

LLANGATWG SCHOOL - NET ZERO CARBON - RIBA 3 v3

Introduction

Arda Consulting have been appointed by Morgan Sindall to advice on the Whole Life Carbon impact of Llangatwg School, a new build circa 8,713m² Comprehensive school located on the existing Llangatwg School grounds. This technical note clarifies the definitions of Net Zero Carbon (NZC), including Operational Energy and Embodied Carbon, and reports on project team progress to date. Opportunities and constraints are also identified.

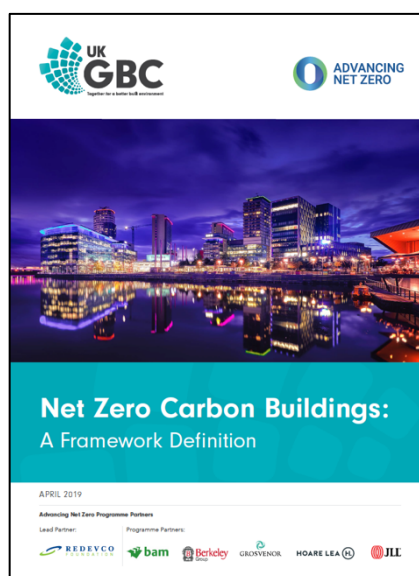
The project team will take a **Whole Life Carbon** approach at Llangatwg, reporting on the combined impact of Embodied Carbon and Operational Energy over the life of the building, typically reported as 60-years. A whole life approach to NZC will introduce a temporal approach to decision making, ensuring that the future impact of any design decision is understood from the outset, i.e. on-going maintenance and replacement frequencies of building components, both of which have different implications with regards to carbon.

This report should be read in conjunction with the following supporting documents:

- 26CC07-ARD-10-XX-T-OS-2001 - Whole Life Carbon - RIBA 2
- 26CC07-TBA-10-XX-T-ME-0003 - P04 - Operational Energy Analysis - RIBA Works Stage 3

Defining Net Zero Carbon

The project team understand that of critical importance to the successful delivery of a NZC building is to immediately and clearly establish a robust and transparent definition of NZC. In accordance with 'Llangatwg Comprehensive NZC Outline Design Brief', the project team have adopted the UK Green Building Council (UKGBC)¹ definition of NZC, namely:



“When the amount of carbon emissions associated with a building’s embodied and operational impacts over the life of the building, including its disposal, are zero or negative.”

In addition, the UKGBC provides corresponding definitions of NZC (Embodied Carbon) and NZC (Operational Energy), both of which have been adopted by the project team.

The UKGBC defines **NZC (Embodied Carbon)** as follows:

“When the amount of carbon emissions associated with a building’s product and construction stages up to practical completion is zero or negative, through the use of offsets or the net export of on-site renewable energy.”

The UKGBC defines **NZC (Operational Energy)** as follows:

“When the amount of carbon emissions associated with the building’s operational energy on an annual basis is zero or negative. A net zero carbon building is highly energy efficient and powered from on-site and/or off-site renewable energy sources, with any remaining carbon balance offset.”

¹ UK Green Building Council, Net Zero Carbon Buildings: A Framework Definition, April 2019

Supplementary Targets

The project team would supplement the UKGBC definition of NZC with the following supporting design targets as stipulated within the 'Llangatwg Comprehensive NZC Outline Design Brief', and recently published Net Zero Carbon Building Standard (Pilot).

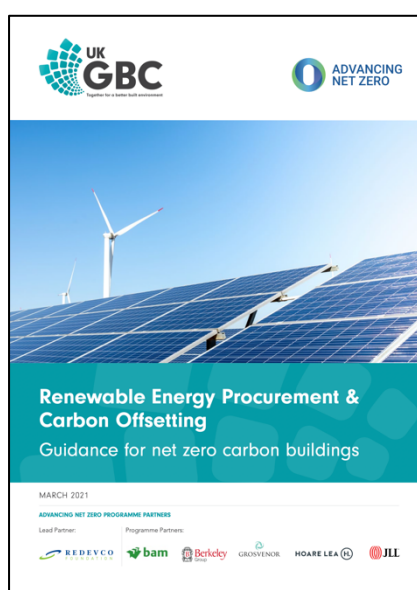
NZC Target	Space Heating Demand	Energy Use Intensity	Upfront Embodied Carbon
Llangatwg NZC Brief	<10 kWh/m ²	<65 kWh/m ²	500 kgCO ₂ e/m ²
NZC Building Standard ²	-	59 kWh/m ²	505 kgCO ₂ e/m ²

