Comparative Life Cycle Assessment for a notional school building

Prepared for: John Metcalfe, Peikko UK

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Peikko – Notional School LCA **www.peikko.com**

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EXECUTIVE SUMMARY

Aim of the project

The aim of this project, commissioned by Peikko UK, is to assess the life cycle carbon impacts associated with the use of Peikko's Deltabeam compared to the use of Universal Beams in a standard school building design.

The objectives of this study are as follows:

- To calculate the lifecycle carbon impacts of a notional school building using Deltabeams, from cradle to grave over 60 years, in close consistency with the most recent international LCA standards (ISO 14040)

- To calculate the lifecycle carbon impacts of the same notional school building using Universal Beams, from cradle to grave over 60 years, in close consistency with the most recent international LCA standards (ISO 14040)

- To compare the lifecycle carbon impacts, and highlight and quantify the major environmental differences between the two scenarios.

Scope

The object of comparison is a school building developed by a leading construction and civil engineering company. The building is one block of a larger school development; it includes the building shell & limited fit out and excludes external areas and services. The notional block is supplemented with data obtained from a cost model for a similar school building developed by Davis Langdon (2007).

The main features are:

- 2,202 m2 GIA
- Pad foundations
- 3 storeys
- steel frame
- 7.2m×8m spans
- Double glazed windows
- Steel/timber doors
- Brick cladding

The two options for comparison are;

1. Universal beams (U-beam), varied sizes according to structural design (all sections), universal columns, holorib decking
2. Deltabeam D25-400 (internal sections), universal beams (perimeter sections), universal columns, precast hollow core decking

The functional unit used throughout this study is the construction, use and disposal of one square metre of Gross Internal Area (GIA) of the school building over 60 years. As shown in Figure 1, this study assessed lifecycle stages for the building based on the 'total carbon' footprint from cradle to grave, divided into two components:

- **Embodied carbon**, which corresponds to the impacts occurring during the manufacture of raw materials, the delivery of these materials to the construction site, onsite construction activities, maintenance of the building over its lifetime, and its end-of-life.

- **Operational carbon**, the carbon emitted during the building lifetime through energy consumption.

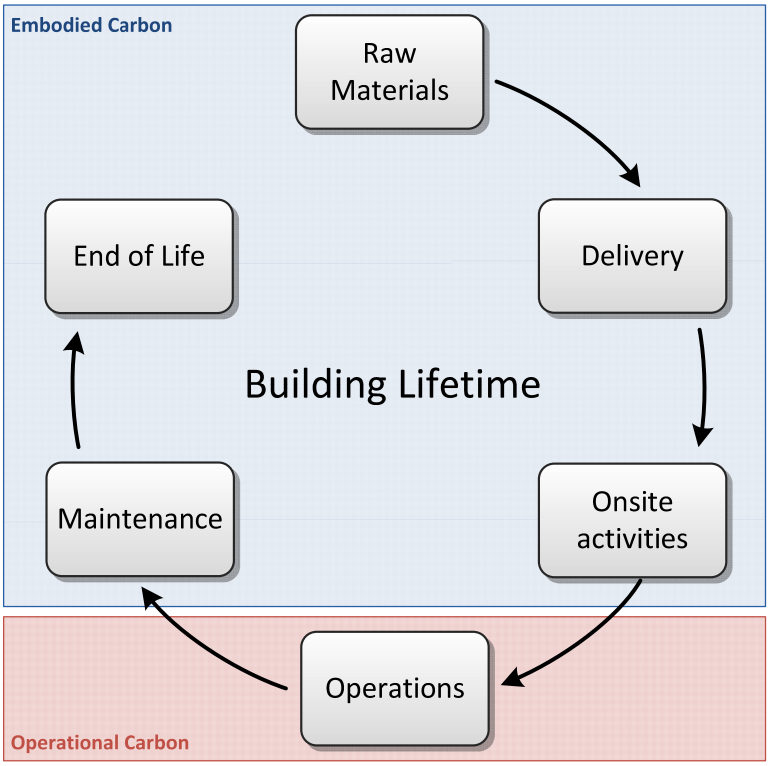


Figure 1: System Boundary

The single impact considered in this study was Global Warming. The calculation methodology uses IPCC (2007) Global Warming Potential (GWP) emissions factors for a 100-year timescale.

The results of this study are for communication by Peikko to both an internal and an external audience. Comparative assertions disclosed to the public should be used carefully by Peikko because full compliance with the ISO standard on LCA requires an independent third party critical review, which was not part of the scope of this study.

Data Analysis (Inventory)

All data and assumptions used as part of this study were fully disclosed and discussed with Peikko.

Results

This section outlines the carbon impacts arising from the use of Universal beams against Peikko's Deltabeam.

Embodied Carbon

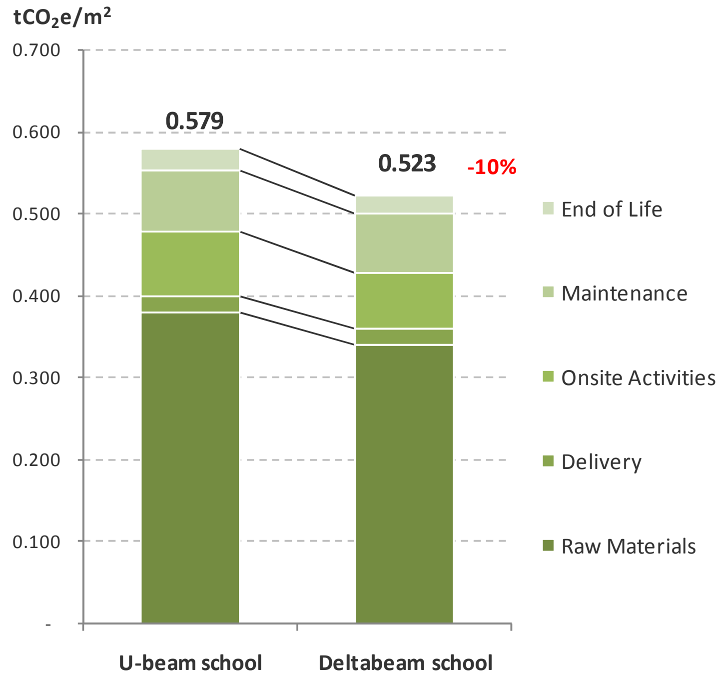


Figure 2: Embodied carbon in U-beam and Deltabeam schools

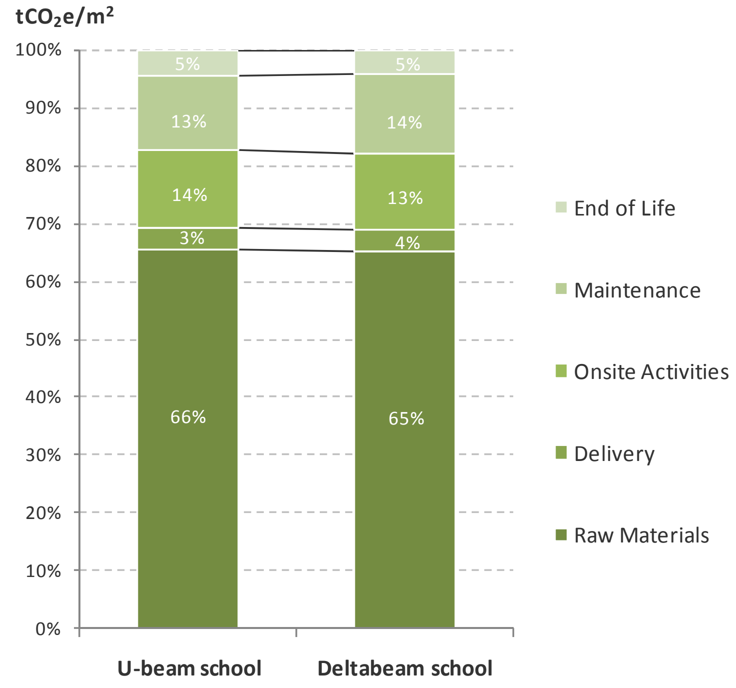


Figure 3: Embodied carbon in U-beam and Deltabeam schools: contribution

Comments on Figure 2 and Figure 3:

- The embodied carbon impact for the notional school is 10% lower for the Deltabeam solution, principally due to a reduction in raw materials required (overall, less steel is required for Deltabeam solutions, and a reduction in ceiling height saves other materials)
- The greatest impact for embodied carbon is found in raw materials due to the large quantities of energy required in their manufacture
- For U-beam and Deltabeam options, there is little difference in the distribution of emissions between the various stages, as seen in Figure 2.

