MAX FORDHAM

University College School

BREEAM Mat 01 - Life Cycle Carbon Report

01

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ISSUE HISTORY

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1.0 INTRODUCTION

A considerable percentage of a building's whole life carbon emissions are related to the materials specified. Life Cycle Carbon Analysis (LCA) aims to help us understand a building material's life cycle carbon impact on an element-by-element basis using this knowledge to:

- Help project teams to understand the overall environmental impact of the building design.
- Ensure that all life cycle greenhouse gas emissions are taken into account in the design, not just operational emissions.
- Reduce the impact of the construction industry and construction product industries.
- Assess the environmental impacts at the building level to provide flexibility when specifying construction products, to take into account project-specific conditions and priorities.
- Allow optimal solutions to be identified and adopted to reduce overall environmental impacts arising from construction product use.

A LCA study was undertaken for the University College School project during RIBA Stage 2, exploring the associated carbon emissions from building materials over the course of the development's design life.

1.1 BREEAM Credits Targeted

Depending upon the scope of the project the number of options appraised will vary as will the number of credits the process can contribute towards BREEAM. However as a minimum the following number of options must be considered:

Superstructure - Up to 6 credits

- RIBA Stage 2:
  Options appraisal, comparison of 2 to 4 (including the 'baseline' scenario) significantly different superstructure design options.
- RIBA Stage 4:
  Options appraisal, comparison of 2 to 4 (including the 'RIBA Stage 2 chosen solution) significantly different superstructure design options.

The comparison with the BREEAM LCA benchmark during Stage 2 and 4, where credits are awarded based on a reduction in life cycle carbon when compared to a BREEAM benchmark for a similar type building, is required for office, industrial and retail buildings only. Therefore this is not currently in the scope for this assessment.

Substructure and Hard Landscaping - 1 credit

- RIBA Stage 2:
  Options appraisal, comparison of at least 6 (including the 'baseline' scenario) significantly different substructure and Hard Landscaping options.

Core Building Services - 1 exemplary credit

- RIBA Stage 2:
  Options appraisal, comparison of at least 3 (including the 'baseline' scenario) significantly different core building services design options.

1.2 Methodology

As mentioned, the life cycle assessment calculation was undertaken using One Click LCA which is officially approved for the BREEAM UK Mat 01 credit by BRE. In order to identify potential reductions in life cycle carbon a ‘baseline’ scenario was developed within the tool. The methodology undertaken at each stage of the design is shown in Figure 3.

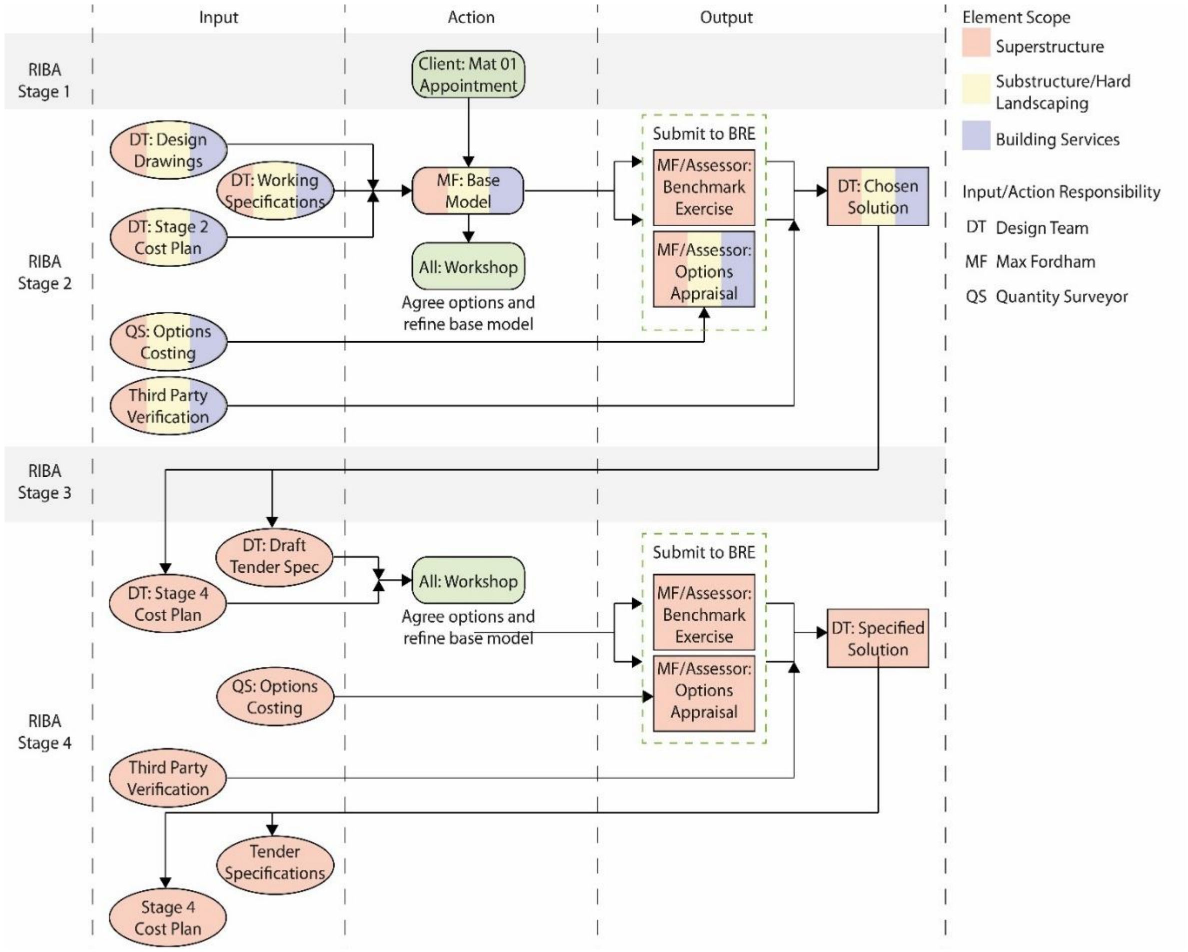


Figure 1 Overarching Methodology for Mat 01 LCA Study

The discussion around the work necessary to satisfy the Mat 01 requirements was firstly undertaken on a meeting held on Microsoft Teams in October 2023, with the Client and members of the project Design Team (Architect, Structural Engineer and M&E Engineer).

A Mat 01 Option Proforma was issued to all relevant Design Team members to collect information on the preferred material strategy. Further conversations to develop the final Mat 01 optioneering strategy were held with the relevant team members and various material alternatives were discussed.

Finally, the LCA model was developed through exploring the available materials on the One Click LCA database, in accordance with what agreed with the Design Team. It has been assured that all design options assessed fulfil the same functional requirements and all statutory requirements (to ensure functional equivalency).