Table 1: Supplementary NZC Design Targets for Llangatwg Comprehensive School

Carbon Offsetting

Of equal importance with regards to defining NZC, is the adoption of a robust framework regarding carbon offsetting, particularly in the context of potential residual carbon emissions associated with Operational Energy Consumption.

NZC (Operational Energy)



With specific regards to **NZC in Operation**, the UKGBC define this as: *“When the amount of carbon emissions associated with the building’s operational energy on an annual basis is zero or negative. A net zero carbon building is highly energy efficient and powered from on-site and/or off-site renewable energy sources, with any remaining carbon balance offset.”*

In accordance with ‘UKGBC NZC Building Framework’ and supporting ‘UKGBC Renewable Energy Procurement and Carbon Offsetting Guide³’ (REPCO) the following hierarchy to displace/offset operational energy consumption and thus achieve NZC in Operation is stipulated.

1. On-site renewable energy source should be prioritised.
2. Off-site renewables should demonstrate additional⁴.
3. Any remaining carbon should be offset using a recognised offsetting framework.

To ensure a robust and transparent framework to achieve NZC in Operation, the project team would also look to adopt the REPCO offsetting hierarchy, moving down the hierarchy only when all realistic opportunities to comply with the former stage have been developed in full, and subsequently discussed with, and agreed by, the NZC Steering Group.

NZC (Embodied Carbon)

In accordance with UKGBC, to achieve NZC (Embodied Carbon) then 100% of embodied carbon associated with the development at Practical Completion should be offset through an approved carbon standard, including the UK Woodland Carbon Code, and UK Peatland Code.

The project team would report on total carbon impact of the development at each RIBA stage to assist Neath Port Talbot understand the implications of achieving NZC (Embodied Carbon) through carbon offsetting in practice. We will work with the client team to establish a viable and preferred method to offset all residual embodied carbon to Practical Completion. For example, offsetting schemes could include or be linked to **community resilience funds**, **community energy efficiency funds**, or local **biodiversity enhancements**, thus assisting wider community adapt to the impact of climate change and reduce energy consumption.

² Note: NZC Building Standard’s Embodied Carbon Target excludes Renewable Energy Systems.

³ <https://ukgbc.org/resources/renewable-energy-procurement-carbon-offsetting-guidance-for-net-zero-carbon-buildings/>

⁴ Where new off-site renewable energy generation is considered, the retirement of corresponding Renewable Energy Guarantees of Origin (REGO) certificates must be confirmed.

NZC Strategy (RIBA 3)

NZC (Operational Energy)

Space Heating Demand

Space Heating Demand is a useful proxy to establish whether the building itself is 'highly energy efficient', i.e. using no more than the minimum energy that is required to support occupant health and comfort while allowing the building to function. Space heating demand is thus one of the fundamental principles of achieving NZC Operational Energy, of which the 'Llangatwg NZC Brief' requires a maximum space heating demand of **10 kWh/m²**.

The project team have taken a proactive approach to reducing heat loss by proposing enhanced fabric performance measures across the building, of which a comparison between recommended design standards is given in the table below.

Element	Llangatwg NZC Brief	Proposed
External Wall (W/m ² K)	0.13 - 0.15	0.13
Ground Floor (W/m ² K)	0.09 - 0.12	0.10
Roof (W/m ² K)	0.10 - 0.12	0.10
Windows (W/m ² K)	1.0	1.2
Air Tightness (m ³ /h.m ² @50Pa)	1	3

Table 2: Proposed Fabric Performance

RIBA Stage 3 CIBSE TM54 energy modelling by TB&A confirmed the estimated space heating demand of the building as **2.96 kWh/m²** thus compliant with the projects 'Llangatwg NZC Outline Design Brief'.

