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Whole Life Embodied Carbon Comparative Analysis

Variety Barn
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Contents

1	Introduction	2
2	Key Findings	3
2.1	Embodied Carbon	3
2.2	Embodied carbon distribution in materials	3
3	Building Better Buildings Now	4
3.1	RIBA 2030 Challenge	4
3.2	The Energy Hierarchy	4
3.3	Key Design Considerations	5
4	Policy & Climate Emergency Statement	5
4.1	Climate Emergency Statement in the UK	5
4.2	RIBA2030 Climate Change Policy	5
4.3	Importance of Considering Operational Energy	5
4.4	Importance of Considering Whole Life Embodied Carbon	5
4.5	Materials Embodied Carbon	6
5	Predicted Energy Use & Embodied Carbon Methodology	6
5.1	Space Heating	6
5.2	Domestic Hot Water (DHW) Requirements	6
5.3	Electricity Use	6
5.4	Embodied Carbon	7
6	Embodied Carbon	7
6.1	RIBA Sustainable Outcomes for Embodied Carbon	7
6.2	Principles of construction	7
6.3	Embodied carbon outcome	8
6.4	Embodied carbon detail	8
6.5	PV carbon reduction	9
7	Conclusive argument	9
8	Appendix A: Life-cycle assessment results for BREEAM UK according to EN 15978	10
9	Appendix B: Project most contributing materials	11

Revision Log

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All	For review and comment	Draft	24/10/2023
All	Correction of typos, and notes	RevA	31/10/2023
All	Amendments	RevB	03/11/2023

1 Introduction

Richmond Bell Architects are working on the Variety Barn project, where they are planning to build a bespoke family home.

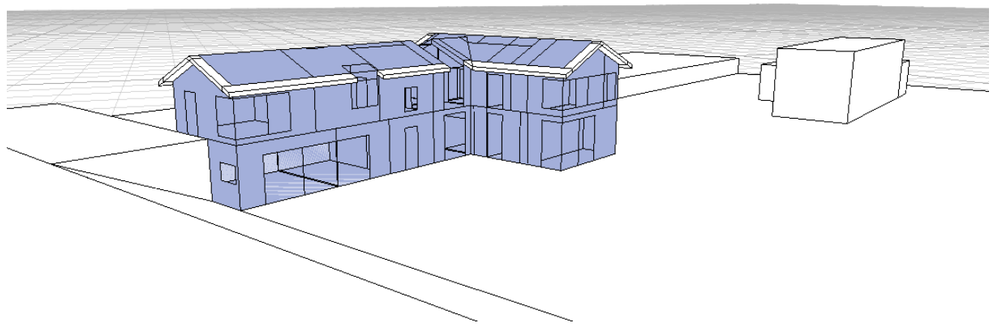

Figure 1: The IES-VE model

Mesh Energy have been commissioned to assess the whole life carbon impact of the property based on the materials selected and also determine the expected operational energy to ensure that the proposed design demonstrates a low carbon impact.

This study considers a whole life cycle assessment of the property and will take into account various life cycle stage of the building. The study will demonstrate carbon impact occurring from each element through its embodied carbon while also demonstrating carbon impact from energy use through operational carbon. Importantly, Materials used for the foundations and additional required internal structure, such as beams and columns will not be considered as the structural design has not been defined due the early design stages of the project.

2 Key Findings

2.1 Embodied Carbon

The findings of the report indicate that the revised proposal will produce an estimated of 500 kg CO^2e/m^2, which falls into RIBA 2030 standards. It is worth noting that foundations and structural elements have not been considered; regardless, the results demonstrate a carbon impact well under the RIBA 2030 standard and current building regulations. The following graphic shows the embodied carbon threshold of the RIBA standards in comparison to the Variety Barn project, including a 25% estimate of embodied carbon of materials for foundations added to the results gathered from OneClickLCA. Full results can be found in Appendix A.