Where exact material selections were not determined, the closest equivalent available within the One Click data base was selected. A full break down of inputted material quantities into the LCA One Click software corresponding to the results presented can be found in Appendix B.

The results represent the total life cycle impact for 60 year service life according to BS EN 15978:2011 for the proposed design.

The life cycle stages considered in this study are also compliant with BS EN 15978:2011 and includes the embodied impacts, transport to site (typical figures are used), construction and installation impacts, refurbishment and replacement, de-construction and disposal as set out in Figure 4.

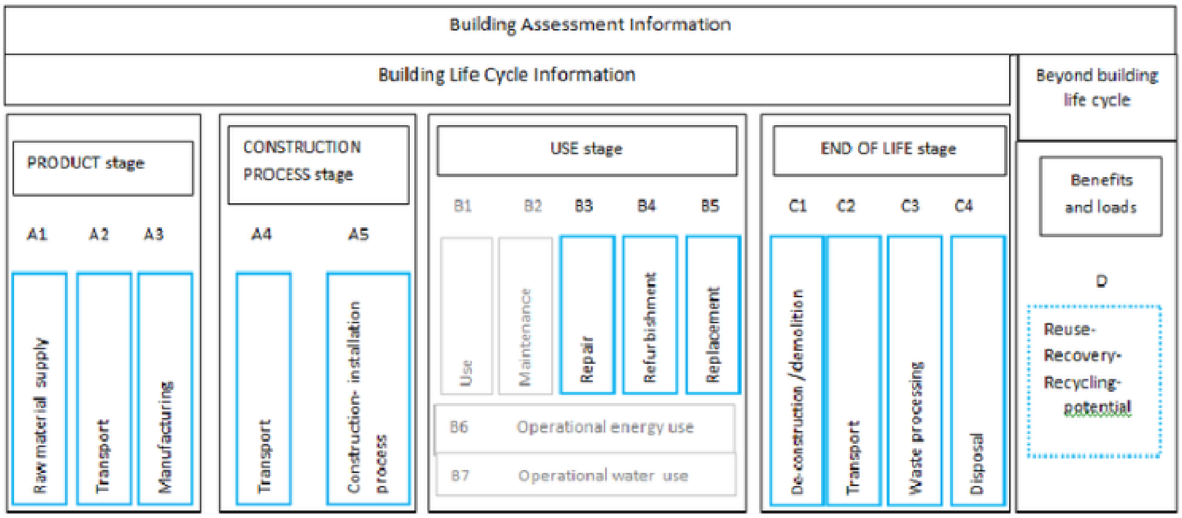


Figure 2 Life Cycle Stages from BS EN 15978:2011

The results reported in this study specifically refers to:

- Upfront Carbon (A1-A5) - Carbon emissions associated with the construction of a building. These are the carbon emissions that a project team can most directly control through modelling the upfront carbon and choosing low-carbon construction materials coupled with leaner material use.

- Embodied Carbon (A1-C4, excl. B6-7 & D) – Carbon emissions associated with the construction, maintenance, repair and end-of-life of a building. Considering embodied carbon, in addition to Upfront Carbon, allows the project team to identify material choices that have a low upfront carbon cost, but avoid high ongoing carbon emissions associated with maintenance and repair.

This study must be BREEAM compliant and therefore the building elements modelled are in line with the BREEAM New Construction 2018 Manual - 'In Scope Elements' - as set out under the Mat 01 issue. The full list of building elements and sub-elements assessed and out of the scope can be found in Appendix A

1.3 Options Considered

Selected design option is highlighted within pink box.

SUPERSTRUCTURE

Element	Option 1 - Proposed Design	Option 2	Option 3	Option 4
FRAME	Steel Frame	Steel Frame	Steel Frame	Steel + Steel Ties
UPPER FLOORS	Precast Hollowcore Composite Slabs CLT & Glulam – Recital room	Precast Hollowcore Non-Composite Slabs CLT & Glulam – Recital room	Coffered Slab - classrooms Precast Hollowcore Composite Slabs CLT & Glulam – Recital room	Tie- Vault - classrooms Precast Hollowcore CLT & Glulam – Recital room
ROOF	Tennis Court / General Play Zinc Standing Seam Green Roof	Tennis Court / General Play Zinc Standing Seam Green Roof	Tennis Court / General Play Copper Standing Seam Green Roof	Tennis Court / General Play Green Roof Green Roof
STAIRS	Steel access	Concrete Stairs external	Steel access	Concrete Stairs external
FAÇADE	West - Red Brick (non standard) - Lime Mortar Rockwool Blockwork	West - Red Brick (Waste Brick) - Lime Mortar Hemp SFS	West - Red Brick (K-Briq) - Lime Mortar Wood fibre Blockwork	West - Red Brick (non standard) - Lime Mortar Insulation - Rockwool Blockwork
	East - Glazed Ceramic Tiles Rockwool Blockwork	East - Glazed Ceramic Tiles Rockwool Blockwork	East - Glazed Ceramic Tiles Rockwool Blockwork	East - Glazed Ceramic Tiles Rockwool Blockwork
WINDOWS	Alu/Timber Comp Double	Double	Double	Alu/Timber Comp Double

SUBSTRUCTURE

Element	Option 1 / Base	Option 2	Option 3
FOUNDATIONS	New raft + reuse of existing raft	New raft + reuse of existing raft	New raft + reuse of existing raft
BASEMENT - RETAINING	Secant (hard - soft piles) + Liner	Secant (all reinforced) + Liner	Sheet pile wall (quiet sheet piling) + Liner
EXISTING RETAINING	Partially retained existing contig wall	Partially retained existing contig wall	Partially retained existing contig wall

HARD LANDSCAPING

Element	Option 1 / Base	Option 2	Option 3
Pedestrian courtyard walkway: permeable	Gravel w/Plastic Gravel Grid	Gravel w/Plastic Gravel Grid	Gravel w/Plastic Gravel Grid
Pedestrian walkway top terrace: impermeable	Tarmac Asphalt	Reclaimed paving slabs	Reclaimed paving slabs
Pedestrian Walkway: impermeable	Block paviour	Block paviour	Block paviour
Pedestrian Walkway: permeable	Block paviour	Block paviour	Block paviour
Vehicle access: permeable	Block paviour	Block paviour	Block paviour (reduced area) and Tarmac
Pedestrian Walkway: permeable	Decorative macadam	Non-slip sports paint on asphalt	Decorative macadam
Kick-about area with Vehicular Access: permeable	Tarmac Asphalt	Non-slip sports paint on asphalt	Tarmac Asphalt
Vehicular Access: impermeable	Tarmac Asphalt	Tarmac Asphalt (reduced area)	Tarmac Asphalt

Car-park - reinforced grass	Limestone Grid, w/Plastic Gravel Grid and grass seed on soil	Limestone Grid, w/Plastic Gravel Grid and grass seed on soil	Limestone Grid, w/Plastic Gravel Grid and grass seed on soil