Operational Carbon impacts assessment

As explained in the Inventory Analysis, the operational carbon assessment uses energy figures for a school science block. Further detail on the energy consumption and the assumptions made is given in Appendix A.

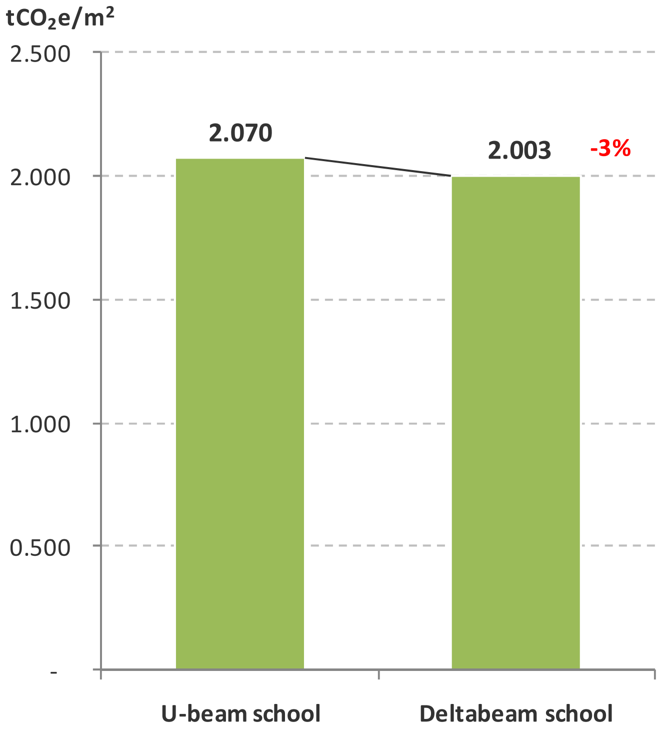


Figure 4: Operational carbon for U-beam and Deltabeam schools

Comments on Figure 4:

- Operational carbon over 60 years decreases by 3%.
- This decrease is due to an 8% reduction in energy consumption for heating and cooling assumed to arise from the 10% reduction in the building's volume.

Total Carbon impacts assessment

The total carbon impact assessment combines embodied and operational carbon over 60 years.

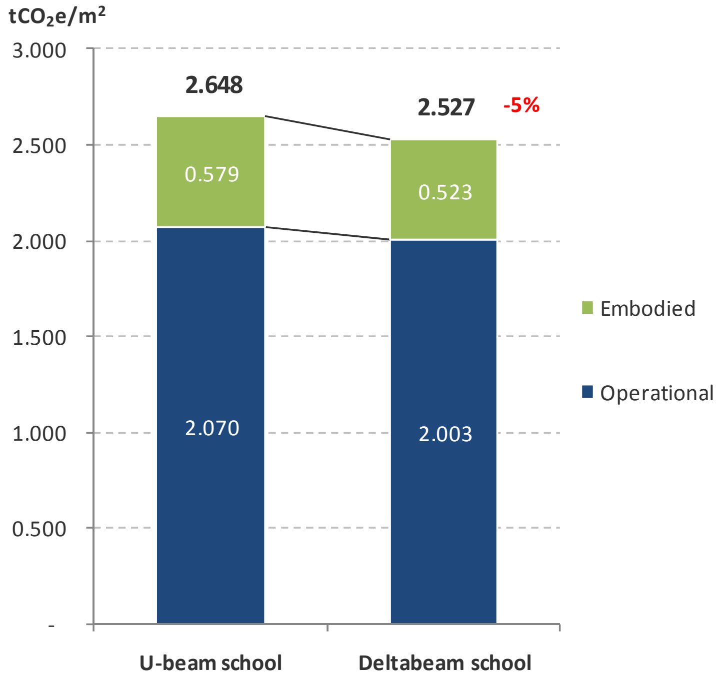


Figure 5: Total carbon footprint of U-beam and Deltabeam schools

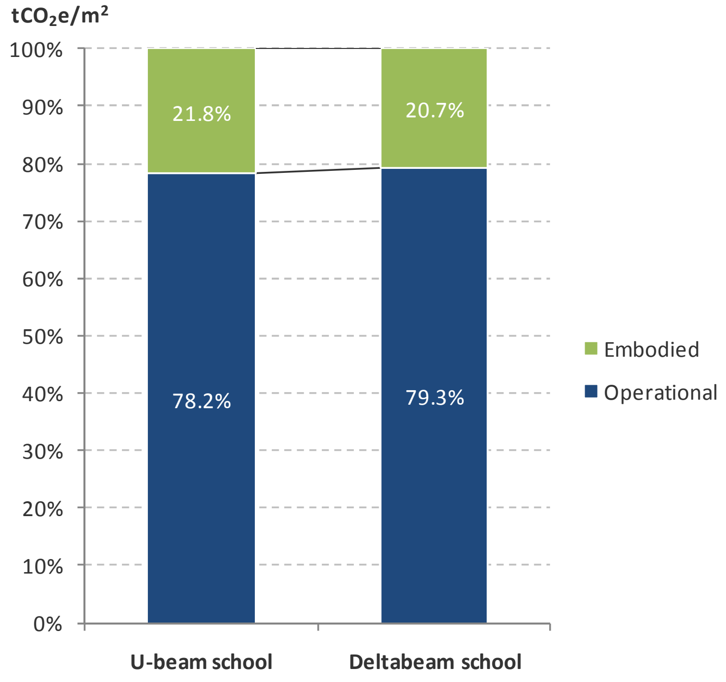


Figure 6: Contribution analysis of embodied / operational carbon

Comments on Figure 5 and Figure 6:

- Overall, the Deltabeam option has a lesser carbon impact than the Universal beam design in both embodied and operational, with a 5% total reduction in carbon impacts.
- **This represents a total carbon saving of 267 tCO_2e from cradle to grave over 60 years on this design.**
- The contribution analysis of Figure 6 shows that the ratio of operational to embodied carbon in the Universal beam is 78.2:21.8, changing minimally to 79.3:20.7 in the Deltabeam solution.

Recommendations for Further Work

1. Further LCA studies

It is expected that similar results may be found for alternative specifications, in particular alternative loading requirements for U-beam and Deltabeam comparisons.

Since the material and volume savings brought about by the Peikko Deltabeam generally increases with the number of storeys, it is also recommended that this focus upon commercial buildings (e.g. offices or hotels).

2. Life cycle costing

Potential cost savings should also be investigated as part of a separate study. These are believed to arise from two main areas: the capital expenditure due to the building construction, and the cost of operating the building.

3. Carbon Labelling & LCA Standards

Given the comparative nature of this LCA, an independent third party review of this study could also be undertaken in order to achieve full compliance with ISO 14040, the principle standard for LCA.

Also, consideration should be given to environmental accreditation schemes for Peikko buildings, such as the Planet Positive Scheme, where a building developer follows a 4-step process of:

- Measuring its carbon footprint
- Reducing this footprint
- Acting outside the boundaries of the building by investing into charitable community schemes or offsetting options related to a low carbon future
- Reporting and communicating the success of this work and actions

Conclusion

Compared to a business as usual approach using Universal beams, the Deltabeam option offered a 5% saving in total carbon impacts over the lifetime of the building.

The impact assessment also demonstrated that using Deltabeams instead of Universal beams result in embodied carbon savings of 10%, and operational carbon savings of 3%.

Finally, recommendations were made for further work in order to widen the applicability of these findings to a larger number of buildings, increase the accuracy surrounding results and certify to LCA standards and Environmental schemes.

1. INTRODUCTION

1.1 Peikko

Peikko Group is a Finland based company specialising in fastening technology of concrete structures. Peikko Group is accredited with ISO 9001: Quality Management Standard, ISO14001: Environmental Management Systems and EN 729-2 stating quality requirements for welding. dcarbon8 has been working with Peikko to present solid environmental arguments for the performance characteristics of its buildings, in particular the use of Peikko's Deltabeam product.

1.2 Climate Change

In recent years, the mitigation of human induced climate change has become one of the major topics of global politics. Scientific evidence clearly shows a direct relationship between increasing greenhouse gas concentrations from burning fossil fuels (in particular carbon dioxide or CO_2), and a warming of the Earth's atmosphere as a result of increased solar radiation trapped within our atmosphere. Other greenhouse gases contributing to climate change include methane from cattle farming, and nitrous oxides from agricultural practices. In response to the highly detrimental economic, environmental and social impacts of the weather changes brought about by this warming, industry has taken responsibility to reduce its share of greenhouse gas (or "carbon") emissions.