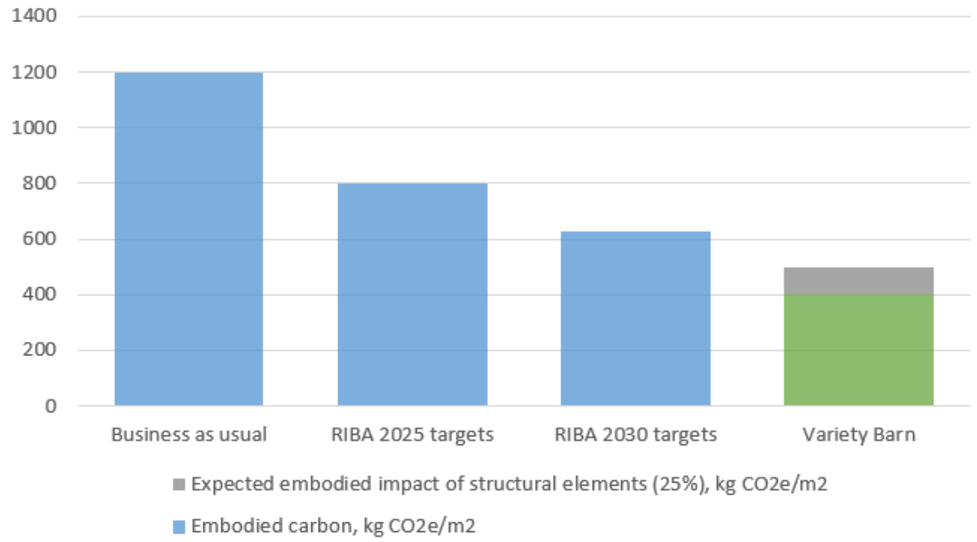

Figure 2: Whole life embodied carbon assessment, embodied carbon threshold of the RIBA standards in comparison to the Variety Barn project

The carbon savings of the Variety Barn project are a result of its sustainable design, incorporating features such as high fabric thermal efficiency, low embodied carbon insulating materials and efficient heating solutions. These design choices minimise heat loss, maximise insulation, and reduce reliance on energy-intensive heating.

2.2 Embodied carbon distribution in materials

This results also shows the distribution of the embodied carbon of the different materials used in the construction, including the services element that contemplates the renewable technology such as MVHR system, PV panels and heat pump. Full details can be found in Appendix B.

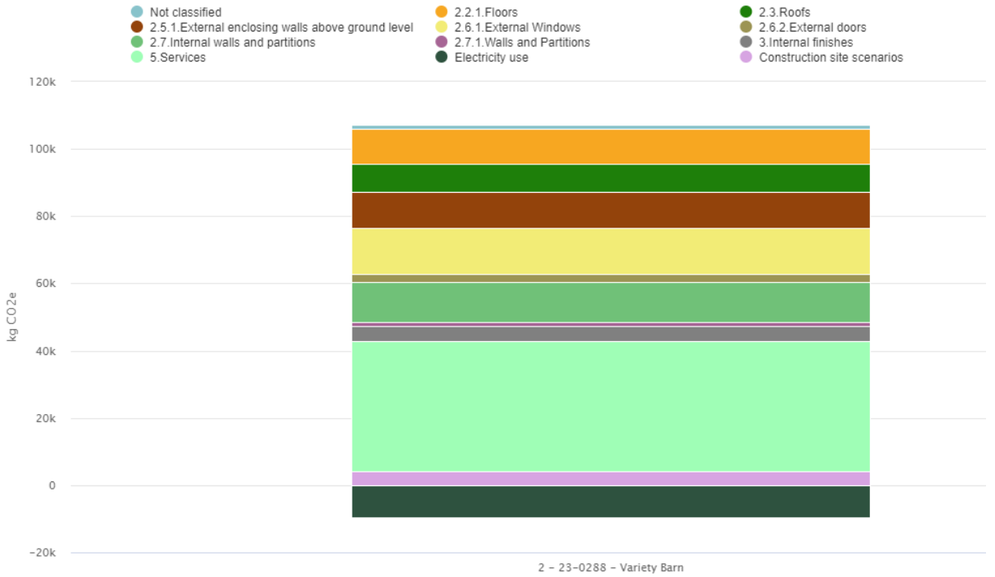

Figure 3: Comparison of embodied carbon per element - Global warming, kg CO2e - Elements

3 Building Better Buildings Now

3.1 RIBA 2030 Challenge

The RIBA has developed targets for operational energy use, embodied carbon and water use reduction. These take into account the latest recommendations from the Green Construction Board and have been developed by the RIBA in consultation with other UK professional bodies. The targets are progressive yet realistic, and a vital first step to ensure the construction industry has delivered the significant reductions necessary by 2030 in order to have a realistic prospect of achieving net zero carbon for the whole UK building stock by 2050.

