the baseline masonry (PIR) scenario assumed use of clay bricks. A sensitivity analysis was additionally carried out which considered use of other types of brick, being concrete or sand lime. Overall conclusions remain valid with use of these types of brick instead of clay bricks, but the magnitude of carbon savings was found to reduce. For example, the estimated carbon saving when using I-Stud (weberwall) for a house (excluding biogenic carbon) instead of masonry (PIR) was reduced to no less than 8 tonnes CO_2e (from a 9.5 tonne CO_2e saving). In the case where I-Stud is used with a brick façade, the house level carbon saving reduces to 2 tonnes CO_2e (from 3.4 tonnes CO_2e).

6.1 Limitations

Buildings are generally long-lived, and in this study, eHome2 is assessed over 60 years. This presents some limitations from a life cycle perspective discussed below:

- **Replacement of building materials (module B4):** Table 7 shows the significant contribution made by module B4 for all options, which concerns replacement of building materials during the 60-year service life of eHome2. The calculation of this replacement of materials tends to be based on current manufacturing processes, logistics and construction practices. However, these replacement activities will occur many decades in the future (even after 2050), when we would expect there to have been significant implementation of decarbonisation strategies. Thus, these figures can be considered as highly conservative, and likely to be significantly lower (depending on the manufacturing process and time when replacement occurs).

- **End-of-life (modules C1 – C4):** Table 7 shows that future end-of-life emissions from the I-Stud options are significantly higher than end-of-life emissions from the masonry (PIR) option due to the “emission” of additional sequestered carbon dioxide. These future emissions are much less certain than upfront embodied carbon emissions and should be treated with caution because eHome2 built today and lasting at least 60 years, would not be demolished until well after 2050, when the UK should have already achieved its net zero carbon target. Therefore, we would expect processes post-2050 to be significantly decarbonised, diversion from landfill to be significantly higher, and more widespread adoption of circular rather than linear life cycles. This should mean greater reuse and recycling of timbers and engineered woods, providing opportunities to maintain carbon dioxide sequestered in construction products, rather than emitting it. Therefore, these figures should be considered conservative.

• **Potential benefits/loads beyond the building life cycle (module D):** For similar reasons, the potential module D benefits are also uncertain and likely to be overstated because these processes occur much later in the building life cycle, largely when eHome2 reaches its end-of-life. Furthermore, the calculation of module D tends to be based on current technology and practices. Given that most of these processes will occur many decades in the future (and after 2050 when the UK should already have achieved its net zero carbon goal), it is likely that these will be significantly different. Module D "benefits" can be expected to trend towards zero, as the secondary processes and primary processes they substitute, decarbonise.

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