1.3 Life Cycle Assessment

A Life Cycle Assessment (LCA) study starts by mapping the 'life cycle stages' of a product system – in this case, a building. Also, commonly called 'cradle-to-grave' assessment, these life cycle stages encompass all steps and processes in the product's life, from the production and supply of raw materials to final disposal options at the end of its life.

Each stage of the product's life cycle consumes natural resources and as a result, emissions to air, water and land are released to the environment. When carrying out an LCA for a particular product system, the consumption and emissions (termed to be 'inputs and outputs') are quantified for each life cycle stage, using a systematic, internationally standardised process set out in the ISO 14040 series of standards. The result is a life cycle inventory (LCI) of all inputs and outputs.

The inputs and outputs compiled in the life cycle inventory are then related to environmental impacts, such as global warming and depletion of the ozone layer, using scientifically-derived methods. This results in a quantified environmental impact profile of the product and/or system under study.

This approach provides important information about major stages of the product life cycle and relates them to specific environmental issues, therefore enabling environmental management efforts to be successfully directed.

1.4 Project Team

1.4.1 dcarbon8

dcarbon8 is an environmental consultancy with expertise in managing the sustainability and carbon impacts of businesses, their supply chains and products. Its clients include major organisations such as Lend Lease, Sainsbury's, Land Securities and Marks and Spencer. The project team employed on this project is as follows:

- **Guy Battle** was Project Director for the study. Guy has had over 20 years of experience as a consulting engineer in the construction industry starting his career at Ove Arup in London. In 1993 he became a founding partner of the world-renowned firm of consulting engineers Battle McCarthy where he continued to build his reputation as an expert in sustainable practices and design. Since then he has set up dcarbon8 to expand and specialise within the field of sustainability reporting and carbon management.
- **Tony Siantonas** was Project Manager, running and managing a team of consultants to complete the project. Tony is an Environmental Scientist with 5 years in consultancy, covering sustainability and carbon footprinting. Tony specialises in lifecycle assessment and supply chains, and has extensive experience in sustainability and carbon management for cities, buildings, and consumer products. He has also lectured widely on LCA, eco-labelling and sustainability.
- **Maeve Hall** worked as consultant on the project. Maeve is a consultant specialising in water footprinting and carbon LCAs. Her background has been in technical approaches to water and sanitation, development of integrated water resource management programmes and water policy.
- **Charles-Eric Pigeot** worked as consultant on the project. Charles-Eric is a LCA carbon consultant specializing in building LCA. He has detailed experience in building environmental assessments by modeling detailed carbon impacts and energy consumption, and performing cost-benefit analysis of energy and carbon savings.

1.5 Acknowledgements

dcarbon8 would like to thank the following individuals and organisations for their help in collating data and information for this study:

- John Metcalfe, Peikko UK
- Michal Horak, Peikko Slovakia
- Harri Onikki, Peikko UK
- Phil Peacock, Peikko UK

2. GOAL OF THE STUDY

The aim of this project, commissioned by Peikko UK, was to assess the life cycle carbon impacts associated with the use of Peikko's Deltabeam compared to the use of Universal Beams in a standard school building design.

The objectives of this study are as follows:

1. To calculate the lifecycle carbon impacts of a notional school building using Deltabeams, from cradle to grave over 60 years, in close consistency with the most recent international LCA standards (ISO 14040);

2. To calculate the lifecycle carbon impacts of the same notional school building using Universal Beams, from cradle to grave over 60 years, in close consistency with the most recent international LCA standards (ISO 14040);

3. To compare the lifecycle carbon impacts, and highlight and quantify the major environmental differences between the two scenarios.

The results are intended to be used internally and externally by Peikko as both a marketing tool and also as a means of informing its design and sustainability teams.

3. SCOPE OF THE STUDY

This section describes the system to be studied, its functional units, the boundary, and the main data requirements and collection processes for this study. It also addresses the impact category used and gives an overview of the interpretation and requirements for a third party review.

3.1 Product System

3.1.1 Specification

To ensure a like-for-like comparison, the same school development was used as the basis of the comparison in both scenarios, i.e. with universal beams and Deltabeams. Where possible the structural designs of a leading contractor and civil engineering company were used and where data was not available, a cost model for a block of a school building (GIA 1,450, steel framed, 3-storey) was referred to (Davis Langdon 2007). The school building's main features are:

- pad foundations;
- 3-storeys;
- steel frame;
- 7.2m×8m spans
- walls are comprised of brickwork, cavity, concrete block, plasterboard;
- Gross Internal Area (GIA) of 2202 m^2;
- no external areas.

A full description of the building's specific features under the two scenarios is given in the Inventory Analysis (Appendix A: Inventory Analysis).

3.1.2 Physical inclusions and exclusions

This section defines the parts of the building included and excluded within the system considered. The development is broken down into four main zones (Figure 7):

- foundations, i.e. piling and pile caps or pads;
- substructure, i.e. the ground bearing slab;
- superstructure, i.e. the frames (beams and columns), floor slabs, external walls, cladding and roofing, etc.;
- basic fit-out, i.e. lightning protection & earth bonding, electricity, gas and water supply, sprinklers, partition walls, finishes, etc.

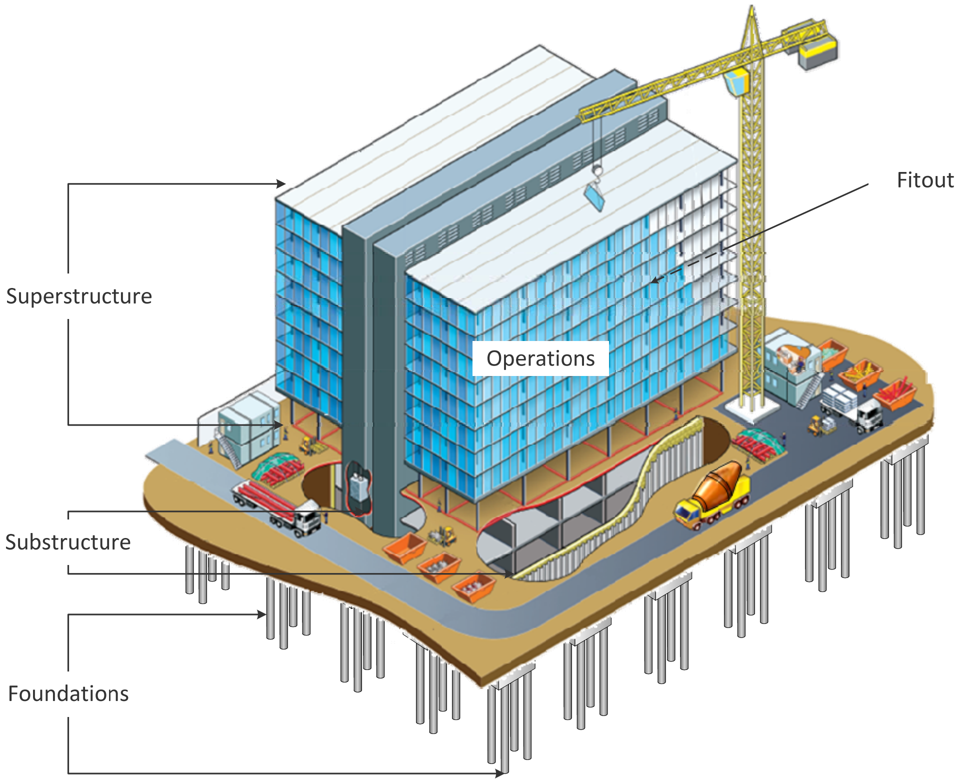


Figure 7: Building zones considered

These zones are then sub-divided into building components. Table 1 provides a list of the main components included for this LCA:

Building Zone	Building Component
Foundations	Pad foundations
Substructure	Ground beams
	Ground bearing slab
Superstructure	External Walls
	External Windows
	External Doors
	Floor Slabs
	Internal Structural Walls
	Main Building Frame (Columns & Beams)
	Roof & roof covering
Fit-out (Shell & Core)	Ceilings
	Floor finishes
	Partition walls

Table 1: Main Building Components

This list of inclusions was defined in line with both the scope of the study and with the cut-off criteria defined in section 3.5.