RIBA Sustainable Outcome Metrics	Business as usual (new build, compliance approach)	2025 Targets	2030 Targets	Notes
Operational Energy kWh/m²/y	120 kWh/m²/y	< 60 kWh/m²/y	< 35 kWh/m²/y	Targets based on GIA. Figures include regulated & unregulated energy consumption irrespective of source (grid/renewables). BAU based on median all electric across housing typologies in CIBSE benchmarking tool. 1. Use a 'Fabric First' approach 2. Minimise energy demand. Use efficient services and low carbon heat 3. Maximise onsite renewables
Embodied Carbon kgCO₂e/m²	1200 kgCO₂e/m²	< 800 kgCO₂e/m²	< 625 kgCO₂e/m²	Use RICS Whole Life Carbon (modules A1-A5, B1-B5, C1-C4 incl sequestration). Analysis should include minimum of 95% of cost, include substructure, superstructure, finishes, fixed FF&E, building services and associated refrigerant leakage. 1. Whole Life Carbon Analysis 2. Use circular economy strategies 3. Minimise offsetting, use UK schemes (CCC) BAU aligned with LETI band E; 2025 target aligned with LETI band C and 2030 target aligned with LETI band B.

Figure 4: RIBA 2030 Climate Challenge target metrics for domestic buildings

These metrics provide a valuable set of benchmarks that can be followed to achieve the design objective. Mesh Energy strongly believes in developing high-performance, efficient buildings, a commitment validated by this study which demonstrates that the carbon impact will meet the set goal of RIBA 2030.

3.2 The Energy Hierarchy

Before starting to look at energy efficiency and renewable energy technology options it is worth explaining the general energy strategy steps employed on modern low energy homes to ensure worthwhile money allocation on the most beneficial and cost-effective areas.

Step 1: Reduce elemental building fabric heat loss
Step 2: Reduce unnecessary ventilation and air heat losses
Step 3: Harvest energy more efficiently to heat home and produce hot water
Step 4: Incorporate micro-generation to generate electricity and power efficient technology
Step 5: Store surplus locally generated electricity to reduce imported electricity from the grid

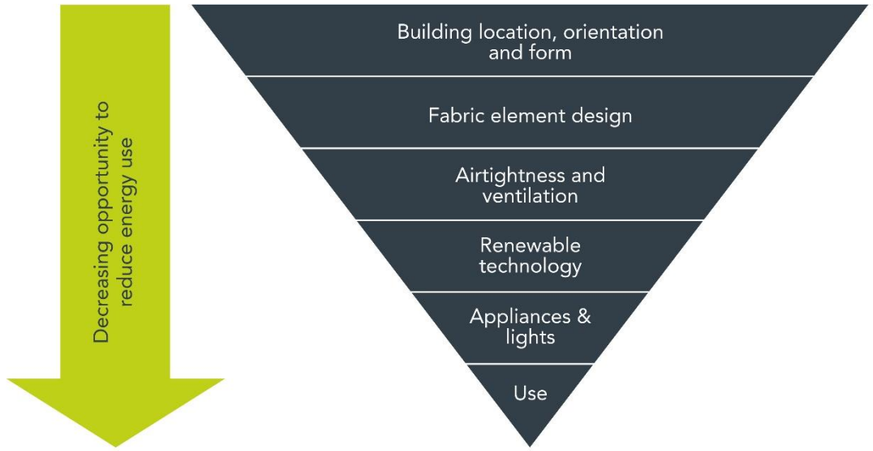

Figure 5: The Energy Hierarchy

Most successful construction projects start with a fabric first approach and aim to reduce the amount of energy the building loses through windows, doors, walls, floors and ceilings. Heat can escape through the fabric itself and through small gaps in the thermal envelope. Minimising fabric losses is easier when designing a new building than renovating existing building. The existing building tends to have a lower thermal performacne and poor building fabric which leads to a greater loss of heat due to air infiltration.

Modern buildings typically are so thermally insulated that becomes necessary to incorporate ventilation. This ensures that the inside air remains fresh and any warm air removed from a building during the winter will be replaced with cold air. The heat can be extrated from the warm air and supplied again to the rooms which reduced energy demand.

Once the heat loss of the building has been minimised the use of energy efficient, renewable heating systems can help to reduce equivalent running costs by as much as 30%.

Increasingly, the most efficient heating solutions finding their way into homes are electrically powered and installing electrical micro-generation technologies in the home only assist further in reducing household electrical costs.

This development will further benefit from communal generation and storage resources, allowing a balance of lifestyles to flatten the peaks and troughs of energy demand and respond to flexible grid pricing.