Estimated Energy Consumption

RIBA Stage 3 CIBSE TM54 analysis by TB&A calculated predicted total annual energy consumption of the building, including both regulated and unregulated energy use. Total predicted energy consumption, including a Management Factor of 5%, was calculated to be 56.8 kWh/m², or **487,926 kWh per annum** based on a modelled GIFA of 8,595m².

It should be noted that the RIBA Stage 3 CIBSE TM54 analysis excluded any use of the school outside of core hours and thus excludes any potential community use of the building.

'Small Power' accounted for the greatest end use at **15.3 kWh/m² (28%)**, with the 'Server' accounting for **9.3 kWh/m² (17%)**. 'Fans' accounted for **8.2 kWh/m² (15%)**, with the 'Kitchen' a further **5.1 kWh/m² (9%)**, and 'Internal Lighting' an additional **4.4 kWh/m² (8%)**.

Whilst the predicted EUI is below the 65 kWh/m² target, there remain opportunities to reduce the buildings total energy consumption, of which the project team will continue to develop as the design progresses. The TB&A project team will continue to refine the CIBSE TM54 analysis at each RIBA Stage to ensure that total energy consumption of the building is understood.

End Use	Energy Use Intensity (kWh/m ²)	Energy Consumption (kWh)
Cooling	3.5	29,862
Fans	8.2	70,860
Pumps	1.9	16,640
Lighting	4.4	37,488
Small Power	15.3	131,109
Laboratory Gas	1.6	13,406
Space Heating	1.0	8,719
DHW	1.9	16,596
Kitchen	5.1	43,715

End Use	Energy Use Intensity (kWh/m ²)	Energy Consumption (kWh)
External Lighting	1.3	11,262
Lifts	0.1	766
CCTV	0.4	3,048
Access Control	0.2	1,394
Server	9.3	79,826
<i>Sub-Total</i>	<i>54.1</i>	<i>464,691</i>
Management Factor (5%)	2.7	23,235
Total	56.8	487,926

Table 3: CIBSE TM54 Predicted Total Annual Energy Consumption

Step 1 - On Site Renewable Energy Generation

In accordance with the 'Llangatwg NZC Outline Design Brief', on-site energy generation should exceed the Operational Energy Use Intensity (EUI) by 5 to 10% to provide a buffer to mitigate discrepancies between predicted and actual in-use energy consumption. As such, target renewable energy generation across the site based on a **10% buffer** margin equated to **536,718 kWh**.

The RIBA 3 design strategy for Llangatwg School included an allowance for a 282 kWp (1,848m²) of solar photovoltaics mounted on the roof of the development. This equated to **336,378 kWh** of renewable energy generation per annum, i.e. 63% of predicted building energy consumption including a 10% buffer margin. Thus, based on current assumptions regarding building energy consumption, a residual energy balance of 200,340 kWh would require offsetting to achieve NZCio.

It should be noted that the proposed 282 kWp solar photovoltaic system, generating 336,378 kWh per annum equates to a renewable energy generation intensity of 81 kWh/m² based on a building footprint of 4,173m², which significantly exceeds the minimum 65 kWh/m² renewable energy generation target as set by the NZC Building Standard.

Llangatwg School	Annual Energy (kWh)
Building Energy Consumption + 10% Buffer Margin	536,718
On-Site Renewable Energy Generation (282 kWp)	336,378
Residual Energy Balance	200,340
NZCio Compliant?	NO

Table 4: Building Integrated Renewable Energy Generation

National Grid Capacity

Initial consultation by the project team with National Grid suggests a preliminary **350 kWp** export capacity limit across the site, referred to as a **G100 Export Limitation**. As such, the proposed 282 kWp PV array should not exceed export limitations.

It is recommended that the project team apply for National Grid determination at the earliest of opportunity to establish actual grid capacity.