Therefore the following exclusions in the building were made:

- external areas; roads and vehicle parks, hardstanding / yard areas, site enclosure;
- drainage (foul, land and surface water);
- water supply systems;
- fire protection systems
- gas & electricity supply systems
- earthing & lightning protection
- furniture

3.2 System Boundary

This study assessed lifecycle stages for the building from cradle to grave. The 6 lifecycle stages are displayed below:

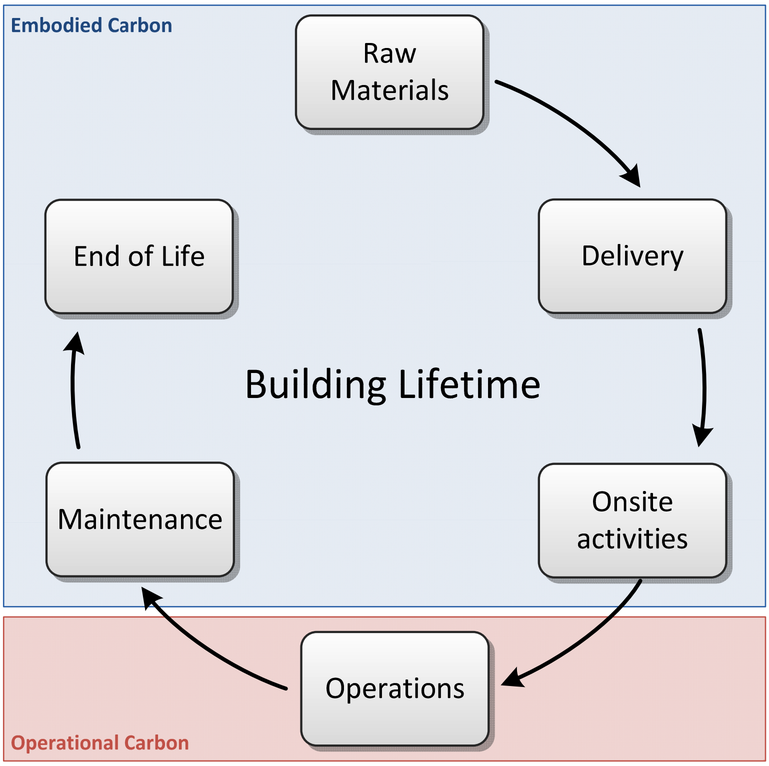


Figure 8: System Boundary

A total carbon footprint from cradle to grave is divided into two components:

- **Embodied carbon**, which corresponds to impacts occurring during the manufacture of raw materials, the delivery of these materials to the construction site, onsite construction activities, maintenance of the building over its lifetime, and its end-of-life.
- **Operational carbon**, the carbon emitted during the building lifetime through energy consumption.

3.2.1 Production of raw materials

- **Inclusions:** extraction of raw materials, transportation of all raw materials (including wasted materials) to manufacturer gate, manufacturing processes, intermediate consumables (for example solvents for machinery) and the packaging and storage processes for building materials;
- **Exclusions:** carbon sequestration by natural products (e.g. timber), carbonation of concrete and other cementitious materials, due to large variability between available sets of data.

3.2.2 Delivery

- **Inclusions:** transportation of all building materials from manufacturers' gate to construction site.

3.2.3 Onsite Construction Activities

- **Inclusions:** energy consumption during the building construction phase, contractor travel; disposal of construction waste, covering transportation and landfill emissions.
- **Exclusions:** energy recovery from construction waste incineration and carbon savings on the UK electricity grid due to reuse and recycling of waste materials as fuel for power stations (e.g. timber).

3.2.4 Operations

- **Inclusions:** energy consumption over the building's lifetime covering electricity and fuels required for building services (i.e. heating, cooling, auxiliary, hot water, lighting and equipment);
- **Exclusions:** occupant's waste, occupant's travel, increased energy requirements due to climate change; passive cooling;

3.2.5 Maintenance

- **Inclusions:** raw materials needed to maintain the building through the replacement of relevant components during its lifetime;

  N.B.: for specific items, the exact year of replacement is difficult to predict in advance (the design life of an item is merely an indication and does not guarantee that it will not have to be replaced beforehand), therefore maintenance activities are based on the likelihood of an item's replacement at each year using a normal distribution model.

3.2.6 End of Life

- **Inclusions:** energy required for building deconstruction (soft-strip/demolition), transportation of waste materials, emissions for each material occurring from the following scenarios: reuse, recycling, landfilling, incineration (only the impacts of transportation to the incineration site) collection and disposal of maintenance items;
- **Exclusions:** energy required to reprocess building waste (this impact is covered in subsequent lifecycles), avoidance of carbon emissions at end of life due to recyclable materials / products based on system expansion (methodology is based on recycled content only), carbon savings on the UK electricity grid due to reuse and recycling of waste materials as fuel for power stations (e.g. timber).

3.2.7 Other exclusions

- Upkeep of roads, ports and airports involved in the transportation of intermediate products, all physical infrastructure requirements for capital goods (machinery, transportation equipment, construction tools, etc) including replacement of machinery parts for equipment used in the manufacturing of offsite building products and in the building construction.

3.3 Functional Units

In accordance with the ISO 14040 series of standards, the study has been conducted to enable comparisons between building systems on the basis of functional equivalence.

The functional equivalence is established by comparing building systems for the same allocated building specification. The functional unit used throughout this study is:

- the construction, use and disposal of one square metre of Gross Internal Area (GIA) of the school building over 60 years;

3.4 Allocation Procedures

It is common for some industrial processes to yield more than one product, or to recycle intermediate products or raw materials. When this occurs, the LCA study must allocate material and energy flows, as well as environmental releases, to the different products in a logical and reasonable manner.

Where the need for allocation presented itself, then the inputs and outputs of the inter-related processes were apportioned (as recommended by the ISO standard and PAS 2050):

- in a manner that reflected the underlying physical relationships between them;
- where physical relationship alone cannot be used as the basis for allocation, the inputs were allocated in proportion to the economic value of the products.

Please note the impacts of this LCA are based on recycled content. For greater details on methodological consideration of recycled content and recyclability, please refer to Appendix B.

3.5 Cut-off criteria

The cut-off criteria used in this study is consistent with ISO 14044. Please refer to Appendix B for more details on cut-off rule applied in this life cycle assessment.

3.6 Data Requirements

3.6.1 Use of primary and secondary data

Primary data was collected where possible. Primary data is quantitative measurement of an activity taken during the lifecycle of the building, which can be used to determine the GHG emissions arising from the process.

Where primary data was not available, secondary data was obtained from a variety of sources. The sources are detailed in a later section.

3.6.2 Data Quality Requirements

Data quality requirements for the study are defined in Table 2 based on the ISO standard on goal and scope definition and inventory analysis.

PARAMETER	DESCRIPTION	REQUIREMENTS
Time-related coverage	Desired age of data and the minimum length of time over which data should be collected	Data should represent the situation in 2009 if possible. General data and database data should not be more than 5 years old.
Geographical coverage	Area from which data for unit processes should be collected	Data should be representative of the situation in the country in question
Technology coverage	Technology mix	No defined requirement in study scope
Precision	Measure of the variability of the data values for each data category expressed	No defined requirement in study scope
Completeness	Assessment of whether all relevant input and output data are included for a certain data set	Specific datasets should be compared with literature data and databases
Representativeness	Degree to which the data represents the identified time-related, geographical and technological scope	The data should fulfil the defined time-related, geographical and technological scope
Consistency	How consistent the study method has been applied to different components of the analysis	This study method should be applied to all the components of the analysis
Reproducibility	Assessment of the method and data, and whether an independent practitioner will be able to reproduce the results	The information about the method and the data values should allow an independent practitioner to reproduce the results reported in the study
Sources of data	Assessment of the data sources used	Data should be derived from credible sources and databases

Table 2: Data requirements (source EN ISO 14044:2006)

3.7 Inventory Analysis

Inventory analysis involves data collection and calculation procedures to quantify relevant inputs and outputs of a product system. Inventories of significant environmental flows to and from the environment, and internal material and energy flows, were produced for the building assessed.

For a full assessment of this, please refer to Appendix A: Inventory Analysis for full details.

3.8 Impact Assessment

The impact assessment phase of an LCA assigns the results of the inventory analysis to different impact categories. Selection of appropriate impact categories is an important step in LCA.