BUILDING SERVICES -

Element	Option 1 / Base	Option 2	Option 3
HEAT SOURCE	2-pipe ASHP R32 (2No. 180kW)	4-pipe ASHP 454B	ASHP (R290)
SPACE HEATING AND AIR CONDITIONING	FCU/Fan-Rad	UFH & FCUs	Chilled Beams & FCUs
VENTILATION	AHU/MVHR/Nat Vent Galv. Steel Ductwork	AHU/MVHR Phenolic	AHU/MVHR/Nat Vent Carboard Duct

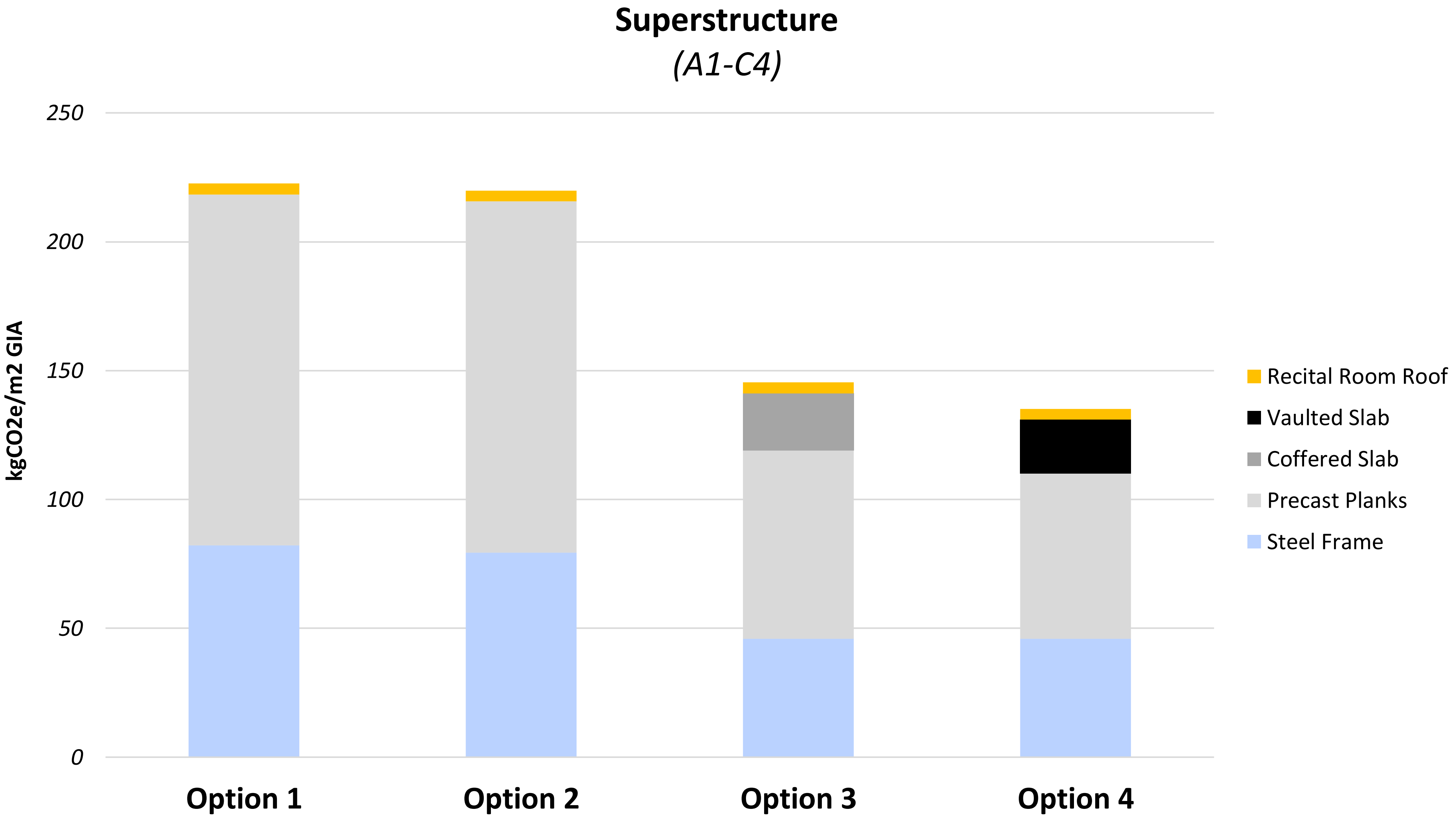
1.4 Superstructure

The options outlined in section 1.3 are justified as follows:

- Option 1: Precast Hollowcore Planks - Composite
    - Economic and relatively lightweight – easily capable of carrying heavy roof loads. Composite action minimise upfront material use but removes end-of-life recoverability of steel beams and columns (recycling still possible)
- Option 2: Precast Hollowcore Planks
    - Economic and relatively lightweight – easily capable of carrying heavy roof loads. Non-Composite action increases upfront material use but allows for end-of-life recoverability of steel beams and columns.
- Option 3: Precast Hollowcore Planks – Composite and Coffered slab over classroom block
    - As option 1, but coffered slabs present a more efficient use of material of the classroom block roof. Large cost increase.
- Option 3: Precast Hollowcore Planks – Composite and Vaulted Concrete Shells + Ties over classroom block
    - As option 1, but Vaulted slabs present a radically more efficient use of material of the classroom block roof. Very large cost increase and complexities forming Tennis court surface and waterproofing details.

The results of the study are on the next page.

Option 1 remained the preferred option, albeit non-composite action will still be considered in the later design stages. The coffered slab and vaulted solutions performed much better from an embodied carbon perspective but were deemed cost prohibitive.


Superstructure
(A1-C4)
kgCO2e/m2 GIA
250
200
150
100
50
0
Option 1
Option 2
Option 3
Option 4
Recital Room Roof
Vaulted Slab
Coffered Slab
Precast Planks
Steel Frame