It is with this methodical approach in mind that the remainder of the report addresses various aspects of the building and internal low carbon systems to achieve a cost effective, progressive and low carbon home.

3.3 Key Design Considerations

3.3.1 Fabric First

This is often referred to as the first principle of energy efficiency, the idea that the initial focus of any low energy project should be on the building envelope efficiency.

These properties have been designed with building envelope efficiency as the highest priority allowing them to use less energy throughout the year.

- A proposed high quality insulation will trap heat within the building.
- The dwelling will be built with a high airtightness level.
- High performance triple glazed windows will be installed.

3.3.2 Renewable Technology

Renewable technology solutions are regarded to be also important in reducing the building's heating load. Well designed, properly sized, simple systems, deployed in an efficient building helps to further reduce the energy consumption.

- A Mechanical Ventilation Heat Recovery (MVHR) system will be incorporated in the design which will recover over 90% of the heat from the 'stale' air.
- An Air Source Heat Pump will provide space heating and hot water, typically seasonal co-efficient of performance (SCOP) of around 4.1 can be achieved.
- A solar PV array, optimally sized for the expected building loads will contribute to reducing the buildings energy consumption and export excess generation to the national grid during the peak summer months.

All these measures will reduce the energy required to heat the building and therefore use less.

3.3.3 Low Embodied Carbon

The building materials selected impact the embodied carbon associated with the project. The revised scheme has been proposed to reduce the embodied carbon as far as possible.

- Use of natural materials with lower manufacturing emissions and that sequester carbon within the structure, such as the timber frame construction and wood fibre insulation
- Avoid using concrete in slabs when possible
- Reuse of timber waste from existing structures.

4 Policy & Climate Emergency Statement

The United Kingdom has taken significant steps to tackle environmental global challenges through the implementation of various policies and initiatives. One such policy is the RIBA2030 climate change policy, which aims to guide the architectural profession towards achieving carbon neutrality in the built environment by the year 2030.

4.1 Climate Emergency Statement in the UK

The UK government declared a climate emergency, acknowledging the severity of the climate crisis and committing to taking necessary actions to combat it. This declaration emphasizes the need for a holistic approach towards achieving net-zero carbon emissions and underscores the importance of reducing the carbon footprint of all sectors, including the built environment. Architects, as key stakeholders in the construction industry, play a crucial role in shaping the built environment and have a responsibility to contribute to the UK's climate emergency response.

4.2 RIBA2030 Climate Change Policy

The Royal Institute of British Architects (RIBA) has developed the RIBA2030 climate change policy which is a strategic framework to guide architectural practices in their efforts to address climate change. It recognises the interdependence of operational energy (the energy consumed during a building's use phase) and whole life embodied carbon (the carbon emissions associated with the construction, operation, maintenance, and eventual demolition of a building) in determining a building's overall carbon footprint.

4.3 Importance of Considering Operational Energy

Operational energy accounts for a significant portion of a building's carbon emissions accounting from the use stage of the building life cycle. By prioritising energy-efficient design strategies, architects can reduce the operational energy demand of buildings, leading to lower greenhouse gas emissions. Considering operational energy in the early design stages allows architects to incorporate passive design principles, energy-efficient systems, and renewable energy technologies, optimizing the building's energy performance. A holistic approach that integrates energy-efficient design principles and explores innovative solutions is crucial for achieving the desired carbon neutrality goals set by the UK's climate emergency statement and the RIBA2030 policy.

4.4 Importance of Considering Whole Life Embodied Carbon

While operational energy is vital, it is equally important to consider the whole life embodied carbon of a building. Whole life embodied carbon refers to the carbon emissions associated with the extraction, manufacturing, transportation, and assembly of building materials, as well as their eventual disposal or recycling. Neglecting embodied carbon can lead to unintended

consequences, such as the displacement of carbon emissions from the operational phase to the construction phase of a building's life cycle. By adopting sustainable material choices, optimizing construction processes, and promoting circular economy principles, architects can significantly reduce the embodied carbon of buildings.

4.5 Materials Embodied Carbon

To achieve carbon neutrality in the built environment, architects must embrace good practices that consider both operational energy and whole life embodied carbon. Integrating energy-efficient design principles and sustainable material choices into architectural projects can result in substantial carbon emission reductions. Full details can be found in the Appendix.

5 Predicted Energy Use & Embodied Carbon Methodology

This section outlines the approach taken to calculate the expected energy loads and embodied carbon figures.