Additional On-Site Renewable Energy Generation Opportunities

The project team identified potential opportunities for additional on-site renewable energy generation across the wider Llangatwg site, including 521m² of PV installed to the Second Floor Façade, generating approximately 78,166 kWh per annum, and a further 1,318 m² of PV installed to dedicated PV canopies above car parking bays, generating a further 269,070 kWh.

As summary of principle locations and indicative annual renewable energy generation are given in the table below. Note, locations that had an estimated renewable energy output of less than 100 kWh/m² were considered non-viable.

It should be noted that additional PV to Car Parking Bays would require an independent structure, which if based on a high embodied carbon impact material such as steel, could outweigh the benefits of renewable energy generation. All opportunities should be evaluated against access and maintenance requirements, and wider health and safety issues.

Location	Available Area (m2)	Annual Energy (kWh)
Vertical PV to Second Floor Facade		
Eastern Courtyard Elevation	119	17,854
South Elevation	278	41,708
West Elevation	124	18,604
Sub-Total	521	78,166
Car Parking Bays		
Disabled Bay	217	42,539
Standard Bays	1,101	226,531
Sub-Total	1,318	269,070
Total	1,839	347,236

Table 5: Potential Additional On-Site Renewable Energy Generation

It is recommended that the project team review all potential on-site renewable energy generation opportunities to establish the technical viability of inclusion during RIBA Stage 4.

Step 2 - Off-Site Renewable Energy Generation

In accordance with the second step of the UKGBC REPCO Carbon Offsetting Hierarchy, where on-site renewable energy generation has been maximised, and a residual energy balance still remains, project teams should subsequently consider opportunities for off-site renewable energy generation, provided that they deliver additionality.

A residual annual energy balance of 200,340 kWh would require a circa **1,101m²** of additional renewable energy generation to achieve NZCiO at Llangatwg School.

It is recommended that the project team undertake a formal review of existing and potential renewable energy generation capacity across the wider educational estate.

Step 3 - Residual Carbon Offsetting

Depending on the viability of corresponding demand management solutions and/or opportunities for off-site renewable energy generation, to achieve NZC in Operation, annual carbon emissions associated with residual energy balance would have to be offset through approved carbon standards.

Approved Offsetting Standards

The UKGBC REPCO identified the following approved standards as listed by the UK Environmental Reporting Guidelines:

- UK Woodland Carbon Code
- UK Peatland Code

Both codes evaluate carbon savings through a process called Carbon Sequestration, i.e. the absorption of carbon from the atmosphere into biogenic material. The UK Woodland Carbon Code focuses on carbon sequestration associated with new woodland planting and on-going management. The UK Peatland Code focuses on carbon sequestration associated with Peatland restoration and on-going management.

Both schemes require land to be remediated for a minimum of 15-years before carbon savings can be formerly claimed, referred to as **Woodland Carbon Units** (WCU) or **Peatland Carbon Units** (PCU), of which 1no. Unit reflects 1 tCO₂e that has been sequestered. Carbon Units are independently verified, are guaranteed to be there, and can be used by companies to report against UK-based emissions or to use in claims of carbon neutrality or Net Zero emissions.

However, to assist in current and future woodland generation and peatland restoration, both codes allow for the purchase of **Pending Issuance Units** (PUI), which are effectively a 'promise to deliver' a WCU or PCU in the future. It should be noted that PUI are not 'guaranteed' and therefore cannot be used to report against emissions until verified. However, it allows companies to plan to compensate for future UK-based emissions or make credible Corporate Social Responsibility statements in support of woodland creation or peatland restoration.

Units are held in the UK Land Carbon Registry. Every 10 years, projects are checked and, if performing well, verified. At each of these points, PIUs delivered are converted to WCUs or PCUs.

Calculating Carbon Offsetting

UKGBC REPCO states that residual operational energy consumption (kWh) should be converted annually to carbon emissions (kgCO₂e) in accordance with the current UK Government Green House Gas (GHG) Conversion Factors for Company Reporting⁵. However, Welsh Government's 'Sustainable Communities for Learning Business Case Guidance'⁶ established annual Carbon Factors for electricity consumption and renewable energy generation until the year 2100. As such, corresponding Welsh Government reported Carbon Factors have been assumed within this technical note.