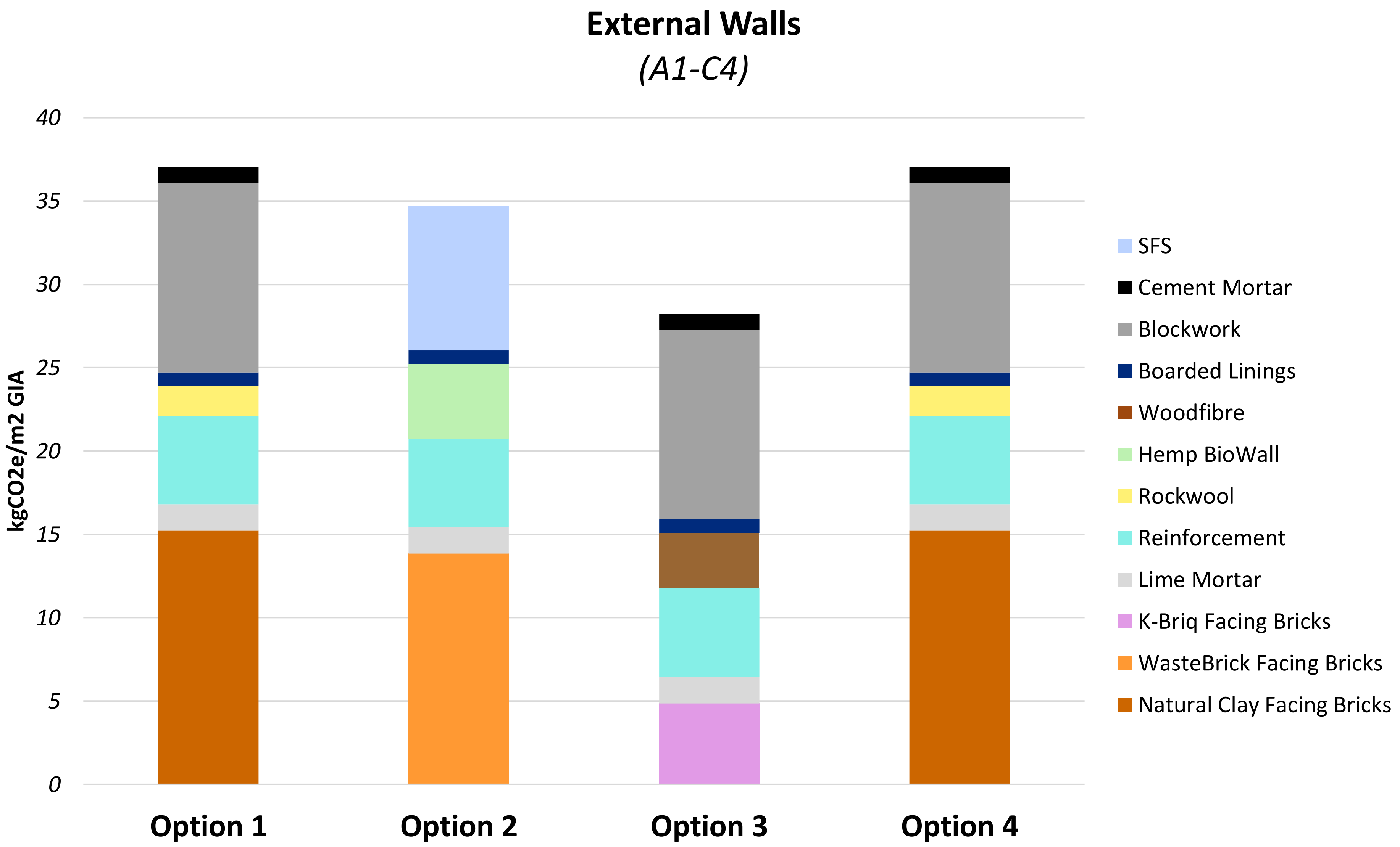
1.5 External Walls

The options outlined in section 1.3 are justified as follows:

- Option 1: New Facing Bricks (lime mortar) with Mineral Wool and Block inner walls.
    - Bricks will be able to match existing vernacular of the site / area. Traditional build-up with known fire performance and cost certainty.
- Option 2: WasteBrick Facing Bricks (lime mortar) with Hemp Insulation and SFS inner lining.
    - Bricks will be less able to match existing vernacular of the site / area but have strong circular credentials in utilising waste material. Embodied carbon very similar. Non-traditional build-up with known less well-known fire performance and cost certainty.
- Option 3: K-Briq Facing Bricks (lime mortar) with Woodfibre Insulation and Block inner walls.
    - Bricks will be less able to match existing vernacular of the site / area but have strong circular credentials in utilising waste material and a much-reduced embodied carbon through the removal of the kilning process. Non-traditional build-up with known less well-known fire performance and cost certainty.
- Option 4: As option 1.

The results of the study are on the next page.

Option 1 remained the preferred option mainly due the ability of the bricks to match the look and feel of the local vernacular. Alternative insulation products will continue to remain in consideration during the later design stages but will be subject to a more detailed understanding of moisture and fire impacts.


External Walls
(A1-C4)
40
35
30
25
20
15
10
5
0
kgCO2e/m2 GIA
Option 1
Option 2
Option 3
Option 4
SFS
Cement Mortar
Blockwork
Boarded Linings
Woodfibre
Hemp BioWall
Rockwool
Reinforcement
Lime Mortar
K-Briq Facing Bricks
WasteBrick Facing Bricks
Natural Clay Facing Bricks