In order to establish the energy requirements of the building in question, a dynamic building physics models were created in the IES Virtual Environment software and building heat loads calculated using the fabric heat loss from the methodologies described in CIBSE Guide A Chapter 5. This process allows individual room elements to be analysed and an optimised heating system to be specified later in development.

5.1 Space Heating

The space heating requirements are expressed in two ways:

- **Annual space heating**

Which refers to the total energy over the year required to keep the building comfortable throughout the year. These calculations are based on average weather data based on geographic location.

- **Peak heat loss**

Which refers to the amount of energy needed for the home to stay comfortable on the coldest day of the year. System designers use this figure to ensure the correct sizing of heating plant installed. These design temperatures are based on geographic location and altitude and are specified by the weather data file for London. For this property the design temperature used for peak heat loss is -4.0°C.

5.2 Domestic Hot Water (DHW) Requirements

The DHW requirements for the dwellings have been calculated as 65lt per person at full occupancy. Full occupancy is assumed to be two persons occupying the master bedroom and single persons occupying the remaining bedrooms.

5.3 Electricity Use

Electricity consumption has been estimated with the help of the IES dynamic thermal modelling simulation. This estimate excludes any electricity associated with space heating or domestic hot water and includes consumer goods, cooking appliances, lighting and other likely typical electrical loads in the home. For the revised scheme the estimated consumption of the MVHR system has also been included.

5.4 Embodied Carbon

Embodied carbon equivalent has been calculated using OneClick LCA software. The study follows the RICS methodology and covers Cradle to grave (A1-A4, B4-B5, C1-C4) approach for the life cycle assessment.

Outside of the RICS methodology scope, but of interest to the local community, is the planned reduction in vehicle movements. At present the site attracts 20 vehicles driving an average of 100miles per day each. This is calculated to contribute 600 tonnes CO_2* to the that will be emitted to the environment every year.

** Based on Diesel vehicles operating with an average of 10MPG*

6 Embodied Carbon

Embodied carbon is a measure of the energy used in the extraction, fabrication, and transportation from place of origin of the materials used in the construction for the lifecycle of the building.

6.1 RIBA Sustainable Outcomes for Embodied Carbon

Today the domestic embodied carbon benchmark is 1200 $kgCO_2e/m^2$. The RIBA Sustainable Outcomes embodied carbon targets are:

- By 2025 a reduction in embodied carbon to <800 $kgCO_2e/m^2$
- By 2030 a reduction in embodied carbon to <625 $kgCO_2e/m^2$

6.2 Principles of construction

The following principles of construction have been applied to the thermal model based on the information provided by Richmond Bell Architects.

Element	Construction
Substructure	Not considered*
Superstructure	Not considered*
External Walls	SIPs system wither recovered limestone recovered from existing building on site or timber cladding.
Internal walls	Plasterboard on acoustically treated timber stud
Roof	Laminated zinc cladding
Ground Floor	Screed finish to concrete slab
Internal floor	Chipboard on acoustically treated timber with plaster board finish
Windows/doors	Double-glazed timber frame
Building services	Air source heat pump heat pump, MVHR
Energy generation	Solar PV, 30 panels

Table 1: Principles of construction; *the whole life carbon analysis results in this report include a 25% estimate of embodied carbon of materials for foundations in comparison to current study levels.

This property was modelled to be in alignment with the design targets and u-values as agreed with Richmond Bell Architects. The heating source is an electrically driven ASHP and MVHR further reduced energy demand.

Construction Element	**U-Value** (W/m²K)
Ground floors	0.13
Walls – stone cladding	0.14
Walls – timber cladding	0.15
Roof	0.15
Windows	1.30
Rooflights	1.70
External doors	1.50
Infiltration Rate	4 m3/h.m2@50Pa

6.3 Embodied carbon outcome

The embodied carbon for the principles of construction were found to be 400 kgCO_2e/m^2, without including the estimated embodied impact of structural and foundation elements (100 kgCO_2e/m^2). The LCA OneClick's embodied carbon benchmark system is a tool designed to assess and measure the embodied carbon emissions associated with construction projects. Embodied carbon refers to the greenhouse gas emissions emitted throughout a project's entire lifecycle, including the extraction of raw materials, manufacturing, transportation, construction, and eventual disposal. The benchmark system provides a standardised framework for evaluating the environmental impact of projects by comparing them to industry benchmarks and best practices. By using this system, stakeholders can gain insights into the sustainability of projects and make informed decisions regarding material choices, design strategies, and construction methods to reduce carbon emissions. The following images shows the cradle to grave embodied carbon as calculated on OneClick LCA.