The table below summarises the carbon emissions that would be required to be offset over a 60-year period, assuming that Llangatwg School is operational in 2028.

Llangatwg School	Residual Carbon Offsetting
Residual Energy (kWh)	200,340
Estimated Carbon Emissions (tCO ₂ e)	498

Table 5: Residual Carbon Emissions (60-year)

Cost of Carbon Offsetting

To date it is understood that Neath Port Talbot have not established a Carbon Offsetting Price to assist project teams understand the cost of achieving NZC in Operation where opportunities for on-site and/or off-site renewable energy generation have been exhausted. In lieu of an established cost, this document refers to reported carbon offsetting and carbon pricing costs from the UK Woodland Carbon Code.

The **UK Woodland Carbon Code** reported that companies were paying on average **£25.36/tCO₂e** for purchases of Pending Issuance Units in 2023⁷. Given the limited number of existing verified carbon units, no cost information was available for either WCU or PCU.

Transition Fund

UKGBC REPCO states that organisations seeking to demonstrate leadership can consider taking a **Transition Fund** approach. The core premise of this approach is to release funds to further support the transition to net zero, i.e., for projects that cannot reasonably be termed a carbon offset credit or carbon unit but still have significant carbon reduction value.

Under this scenario the residual carbon balance is offset through an approved carbon standard such as the Woodland Carbon Code. The remainder of the transition fund can be spent on any type of project that contributes towards the transition of net zero.

HMT Green Book⁸ suggested a central carbon price of £241/tCO₂e in 2020/2021, increasing by 1.5% per year in real terms. Therefore, assuming that Llangatwg School is operational in 2028, the central carbon price would be circa **£271/tCO₂e** in 2028/2029.

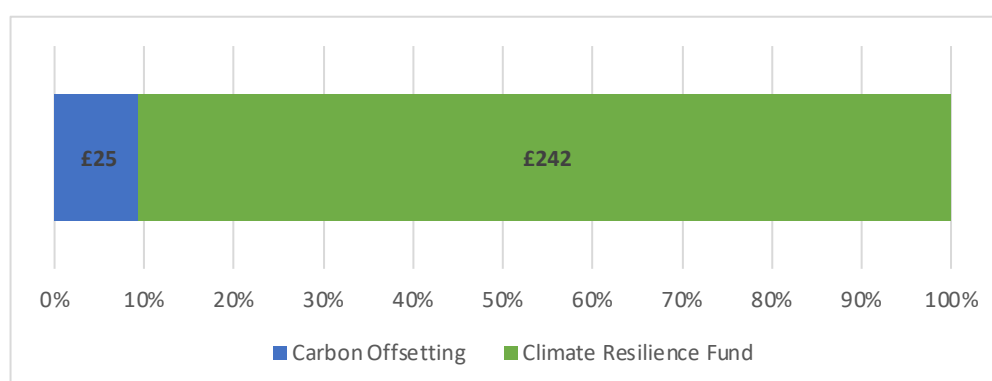


Figure 1: Illustrative Example of a Transition Fund

⁵ <https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting>

⁶ <https://www.gov.wales/sustainable-communities-learning-business-case-guidance>

⁷ <https://woodlandcarboncode.org.uk/uk-land-carbon-registry/uk-carbon-prices>

⁸ <https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-government/the-green-book-2020>

It should be noted that design scenarios reported above should not be viewed in isolation, with potential opportunities to reduced residual carbon emissions associated with reducing building energy consumption, increasing on-site renewable energy generation, implementing demand management solutions, and maximising realistic off-site renewable energy generation.

NZC (Embodied Carbon)

Arda Consulting undertook a Whole Life Embodied Carbon appraisal of the development at RIBA Stage 2, the objective being to identify potential opportunities and constraints associated with designing and delivering the building to a maximum Upfront Embodied Carbon target of 500 kgCO₂e/m².

The evaluation included a review of the following principal building elements, substructure, superstructure, internal finishes, building services and renewable energy systems. Realistic assumptions were made regarding elements of the design that were not yet developed, e.g. internal finishes. Please refer to 'Whole Life Carbon Review - RIBA 2' for further details.