The main impact considered in this study is **Global Warming**. The calculation methodology uses IPCC (2007) Global Warming Potential (GWP) emissions factors for a 100-year timescale. The Global Warming impact category covers the six principle Kyoto gases carbon dioxide (CO_2) sulphur hexafluoride (SF_6), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). The Global Warming Potential (GWP) of these GHGs is compared to that of carbon dioxide which is 1. Methane, for example, has a GWP of 25, meaning that one tonne of methane has the same detrimental effect to the atmosphere as 25 tonnes of CO_2. SF_6 has a GWP of 22,800. The carbon footprint of a building considers the emissions of these six main gases and is therefore measured in tonnes carbon dioxide equivalent (tCO_2e).

3.9 Interpretation

Under LCA Standards such as ISO 14040, major assumptions and variables should be tested to determine their influence on the results of the lifecycle impact assessment as part of sensitivity and contribution analyses. Whilst an extensive sensitivity analysis was not undertaken on the results due to the scope of the project, a contribution analysis was undertaken as part of the interpretation showing percentage impacts for life cycle stages.

3.10 Critical review

The results of this study are meant to be communicated by Peikko to both an internal and external audience. dcarbon8 advises that comparative assertions disclosed to the public against other buildings be used carefully by Peikko. Indeed, if such comparisons are to be made, full compliance with the ISO standard on LCA requires an independent critical review, which is not part of the scope of this study.

4. CARBON IMPACT ASSESSMENT

The impact assessment is split into the following parts:

- embodied carbon impacts of the school under the two scenarios (using Universal Beams and Deltabeams D25-400), with a focus on raw materials carbon impacts;
- operational carbon impacts of the school under the two scenarios;
- total carbon impacts showing detailed results across all life cycle stages.

4.1 Results

This section outlines the carbon impacts arising from the use of Universal beams and Deltabeams within a notional school building.

4.1.1 Embodied Carbon

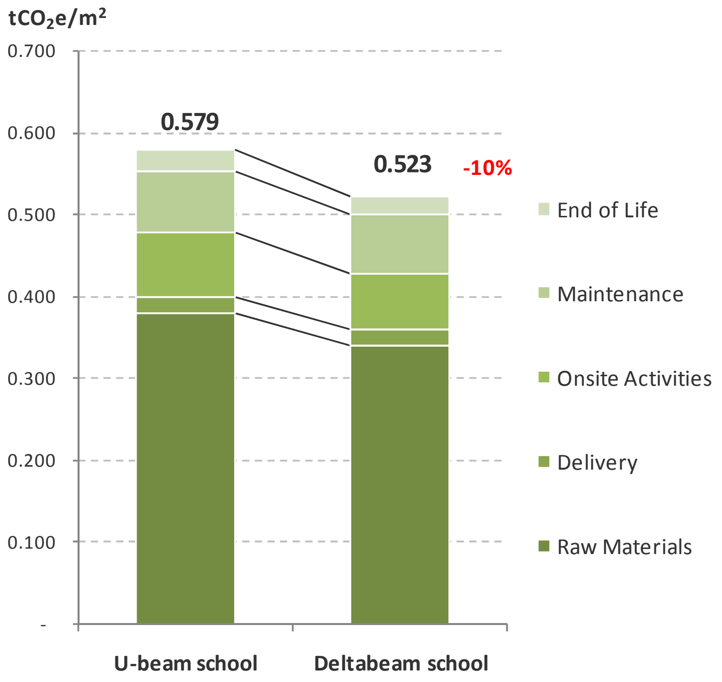


Figure 9: Embodied carbon in U-beam and Deltabeam schools

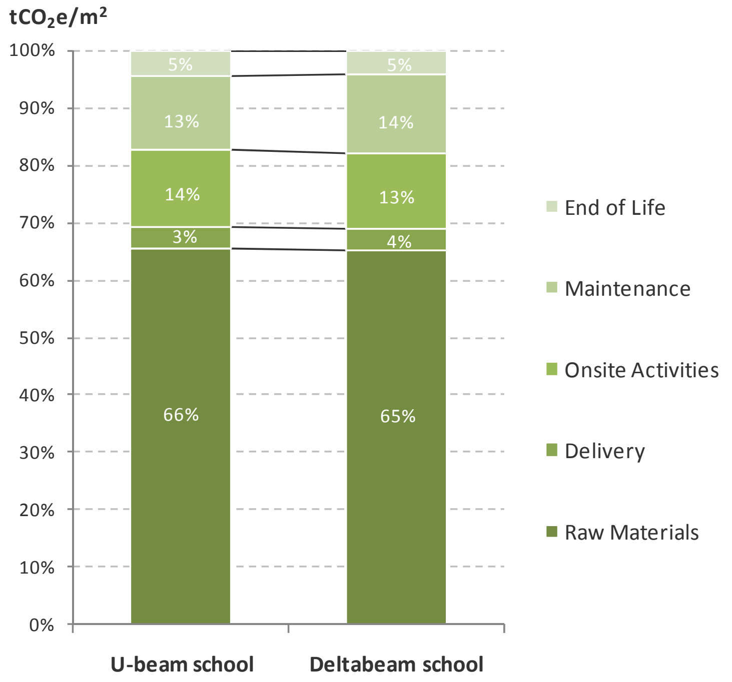


Figure 10: Embodied carbon in U-beam and Deltabeam schools: contribution

Comments on Figure 9 and Figure 10:

- The embodied carbon impact for the notional school is 10% lower for the Deltabeam solution, principally due to a reduction in raw materials required (overall, less steel is required for Deltabeam solutions, and a reduction in ceiling height saves other materials)
- The greatest impact for embodied carbon is found in raw materials due to the large quantities of energy required in their manufacture
- For U-beam and Deltabeam options, there is little difference in the distribution of emissions between the various stages, as seen in Figure 10.

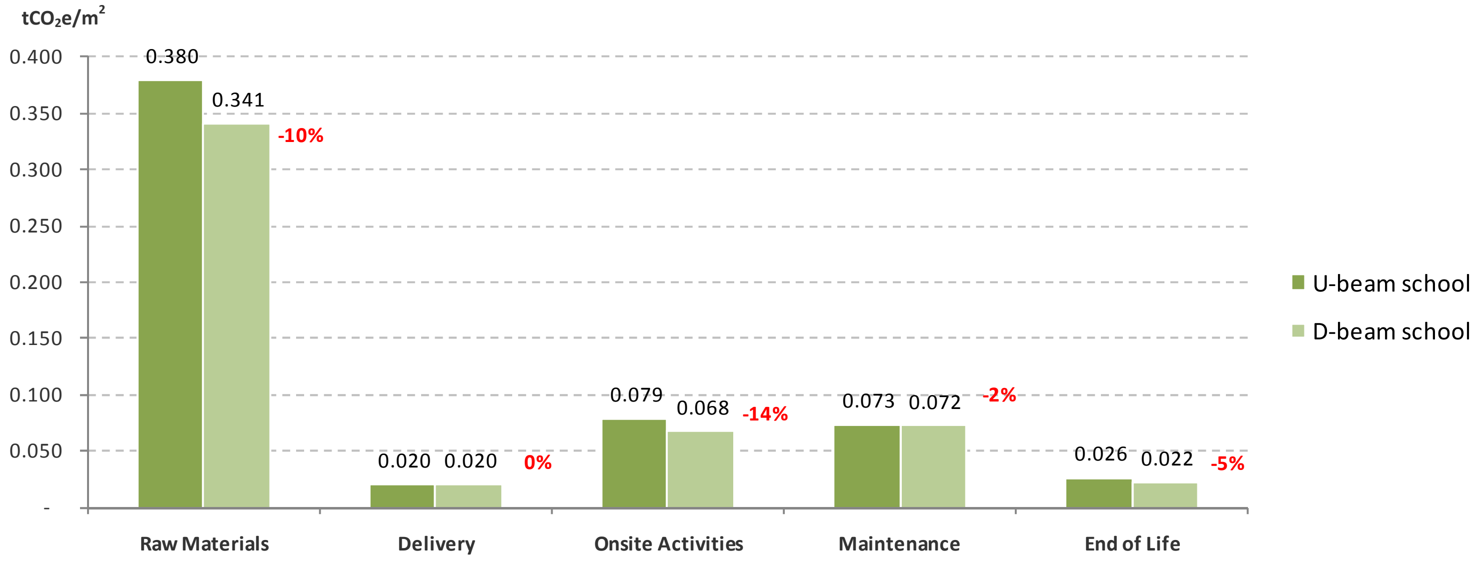


Figure 11: Comparison of the embodied carbon life cycle stages in the U-beam and Deltabeam schools

Comments on Figure 11:

- Within embodied carbon, the largest differences between the Universal beam and Deltabeam were made at the Raw Materials stage (10%).
- The delivery carbon impacts remain very similar, because even though Deltabeams are sourced from further away (Slovakia), the lesser amount of beams sourced offsets this slight increase.
- A 14% reduction in the carbon impact of Onsite activities between Deltabeam and Universal beam was calculated assuming that the Deltabeam twinned with hollow core floor sections reduced the need for wet concrete pours and as a result reduced construction periods.
- A decrease in maintenance carbon (2%) is linked to the lesser amount of materials used in the initial building construction which results in a reduced quantity of materials needing to be maintained.
- End of life savings are again linked to the fewer materials used for the Deltabeams option, meaning less materials are disposed of, leading to a 4% reduction in end of life carbon impacts.