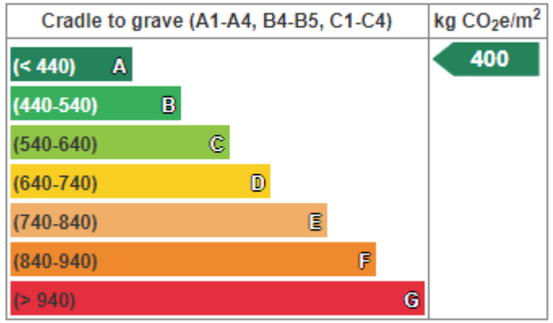

Figure 6: OneClick LCA embodied carbon benchmark (not including structural embodied carbon)

6.4 Embodied carbon detail

The limestone material selected for the project will be recovered from the existing building in the site, which will be demolished as part of the works taken on site. Due to this, an estimated savings of 2.1 tonnes CO2e can be achieved, representing 4% of the total carbon impact of cradle to gate stage.

6.5 PV carbon reduction

The Variety Barn project will instal PV panels to reduce the electricity demand from the grid, which will have a positive impact in the whole life carbon emissions of the project. An estimated of 30PV panels (11.5kWp) solar system is proposed for this site, which will result in estimated annual savings of 1,500 kg of CO_2.



Figure 7: Example of ground mounted PV panel.

7 Conclusive argument

The findings of the report indicate that the revised proposal will produce an estimated of 500 kg CO_2e/m^2, which falls into RIBA 2030 standards. This indicates that the design of the project and the materials included comply with the highest standards of embodied carbon in the UK.

RIBA Sustainable Outcome Metrics	Business as usual (new build, compliance approach)	2025 Targets	2030 Targets
Embodied Carbon $kgCO_2e/m^2$	1200 $kgCO_2e/m^2$	< 800 $kgCO_2e/m^2$	< 625 $kgCO_2e/m^2$

Figure 8: RIBA 2030 Climate Challenge target metrics for domestic buildings

The following image compares the calculated embodied carbon of the Variety Barn project agains the different Sustainable Outcome Metrics as established by RIBA:

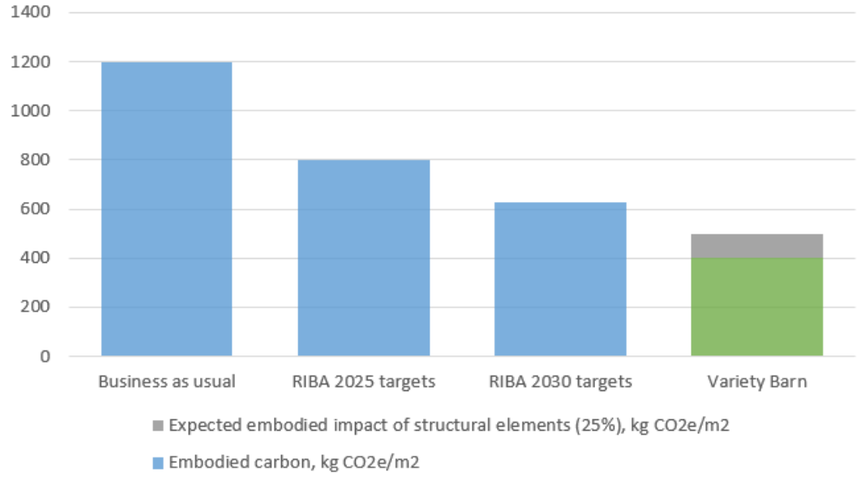

Figure 9: Whole life embodied carbon assessment, embodied carbon threshold of the RIBA standards in comparison to the Variety Barn project, including structure.

The carbon savings of the Variety Barn project are a result of its sustainable design, incorporating features such as high fabric thermal efficiency, low embodied carbon insulating materials and efficient heating solutions. These design choices minimise heat loss, maximise insulation, and reduce reliance on energy-intensive heating.

8 Appendix A: Life-cycle assessment results for BREEAM UK according to EN 15978

The following table shows the full results of the Life-cycle assessment results for BREEAM UK according to EN 15978.