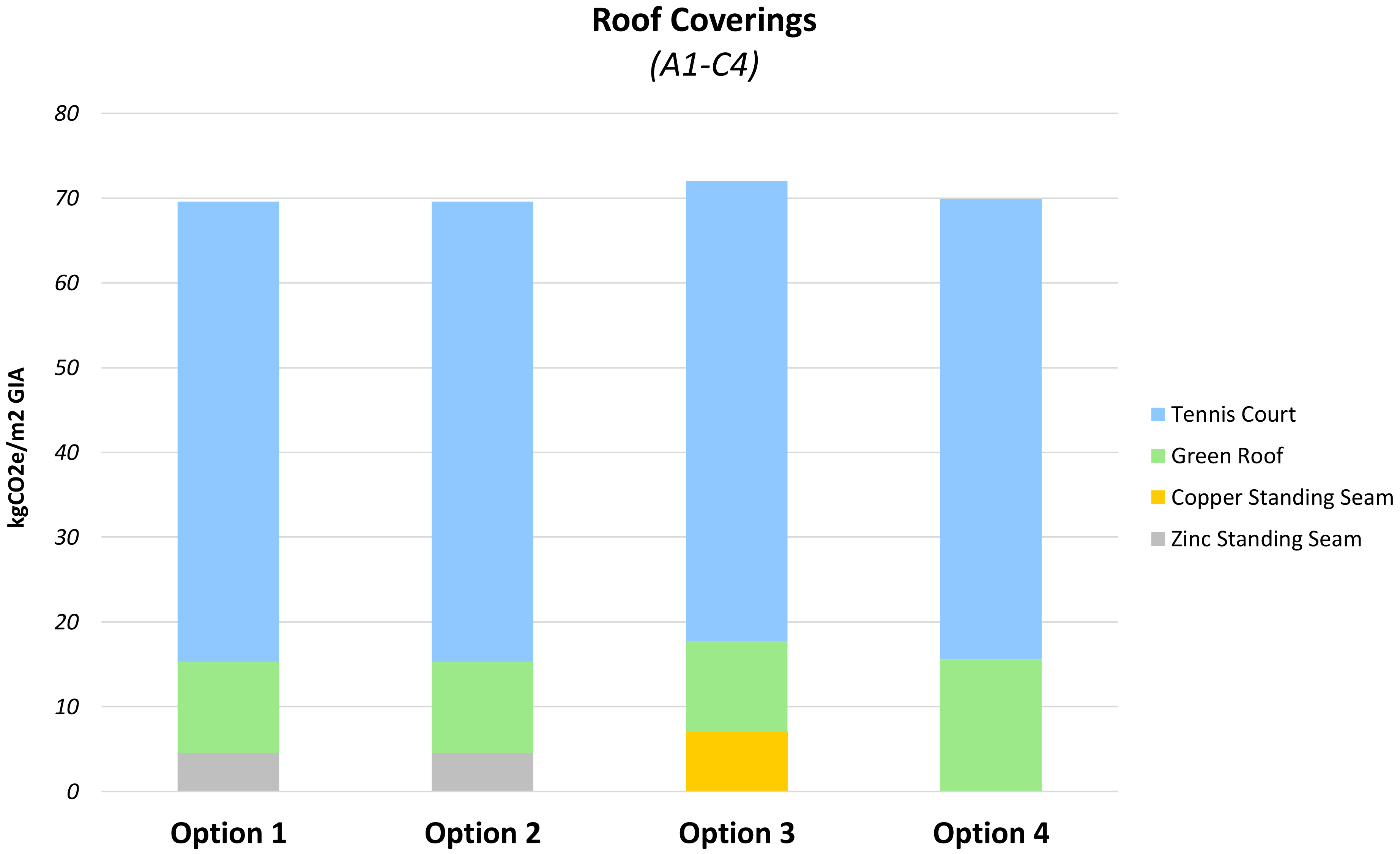
1.6 Roof Coverings

The options outlined in section 1.3 are justified as follows:

- Option 1: Green Roofs, Zinc Standing seam over part of the recital roof and Specialist Macadam over Classroom block.
- Option 2: As above.
- Option 3: Green Roofs, Copper Standing seam over part of the recital roof and Specialist Macadam over Classroom block
- Option 4: Green Roofs and Specialist Macadam over Classroom block

The results of the study are on the next page.

Option 1 remained the preferred option due to no discernible benefit of swapping to a copper standing seam roof. The all-green roof option would also be very challenging on parts of the recital roof slopes and provides no clear carbon benefit. Roof carbon is dominated by the specialist macadam surfacing required for the tennis courts above the classrooms.

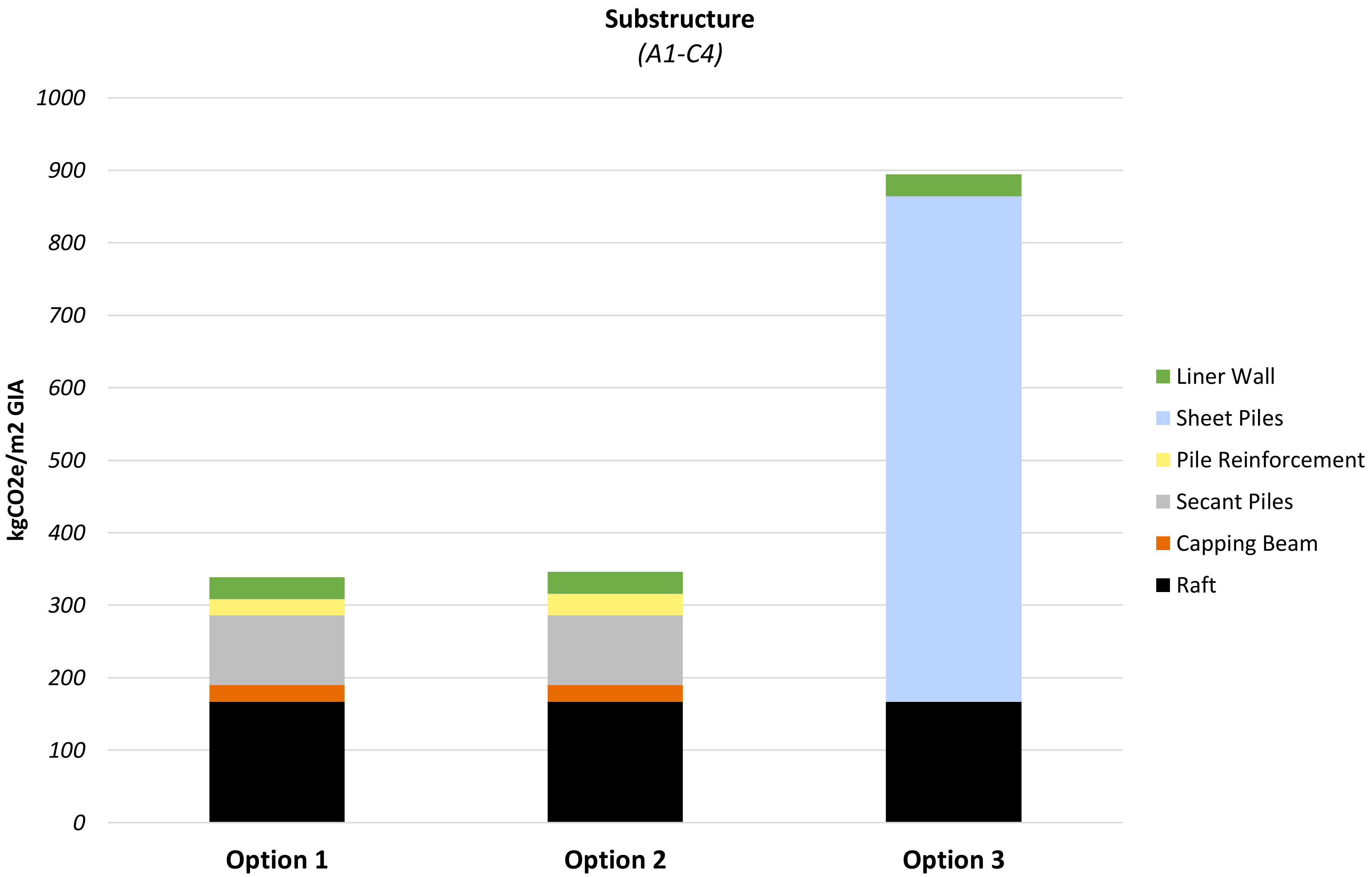

Roof Coverings
(A1-C4)
80
70
60
50
40
30
20
10
0
kgCO2e/m2 GIA
Option 1
Option 2
Option 3
Option 4
Tennis Court
Green Roof
Copper Standing Seam
Zinc Standing Seam

1.7 Substructure

The options outlined in section 1.3 are relatively self-explanatory with the exception of the all-reinforced pile Secant pile option which is present to see the impacts of increasing the strength of the retaining structure with the potential for slightly reduced pile-depth, subject to specialist design.

The results of the study are on the next page.

Option 1 remained the preferred option as the Sheet piled option is clearly much higher carbon, whilst the added complexity of reinforcing the secondary piles is unlikely to have a profound effect on whole life carbon results.