Focus on raw materials

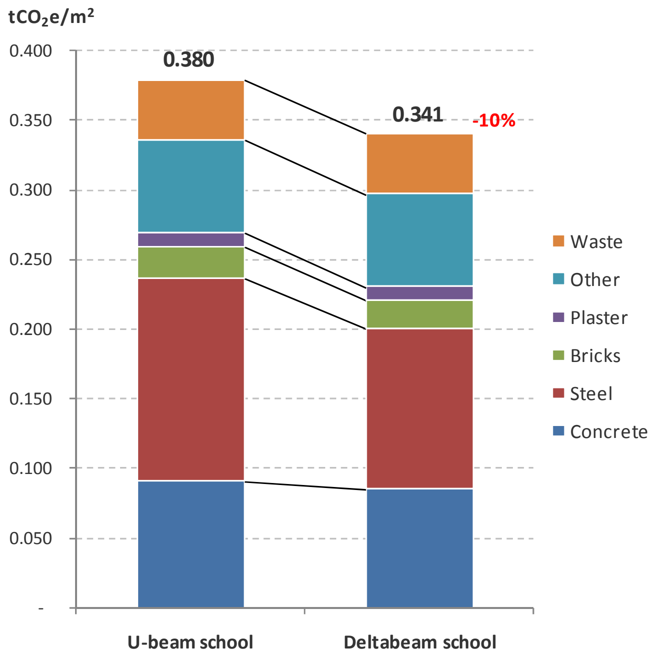


Figure 12: Raw materials carbon impacts

Comments on Figure 12:

- Carbon impacts of raw materials using Deltabeam within the notional school building reduces by 10% when compared against the Universal beam.

- The majority of the raw materials carbon is saved in the steel components due to the reduced number of Deltabeams needed compared to universal beams. Although the mass of one Deltabeam is larger than its universal beam counterpart, a Deltabeam can replace up to 5 internal universal beams in this specific design.

- Small reductions are also achieved in concrete, bricks, plaster and waste, as a function of the overall reduction in height of the build using Deltabeams over Universal beams.

4.1.2 Operational Carbon impacts assessment

As explained in the Inventory Analysis, the operational carbon assessment uses energy figures for a school science block. Further detail on the energy consumption and the assumptions made is given in Appendix A: Inventory Analysis.

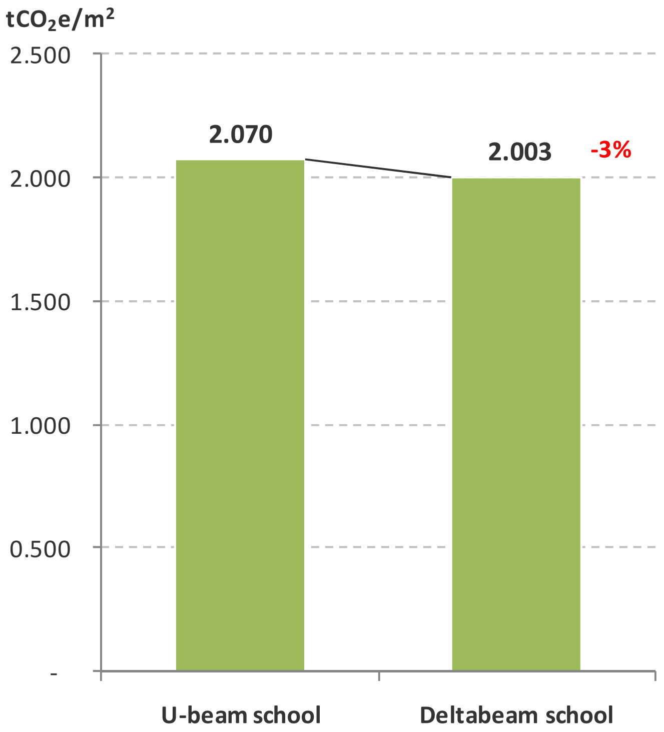


Figure 13: Operational carbon for U-beam and Deltabeam schools

Comments on Figure 13:

- Operational carbon over 60 years decreases by 3%.
- This decrease is due to an 8% reduction in energy consumption for heating and cooling assumed to arise from the 10% reduction in the building's volume.

4.1.3 Total Carbon impacts assessment

The total carbon impact assessment combines embodied and operational carbon over 60 years.

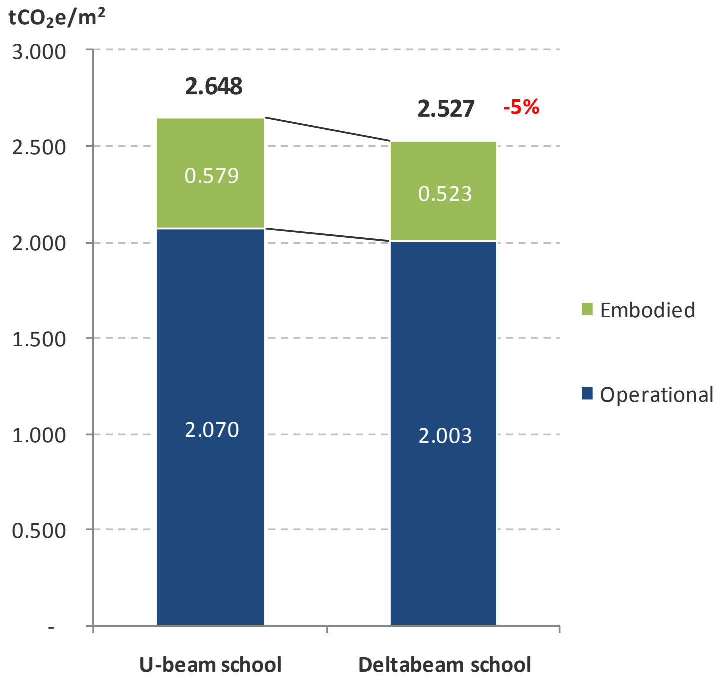


Figure 14: Total carbon footprint of U-beam and Deltabeam schools

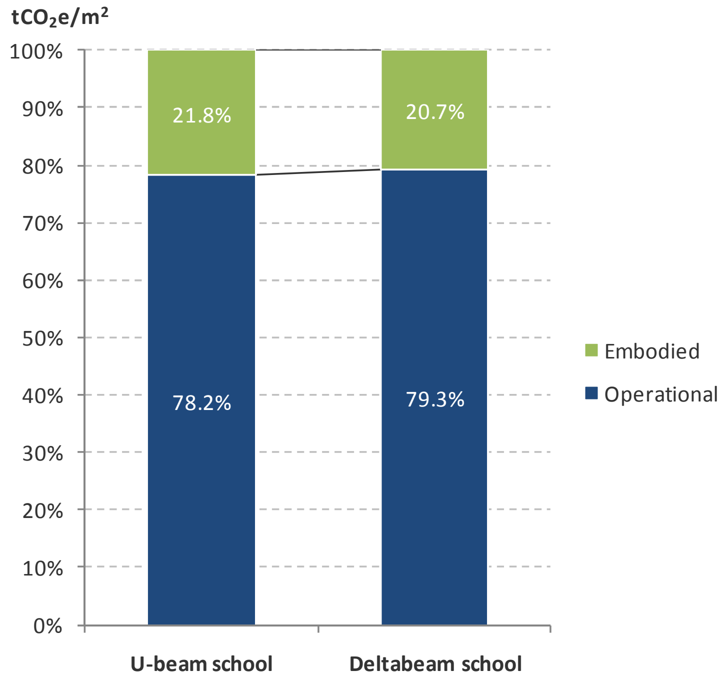


Figure 15: Contribution analysis of embodied / operational carbon

Comments on Figure 14 and Figure 15:

- Overall, the Deltabeam option has a lesser carbon impact than the Universal beam design in both embodied and operational, with a 5% total reduction in carbon impacts.
- **This represents a total carbon saving of 267 tCO_2e from cradle to grave over 60 years on this design.**
- The contribution analysis of Figure 15 shows that the ratio of operational to embodied carbon in the Universal beam is 78.2:21.8, changing minimally to 79.3:20.7 in the Deltabeam.