	Result category	Global warming kg CO2e	Acidification kg SO2e	Eutrophication kg PO4e	Ozone Depletion kg CFC11e	Formation of ozone of lower atmosphere kg Ethenee	Non hazardous waste disposed kg	Biogenic carbon storage kg CO2e bio
A1-A3	Construction Materials	6.00E+04	2.94E+02	9.86E+01	2.22E-02	2.20E+01	5.43E+04	1.62E+04
A4	Transport to the building site	5.19E+02	1.59E+00	3.41E-01	9.51E-05	5.32E-02	2.24E+00	
A5	Construction/installation process	4.17E+03	1.95E+01	4.21E+00	3.57E-04	8.36E-01	3.97E+03	
B4-B5	Material replacement and refurbishment	4.26E+04	2.25E+02	6.71E+01	3.60E-02	1.28E+01	6.53E+04	
B6	Energy consumption	1.12E+05	1.02E+03	1.50E+02	2.44E-02	5.22E+01	7.03E+03	
	Total	**2.19E+05**	**1.56E+03**	**3.20E+02**	**8.30E-02**	**8.78E+01**	**1.31E+05**	**1.62E+04**
	Results per denominator							
	Gross Internal Floor Area (IPMS/RICS) 258.0 m^2	8.49E+02	6.04E+00	1.24E+00	3.22E-04	3.40E-01	5.06E+02	6.28E+01

9 Appendix B: Project most contributing materials

No.	Resource	Cradle to gate impacts (A1-A3)	Of cradle to gate (A1-A3)
1.	PUR (polyurethane foam) insulation panels, unfaced, generic, L = 0.022 W/mK, R = 4.55 m2K/W (26.7 ft2°Fh/BTU), 100 mm (3.94 in), 30 kg/m3 (1.88 lbs/ft3), Lambda=0.022 W/(m.K)	14 tonnes CO_2e	22.5 %
2.	Photovoltaic polycrystalline panel, per m2, 14.5 kg/m2, 210 Wp	12 tonnes CO_2e	19.6 %
3.	Triple glazing windows with wooden frame, 42.6 kg/m2, 1.2 W/m2K, biogenic CO2 not subtracted (for CML)	5.8 tonnes CO_2e	9.7 %
4.	Laminated zinc cladding, 0.7x200x3000 mm, 7.9 kg/m2	3.9 tonnes CO_2e	6.5 %
5.	Ready-mix concrete, normal-strength, generic, C30/37 (4400/5400 PSI), 0% recycled binders in cement (300 kg/m3 / 18.72 lbs/ft3)	3.9 tonnes CO_2e	6.5 %
6.	Gypsum plaster board, regular, generic, 6.5-25 mm (0.25-0.98 in), 10.725 kg/m2 (2.20 lbs/ft2) (for 12.5 mm/0.49 in), 858 kg/m3 (53.6 lbs/ft3)	3.7 tonnes CO_2e	6.1 %
7.	Sectional steel doors, manual, per m2, 2.4 x 2.2 m, 26.94 kg/m2	3.4 tonnes CO_2e	5.7 %
8.	Oriented strand board (OSB), generic, 9.5-28.5 mm (0.37-1.12 in), 610 kg/m3 (38.1 lbs/ft3), min. G4-2	2.8 tonnes CO_2e	4.7 %
9.	Steel sheet hot dip galvanized, 2-20 mm, 7840 kg/m3	2.3 tonnes CO_2e	3.8 %
10.	Hardwood floorboards, oak, 20 mm, 14.375 kg/m2, 700 kg/m3	2.1 tonnes CO_2e	3.4 %
11.	Air/water heat pump for heating and domestic hot water production, 195.9 kg/unit, P=6 kW, 180 L	1.2 tonnes CO_2e	2.0 %
12.	Gypsum plasterboard, 12.5 mm, 8.985 kg/m2 (average product weight)	1 tonnes CO_2e	1.7 %
13.	Roof window (skylight), biogenic CO2 not subtracted (for CML), 35.66 kg/m2	1 tonnes CO_2e	1.7 %
14.	Engineered wood flooring, biogenic CO2 not subtracted (for CML), 7.04 kg/m2	0.98 tonnes CO_2e	1.6 %
15.	Plywood, generic, 4-50 mm (0.16-1.97 in), 620 kg/m3 (38.7 lbs/ft3)	0.86 tonnes CO_2e	1.4 %
16.	Glass wool insulation panels, unfaced, generic, L = 0.031 W/mK, R = 3.23 m2K/W (18 ft2°Fh/BTU), 25 kg/m3 (1.56 lbs/ft3), (applicable for densities: 0-25 kg/m3 (0-1.56 lbs/ft3)), Lambda=0.031 W/(m.K)	0.63 tonnes CO_2e	1.1 %
17.	Air exchanger+heat recovery, 190 liters / s,	0.39 tonnes CO_2e	0.7 %
18.	Screed, self-levelling, 3-40 mm, 1300 kg/m3 (bulk)	0.27 tonnes CO_2e	0.5 %