Substructure
(A1-C4)
kgCO2e/m2 GIA
1000
900
800
700
600
500
400
300
200
100
0
Option 1
Option 2
Option 3
Liner Wall
Sheet Piles
Pile Reinforcement
Secant Piles
Capping Beam
Raft

1.8 Building Services

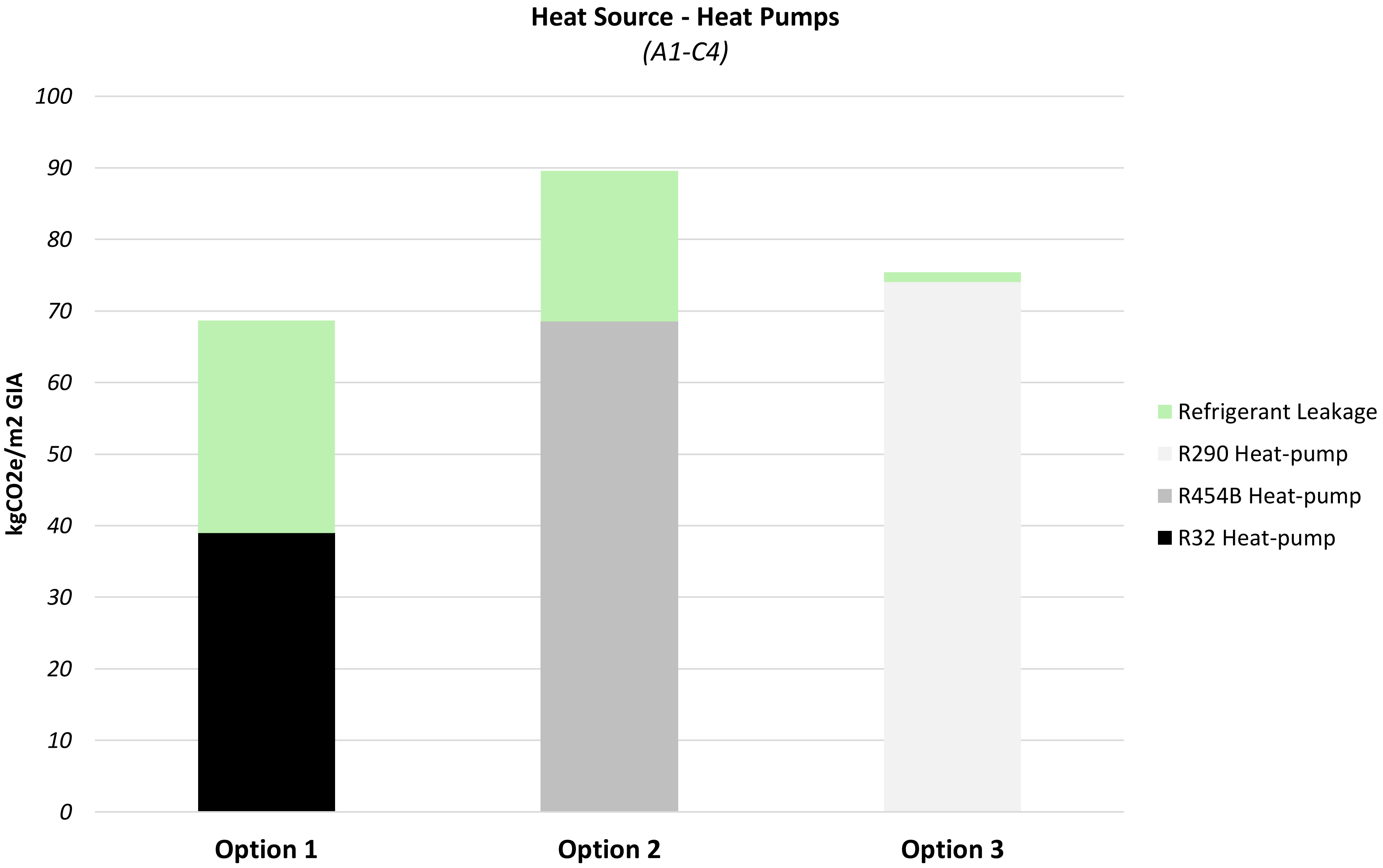
The results of the building services have been broken down into the 3 categories of Heat Source, Heating and Cooling Distribution and Ventilation.

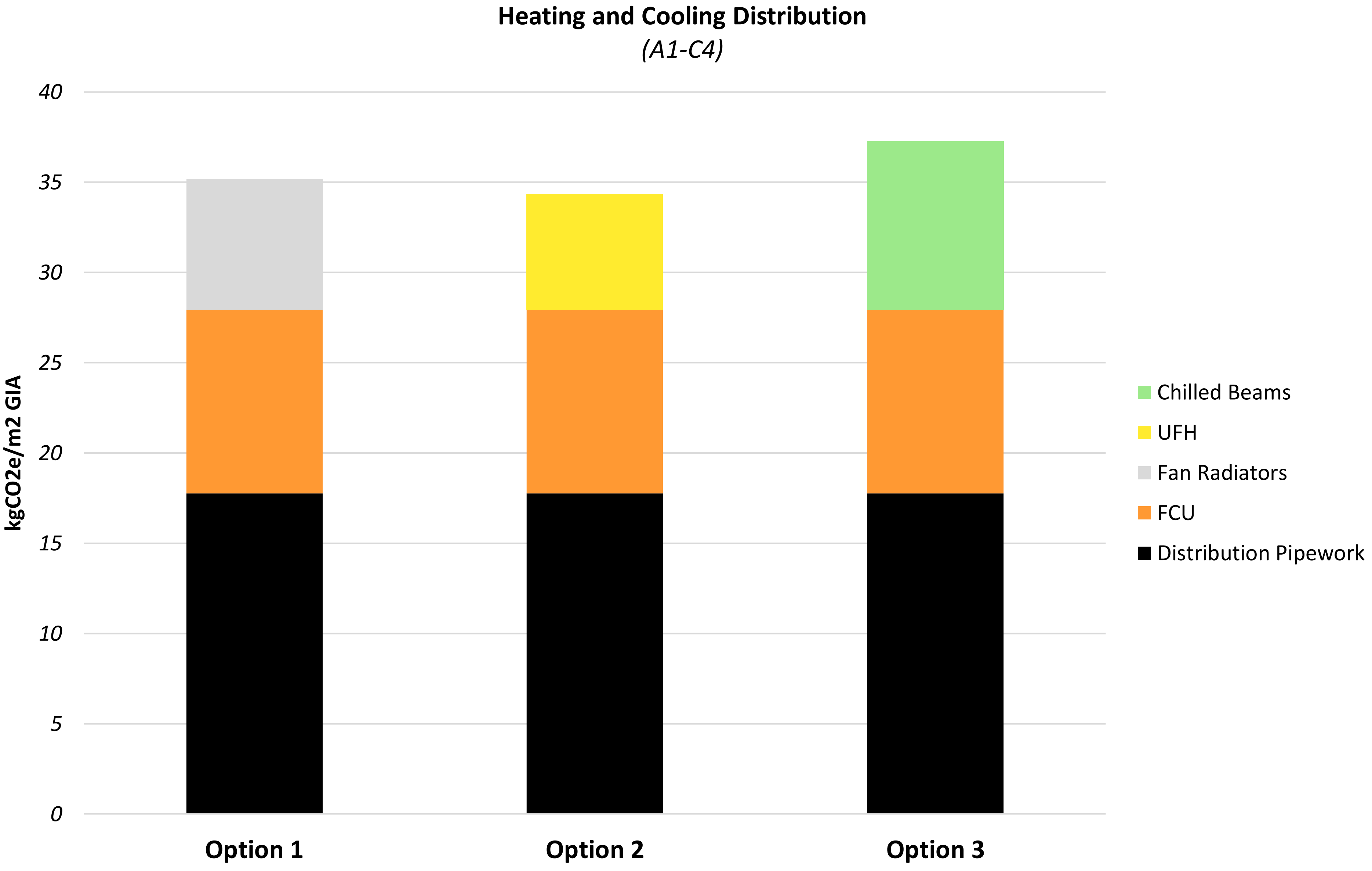
The results of the study are on the following pages.