Table 3 presents all lifecycle carbon impacts for the 2 designs.

Lifecycle Stage	Carbon impacts U-beam school(tCO_2e/m^2)	Carbon impacts Deltabeam school (tCO_2e/m^2) (% change)
Raw Materials	0.380	0.341 (-10%)
Delivery	0.020	0.020 (+0%)
Onsite Activities	0.079	0.068 (-14%)
Operations	2.070	2.003 (-3%)
Maintenance	0.073	0.072 (-2%)
End of Life	0.026	0.022 (-15%)
Total	**2.648**	**2.527(-5%)**

Table 3: Total lifecycle carbon impacts for U-beam and Deltabeam schools

5. RECOMMENDATIONS FOR FURTHER WORK

5.1 Alternative Comparisons

This study assessed the carbon savings that can be achieved across the lifecycle from using Peikk0 Deltabeams in lieu of universal beams in a notional school design. Upon discussions with Peikko, it is expected that similar results may be found for alternative specifications, in particular alternative loading requirements for U-beam and Deltabeam comparisons.

Whilst this may also be the case for other designs such as Deltabeam versus concrete frames, this cannot be confirmed until other buildings are assessed in equivalent detail. Since the material and volume savings brought about by the Peikko Deltabeam generally increases with the number of storeys, it is also recommended that this focus upon commercial buildings (e.g. offices or hotels).

The operational carbon savings due to reduced energy consumption have been assessed using mainly secondary data. Moreover, these operational carbon savings might have been underestimated due to certain exclusions (e.g. passive cooling). Extensive energy modelling on a 365 day basis would provide greater accuracy in the numbers but was not part of this scope.

5.2 Lifecycle Costing

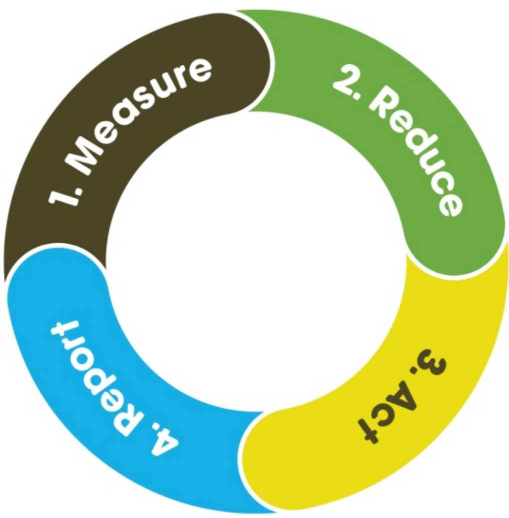
Potential cost savings should also be investigated as part of a separate study. These are believed to arise from two main areas: the capital expenditure due to the building construction, where cost reductions are achieved through a lesser amount of materials used, and the cost of operating the building, where reductions are incurred by savings in energy consumption due to a smaller volume to heat and cool compared to a standard building. In-depth analysis in collaboration with quantity surveyors and building service engineers would be able to quantify these cost savings.

5.3 Carbon Labelling and LCA Standards

Given the comparative nature of this LCA, an independent third party review of this study could also be undertaken in order to achieve full compliance with ISO 14040, the principle standard for LCA. This would entail a review of the goal and scope, the inventory, the impact assessment and its interpretation.

Also, consideration should be given to environmental accreditation schemes for Peikko buildings, such as the Planet Positive Scheme. Planet Positive is an innovative environmental and carbon accreditation scheme which is open to all individuals, businesses and their products. For a product or a building to become Planet Positive the developer must follow a 4-step process of:

1. Measuring its carbon footprint



2. Reducing this footprint

3. Acting outside the boundaries of the business or product by investing into charitable community schemes or offsetting options related to a low carbon future

4. Reporting and communicating the success of this work and actions

6. CONCLUSION

In compliance with the aim and objectives set out at the beginning of this project, and within the scope defined, this study quantified the carbon impacts of a notional school design with Deltabeams. Compared to a business as usual approach using Universal beams, the Deltabeam option offered a 5% saving in total carbon impacts over the lifetime of the building.

The impact assessment also demonstrated that using Deltabeams instead of Universal beams result in embodied carbon savings of 10%, and operational carbon savings of 3%.

Finally, recommendations were made for further work in order to widen the applicability of these findings to a larger number of buildings, increase the accuracy surrounding results and certify to LCA standards and Environmental schemes.

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APPENDIX A: INVENTORY ANALYSIS

This section describes the data gathered in order to create a life cycle inventory for the buildings under study. This relies on ensuring the inputs and outputs of materials and energy are organised to represent the building being assessed, and includes both the primary data collected, as well as the secondary data used, either from existing databases or based on assumptions on particular processes and/or life cycle stages.

Raw materials

The following is a summary of the main inputs in the school building model using the Universal Beam

Foundations
• Pad foundations • 10 pads, 3m × 3m × 0.9m • RC40/50 concrete mix, 30% PFA
Substructure
• Ground bearing slab 175mm thick slab, 734m^2 • RC28/35 concrete mix, 30% PFA, 5KN/m^2 load
Superstructure
• Steel frame (42% recycled content, world average) • Steel Columns, Universal Columns (3 storeys) 58 tonnes +0.3tonne Rectangular Hollow Section (RHS) • 7.2m×8m spans • Universal beams (first floor, second floor + roof): 74 tonnes • Floor slabs and roof slab: Holorib decking; 1,938m^2 , 5KN/m^2 load • RC28/35 concrete mix, 30% PFA; 734m^2 x 0.15m x 3 floors: 793tonnes • Steel section (42% recycled content, world average): 9 tonnes • External walls : total height = 12.375m, overall area = 1365m^2 • Brickwork, concrete block, plasterboard: height = 12.375m, overall area = 1365m^2 • Double glazed PVC framed windows 410m^2 • External doors (4x timber, 4x steel) • Roof (fibreglass insulation, cold asphalt covering) 734m^2 • Volume of airspace: 8752.7 m^3
Fit-out
• Plasterboard walls: 1365m^2 • Plasterboard internal walls (non load bearing): 3945 m^2
Construction Waste
• No primary data available, use of secondary data • Data for 2007 based on BRE Smartwaste tool benchmark for an education building corresponding to the standard practice in the industry • 515 tonnes of construction waste divided in the main waste streams: concrete(23), aggregate(43), soil (349), bricks(13), metals(8), plasterboard(11), food(6).

Emission factors
• Bath ICE 2.0 (Bath University 2009) covering all CO2 emissions, uplifted to give CO_2e using EcoInvent (EcoInvent 2008)

The variations in the inventory analysis for the school building using the specified Deltabeam 225-400 are as follows:

Foundations
• As for the original design using UB
Substructure
• As for the original design using UB
Superstructure
• Steel frame (42% recycled content, world average) • Steel Columns, Universal Columns (3 storeys) 54 tonnes +0.3tonne RHS • 7.2m×8m spans • Steel beams D25-400 replacing the internal UB, external beams remain the same (first floor, second floor + roof): 47 tonnes • Floor slabs and roof slab: pre-cast hollowcore decking; 1,938m^2, 5KN/m^2 load • RC28/35concrete mix 30% PFA • External walls (brickwork, concrete block, plasterboard) height = 11.529m Overall area = 1,266m^2 • Double glazed PVC framed windows 410m^2 • External doors (4x timber, 4x steel) • Roof (fibreglass insulation, cold asphalt covering) 734m^2 • Volume of airspace: 7911.8m^3
Fit-out
• Plasterboard walls: 1,266m^2 • Plasterboard internal walls (non load bearing): 3605 m^2
Construction Waste
• As for the original design using UB
Emission factors
• Bath ICE 2.0 (Bath University 2009) covering all CO2 emissions, uplifted to give CO_2e using EcoInvent (EcoInvent 2008)

Delivery

In the absence of primary data for delivery distances in the specifications and given the application of the study for the UK, an average delivery distance of 50 km was assumed for all items and materials (including wasted materials), for both the Universal Beam and Deltabeam designs, except for the Universal beams and Deltabeams themselves. For Universal beams, it was assumed the following based on market data:

- 25% of U-beams sourced from Redcar (280km)
- 25% of U-beams sourced from Scunthorpe (215km)
- 50% of U-beams sourced from Luxemburg (737km)

Deltabeams are manufactured by Peikko in Slovakia (transportation scenario; 1655km by road, 55km by freight ship).