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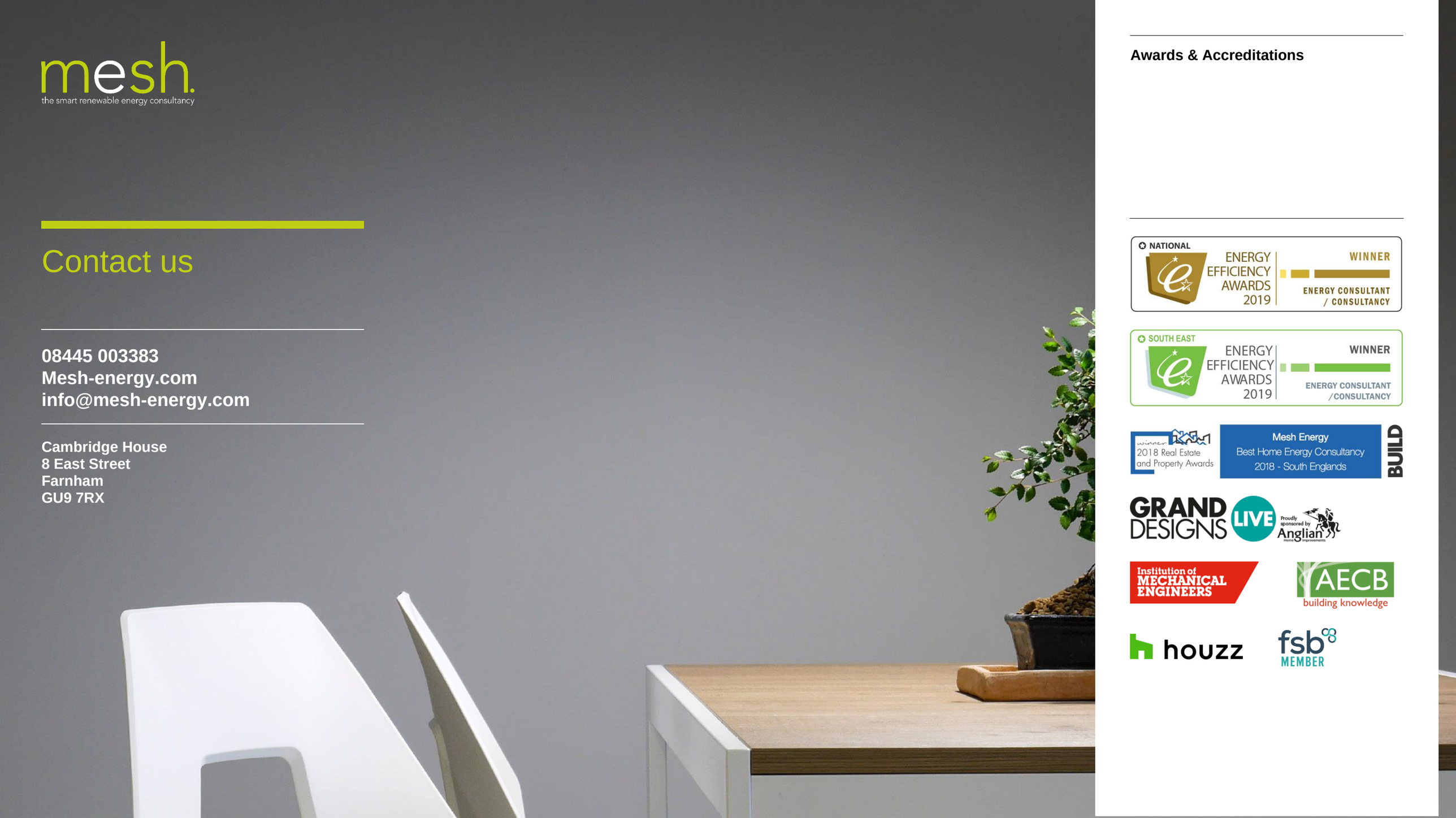

Awards & Accreditations

NATIONAL ENERGY EFFICIENCY AWARDS 2019 — WINNER — ENERGY CONSULTANT / CONSULTANCY

SOUTH EAST ENERGY EFFICIENCY AWARDS 2019 — WINNER — ENERGY CONSULTANT /CONSULTANCY

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