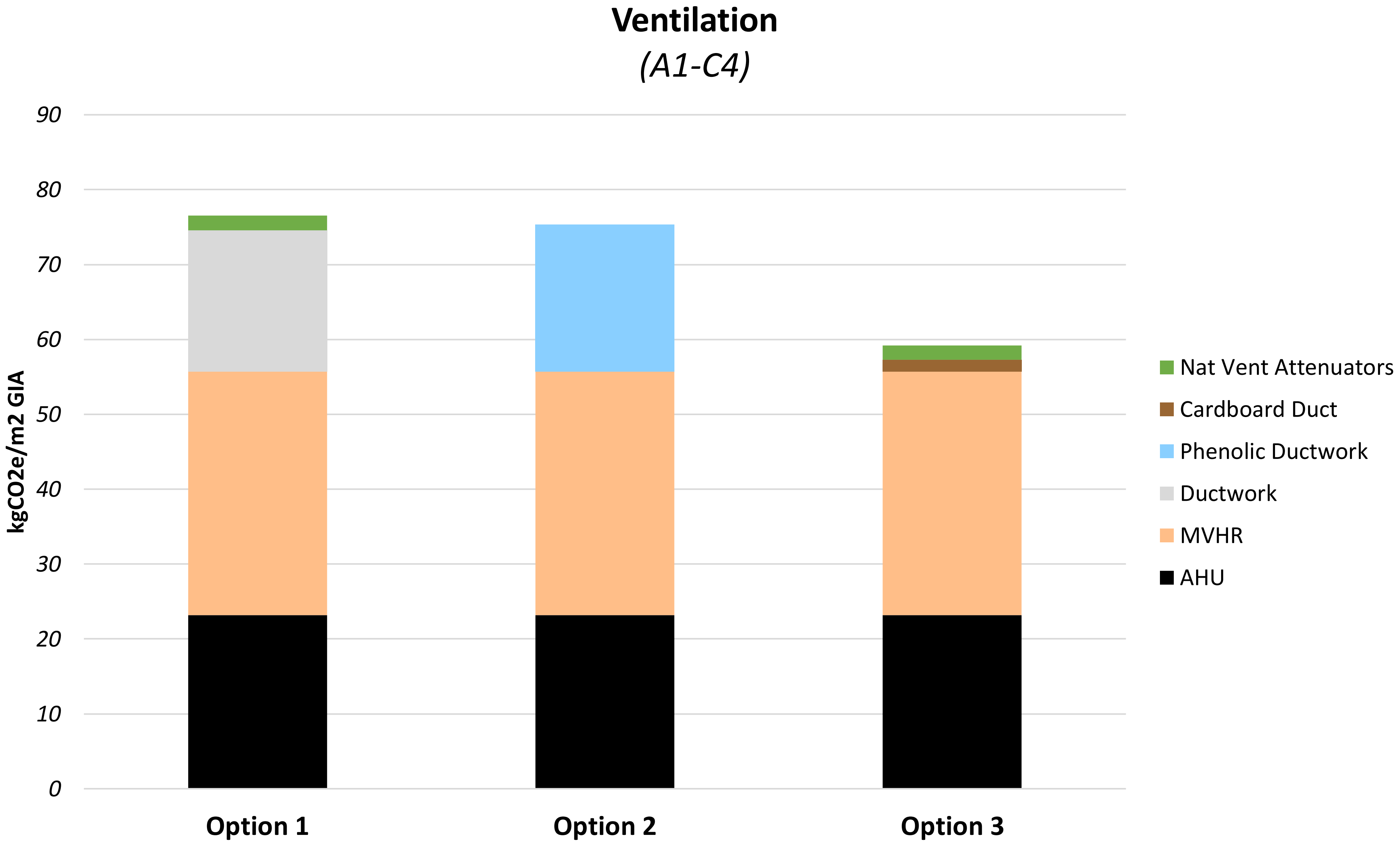
Heat Source
Option 1 remained the preferred option. Despite the higher leakage emissions, the low mass of the unit results in a combined embodied carbon that sits well below competing low-GWP refrigerant products. Due to the constrained site, the suitability of R290 (propane) is highly unlikely given the required exclusion zones around the unit.

Heating and Cooling Distribution
Option 1 remained the preferred option due to their carbon performance and being more economic. Given the uncertainty present that this stage in the design process, options that perform very similar are difficult to be declarative about and it appears under-floor heating (UFH) is in the same ball-park as Fan Radiators and doesn’t justify the cost uplift.

Ventilation
Option 1 remained the preferred option due to their carbon performance and being more economic. Phenolic ductwork does typically represent a carbon reduction compared to galvanised – in this instance, the absence of nat-vent in Option 2 implied more ductwork, negating the carbon reductions. Both phenolic and cardboard ducts will remain in contention subject to detailed acoustics and fire input at later stages.