Upfront Embodied Carbon

The Upfront Embodied Carbon impact (A1-A5) of the building, excluding Biogenic Carbon savings, was calculated as 4,522 tCO₂e, which equated to an **Upfront Embodied Carbon** intensity of **549 kgCO₂e/m²** based on a GIFA of 8,236m². This is above the project target of 500 kgCO₂e/m². Opportunities to reduce the Upfront Embodied Carbon impact of the building have been identified.

Llangatwg School	Baseline
Upfront Embodied Carbon (tCO ₂ e)	4,522
GIFA (m ²)	8,236
Upfront Embodied Carbon Intensity (kgCO ₂ e/m ²)	549
NZC Compliant	NO

Table 5: Upfront Embodied Carbon Intensity 'Baseline'

Upfront Embodied Carbon Impact by Material

A review of Upfront Embodied Carbon impact by individual material established that 722 tonnes of **Hot Rolled Steel** accounted for the greatest impact at **1,810 tCO₂e (44%)**, of which it was assumed that all Steel was produced in the UK, with an average recycled content of 20%⁹.

1,141m³ of **Concrete C32/40** associated with the Substructure, accounted for the second greatest impact at **306 tCO₂e (7%)**, with 1,086m³ of **Concrete C28/35** associated with the Upper Floor and Roof Decks, accounted for a further **267 tCO₂e (7%)**. All concrete was assumed to include 20% cement replacement levels, equating to average cement replacements levels in the UK at present.

The **Metal Deck**, associated with the Composite Concrete Floor Slab to First Floor and Roof, accounted for **240 tCO₂e (6%)** of Upfront Embodied Carbon, with **XPS Insulation** associated with the Ground Floor Slab and Roof accounting for a further **167 tCO₂e (4%)**.

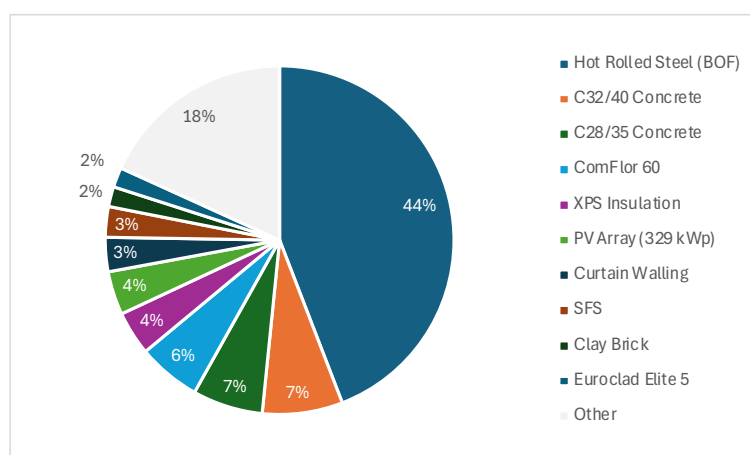


Figure 1: Upfront Embodied Carbon Impact by Material (A1-A5)

⁹ RICS, Whole Life Carbon Assessment for the Built Environment, November, 2017

The 329 kWp **Photovoltaic Array**, required to achieve NZCiO, resulted in an Upfront Embodied Carbon Impact of **165 tCO₂e (4%)**, of which a maximum carbon intensity of the PV array was assumed to be 77.3 kgCO₂e/m².

Embodied Carbon Saving Opportunities

Specifying **Steel** from manufacturers that produce structural steel from **Electric Arc Furnaces**, which typically achieve recycled content rates of 90%, could result in significant carbon savings in the order of **1,275 tCO₂e (28%)**, reducing the Upfront Carbon Intensity of the Building to 393 kgCO₂e/m².

Increasing the **Concrete C32/40** cement replacement levels to **60% GGBS**, which reflect maximum realistic cement replacement levels currently available across the UK would result in Upfront Embodied Carbon savings in the order of **104 tCO₂e (2%)**, reducing the Upfront Carbon Intensity of the Building to 535 kgCO₂e/m².