Heat Source - Heat Pumps
(A1-C4)
kgCO2e/m2 GIA
100
90
80
70
60
50
40
30
20
10
0
Option 1
Option 2
Option 3
Refrigerant Leakage
R290 Heat-pump
R454B Heat-pump
R32 Heat-pump

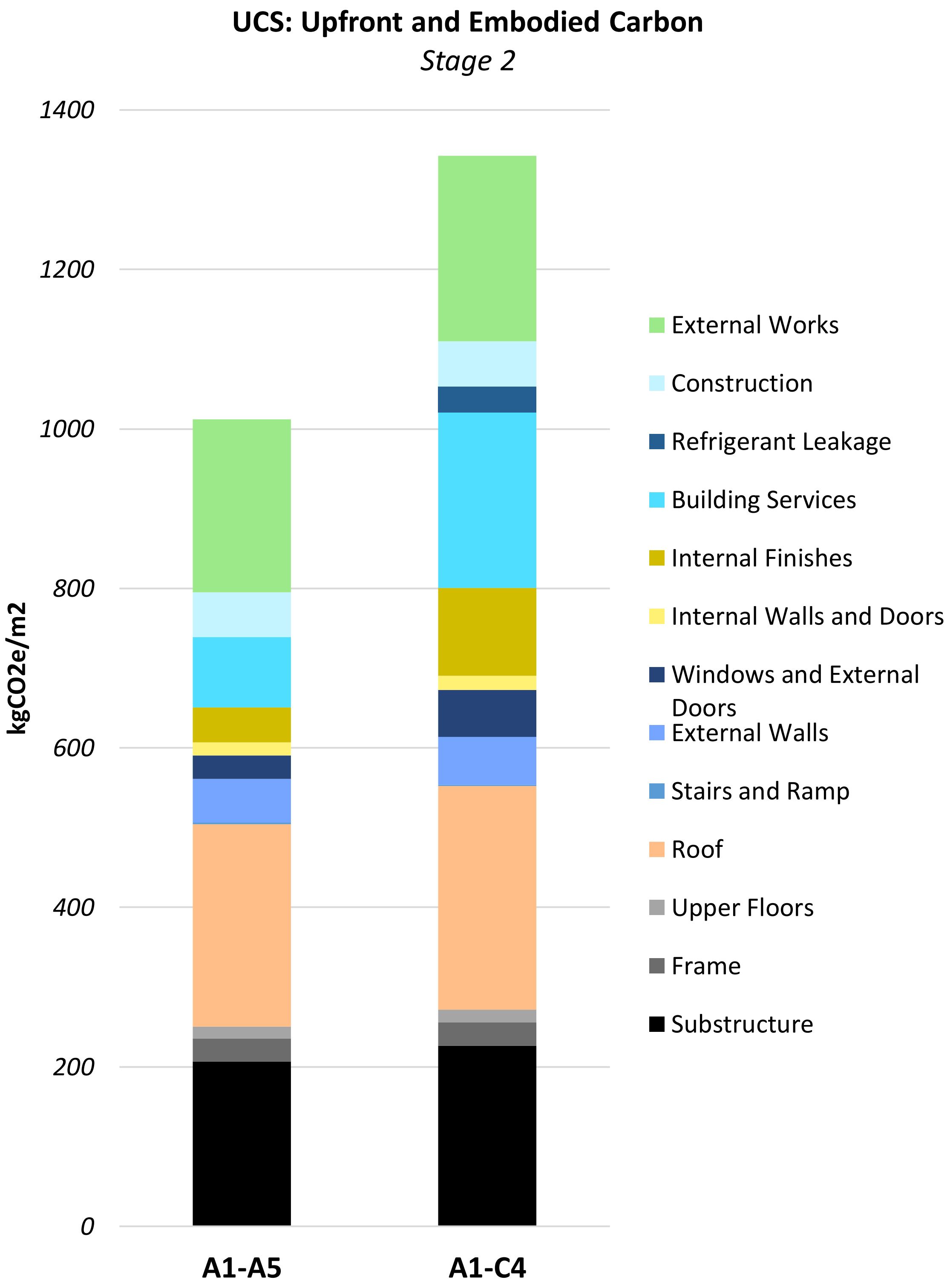

Heating and Cooling Distribution
(A1-C4)
kgCO2e/m2 GIA
40
35
30
25
20
15
10
5
0
Option 1
Option 2
Option 3
Chilled Beams
UFH
Fan Radiators
FCU
Distribution Pipework


Ventilation
(A1-C4)
90
80
70
60
50
40
30
20
10
0
kgCO2e/m2 GIA
Option 1
Option 2
Option 3
Nat Vent Attenuators
Cardboard Duct
Phenolic Ductwork
Ductwork
MVHR
AHU

1.9 Whole Building Breakdown

A full Stage 2 RICS Whole Life Carbon model was developed based off the above optioneering and supplemented with the quantity information for categories excluded in a BREEAM Mat01 study, as well as internal benchmarks for categories that have scare design information at Stage 2 (i.e. Finishes and much of Building Services outside the major kit).

The results are as follows (including a 10% uplift):



Explanatory notes

As can be seen from the graph above, the dominant sources of embodied carbon are:

- External Works
    - The external works are relatively large compared to the area of the new development and certainly provide a skewed view as to the kgCO2e/m2 GIA metric. Other benchmarks exclude these (RIBA and LETI), as it's hard to compare site-to-site. That's not to say these carbon emissions are not both present and important, but simply that it paints a slightly unclear picture when comparing to benchmarks. In this instance, with the external works removed from the equation, the Upfront carbon drops to **795 kgCO2e/m2** and the Embodied carbon to **1110 kgCO2e/m2.** While still above the benchmarks, the notes below provide clarity as to the major sources of these uplifts.
- Substructure
    - The substructure is penalised first due to the constraints of the site requiring retaining structure along the whole of one boundary. The nature of the scheme as a 'short building' also results in a number of penalties. Foundation depths are driven by site conditions. A hypothetical extra storey, resulting in double the GIA, would not require double the foundations – only a marginal increase. This inherent 'penalty' is often unavoidable in short building built on imperfect ground.
- Roof
    - The Roof is another key feature of the 'short building penalty'. Given the roof doesn't provide GIA its generally a carbon 'burden'. A tall building, with the same footprint, can spread that burden over many floors, each providing GIA, while a short building must spread the entire carbon burden over a single storey of GIA. In this instance, the constrained nature of the site - and the need to provide high-quality exercise space for the students – results in a roof structure that cannot be lightweight. The high dead and live loads experienced by the roof of the classroom block results in both a carbon uplift from the roof covering, but most pertinently, a large carbon uplift in the roof structure. All these combine to exacerbate the effects of this 'short building penalty'.

Additional measures taken to minimise Embodied Carbon emissions.

- Partial retention of existing retaining structure
- Partial retention of existing raft slab
- Lime mortar in lieu or traditional cement mortar
- Removal of partial basement
- Intention to re-use existing timber floor in rehearsal rooms in the new scheme

Future potential improvements

There are a number of potential future improvements to be made to reduce embodied and upfront carbon emissions, however, they are unlikely to cause drastic reductions.

- Natural insulation materials, Woodfibre and Hemp insulation. These would be desirable from a renewable perspective, but they are not necessarily a guarantee of carbon reductions – albeit it is possible.
- Cardboard Ducts
- Reclaimed Steel Beams – While the principle will be targeted, we don't typically include their carbon benefits at such an early stage as our ability to include these elements will entirely depend on availability at time of procurement.