Increasing the **Concrete C28/35** cement replacement levels to **60% GGBS**, would result in Upfront Embodied Carbon savings in the order of **95 tCO₂e (2%)**, reducing the Upfront Carbon Intensity of the Building to 536 kgCO₂e/m².

Following a review of the RIBA 2 Embodied Carbon findings with the project team it was agreed that all the above carbon saving opportunities will be implemented in full. As a result, the Upfront Embodied Carbon impact of the building would reduce to 3,039 tCO₂e, equating to an **Upfront Embodied Carbon** intensity of **370 kgCO₂e/m²** and thus compliant with the projects Embodied Carbon targets.

Llangatwg School	Proposed
Upfront Embodied Carbon (tCO ₂ e)	3,048
GIFA (m ²)	8,236
Upfront Embodied Carbon Intensity (kgCO ₂ e/m ²)	370
NZC Compliant	YES

Table 6: Upfront Embodied Carbon Intensity 'Proposed'

Whole Life Embodied Carbon

The Whole Life Embodied Carbon impact (A1-C4) of the building, over a 60-year period, including Biogenic Carbon savings, was calculated as 6,023 tCO₂e, which equated to a **Whole Life Embodied Carbon** intensity of **731 kgCO₂e/m²** based on a GIFA of 8,236m².

Figure 2 below, provides an overview of embodied carbon impact by life cycle stage, of which the Production stage accounted for 4,058 tCO₂e, and the maintenance and replacement of materials during the operation of the building a further 1,176 tCO₂e. Construction Impacts, including transport of materials to site, and installation on site, accounted for 464 tCO₂e, with impacts associated with deconstruction, removal from site and disposal at End of Life, accounting for a further 358 tCO₂e.

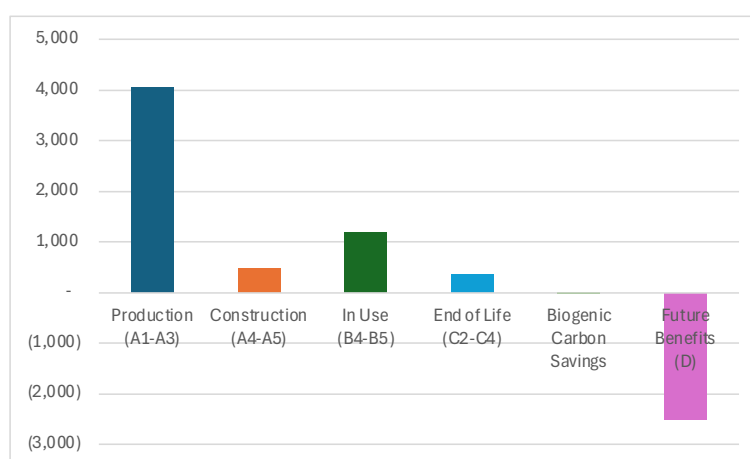


Figure 2: Embodied Carbon Impact by Life Cycle Stage (tCO₂e)

It should be noted that Whole Life Embodied Carbon impact is highly dependent on assumed replacement frequencies of individual materials, of which it is recommended that the project team review.

Carbon Offsetting

In accordance with UKGBC, to achieve NZC (Embodied Carbon) then 100% of embodied carbon associated with the development at Practical Completion should be offset through an approved carbon standard, including the UK Woodland Carbon Code, and UK Peatland Code. As such, Llangatwg School would currently require **4,522 tCO₂e** to be offset to be classified as NZC (Embodied Carbon).

Potential opportunities to offset Upfront Embodied Carbon impact through the UK Woodland Carbon Code, and UK Peatland Code will be discussed with the project team, should the project team aspire to achieve NZC (Embodied Carbon) status.

Next Steps

The project team will continue to refine and challenge the Whole Life Embodied Carbon appraisal of the development as the design progresses, including a detailed review at **RIBA 4**. Realistic opportunities to reduce the Upfront Embodied Carbon impact, and Whole Life Embodied Carbon impact will continue to be identified.