All other items were assumed to be sourced within a 50km radius. Overall, this is deemed to be a conservative approach, given the heaviest items such as concrete and aggregates, which often make up the majority of combined delivery distance (as tonne kilometres), are usually sourced locally, i.e. within a 20 kilometre radius.

The deliveries were also assumed to take place using a "Lorry 3.5-16t, fleet average" as defined in the 2009 Guidelines to DEFRA/DECC's GHG Conversion Factors. The emission factor for this vehicle was provided by these guidelines.

Construction Activities

In absence of primary data for contractor activities, secondary in-house data was used.

The construction phase for the school building with Universal Beams was assumed to last 6 months. Based on conversation with Peikko, it was assumed that construction times were reduced for the Deltabeam school design, principally during the superstructure construction.

Therefore it was assumed that the construction period was 1 month shorter using the Deltabeam and associated pre-cast hollowcore decking. Other benefits of using Deltabeams for the construction stage are not included in this study because they are not directly quantifiable (health and safety issues for example).

The disposal routes for construction waste in 2007 were taken from industry benchmarks (CRW 2008):

- Inert waste: 50% landfilled
- Timber : 58% landfilled
- Plasterboard / Insulation: 90% landfilled
- Plastics:82% landfilled
- Paper/Cardboard: 60% landfilled
- Food: 100% landfilled

For accounting purposes, the onsite activities carbon impacts were allocated to the different parts of the buildings using the following pattern based on in-house data (this was based on allocation by mass used on a previous dcarbon8 project):

- 15% to the foundations
- 5% to the substructure
- 70% to the superstructure
- 10% to the fit-out

Operations

Given the scope of this study, information regarding the carbon emissions arising from energy consumption of the notional building over its lifetime was taken from secondary data.

A benchmark for energy consumption per square metre of GIA per annum, based on Dartmouth Community College part L report (Dartmouth, 2009) was applied to the notional school with universal beams and Deltabeams. This includes energy use for heating, cooling, auxiliary, domestic hot water and lighting.

The Dartmouth Community College benchmark was deemed applicable to the Peikko study due to the similar features of these two buildings in terms of use and layout. The following U-values have been used in the Dartmouth College SBEM model:

Element	U-Value ($W/m^2 K$)
External Walls	0.27
Roof	0.13
Panel	0.22
Internal Wall	0.3
Internal heavy weight	0.3
Glazing	1.5
Glazed External Door	1.5
Personal Door	1.5

Table 4: U-Value for Building Components

Furthermore, the following characteristics were used in the SBEM model:

- Air tightness: $10m^3$/ hr per m^2 at 50 Pa
- Weather location: UK
- HVAC system, heat source efficiency = 0.89
- DHW heat source = 0.75

The energy consumption for Dartmouth College is as follows:

	Heating (kWh/m2 annum)	Cooling (kWh/m2)	Auxiliary (kWh/m2)	DHW (kWh/m2)	Lighting (kWh/m2)	Total (kWh/m2)
Annual Total	75.1	0	5.1	12.8	20.1	113.1
Source of energy used	Gas	Electricity	Electricity	Electricity	Electricity	-

Table 5: Annual operational energy requirements

This energy consumption pattern was applied to the notional school with universal beams. For the notional school using Deltabeams, the 10% reduction in volume compared to the universal beam school (see Appendix A - Inventory Analysis) was assumed to give rise to an overall 8% reduction in the heating load. This was for the following reason: Although the area of facade decreases, the area of the windows stays the same. Whilst this means lighting requirements may be assumed fixed, the proportion of non-glazed, lower U-value facade decreases slightly. This small change means one cannot assume a 10% volume reduction brings about the same reduction in heating loads, and therefore a more conservative assumption of 8% was used.

The annual energy consumption for the Deltabeam school thus becomes;

	Heating (kWh/m2 annum)	Cooling (kWh/m2)	Auxiliary (kWh/m2)	DHW (kWh/m2)	Lighting (kWh/m2)	Total (kWh/m2)
Annual Total	69.1	0	5.1	12.8	20.1	107.1
Source of energy used	Gas	Electricity	Electricity	Electricity	Electricity	-

Emissions factors were taken from DEFRA 2009 guidelines on GHG conversion factors. The emissions factors are as follows;

- Electricity: 0.54418 kgCO_2e/kwh
- Gas: 0.18396 kgCO_2e/kwh

Please note that passive cooling impacts were excluded from these figures due to the limited scope of SBEM modelling.

Maintenance

Maintenance activities were treated the same for both the school building with Universal Beams, and the building with Deltabeams. The structural components in the building, such as the foundations, frames and slabs were assumed to last 60 years. The fit-out items were assumed to have a lifetime of 30 years.

The building's lifetime is defined as 60 years in both building scenarios.

End-of-life

Secondary data was used for the building end-of-life and the same end of life scenario was used for both buildings (Universal Beam and Deltabeam).

The demolition of the building was assumed to last 2 months, using an amount of energy equivalent to that of 2 months of construction activities.

The demolition impacts were allocated equally to the different parts of the building for accounting purposes.

All waste arising from the building demolition is recycled at the end of life, and the transportation distance to recycling site is defined as 20km (taking place with a Lorry 3.5-16t, fleet average).

Data Collection & Quality

This section assesses the quality of the data gathered for this LCA in line with the requirements outlined in Table 2.

Primary datasets

Primary data for the building was mainly based on the drawings provided by Peikko of a block of a school produced by a major contractor and civil engineer. The data for the comparative Deltabeam scenario was based on drawings by Peikko structural engineers. Where data was missing for the main building parts, a cost model for a similar school building described in Davis Langdon's Spon's (2007) was used.

For the collection of the data provided by Peikko, initial meetings were conducted with John Metcalfe, Peikko. Parallel Life Cycle Assessments undertaken by dcarbon8 (Deltabeam D25-400 and the Tera Joint) used data collection sheets which were sent to the different parties, with data requirements, responsibilities and deadlines to ensure consistency with the project scope and boundary. The Deltabeam LCA was used to inform this study.

No specific precision requirement was set for the project, but inaccuracies might have been introduced in the process of converting the drawings and cost model into actual quantities of materials. Moreover, due to the use of two different sources of data for the building model, careful attention was given to the accounting of building parts in order to avoid double-counting.

Although no mass balance was established for the building (due to the lack of information on the complete mass of materials from building demolition), sense checks against in-house data for comparable buildings were undertaken to ensure the precision of inputs was sufficient.

Secondary datasets

All assumptions made followed a conservative approach, (e.g. delivery distances of 50 km), in order to fully account for all impacts in the life cycle.

Where primary data was not available regarding the construction material specification, a cost model for a science building (GIA 1,450 m^2, three-storey steel framed construction) of a school was considered a good approximation.

Some uncertainty surrounding the onsite activities data and assumptions remained in the LCA, because of the use of secondary data only, but the overall impact on the lifecycle is minimal (<3%) and the conclusions of this study would not be affected by changes in the source of data or in the assumptions made.

Another source of uncertainty in the secondary data lies in the operational data used. Due to the scope of the study, no in-depth energy modelling was undertaken to account for changes in the building's volume and fabric under the two scenarios. Conservative assumptions have therefore been made regarding the energy savings in cooling and heating based on in-house data and industry benchmarks (whose applicability was reviewed before use), which means that energy and operational carbon savings might have been underestimated. SBEM modelling or more complex thermodynamic modelling, with an exact definition of the building's features, could be undertaken to obtain more accurate results under the two scenarios.

The dataset used for cradle to gate emission factors is Bath ICE 2.0 (Bath University 2008), the updated version of Bath ICE 1.6 (Bath University 2009) with updated emission factors and improvements in the treatment of concrete mixes, cement, and timber.

However, as Bath ICE provides emission factors in carbon dioxide only, it had to be uplifted to encompass all Kyoto protocol gases in order to report in carbon dioxide equivalent (CO_2e). The uplift factor was provided by the peer-reviewed Ecoinvent database, meaning emissions factors were on average 6-7% higher. While the EcoInvent version used (version 2.0) was released in 2008, the age of certain secondary datasets within this is a concern, as a number of these relate to technologies in 2000 or earlier. This is an issue commonly found in conducting LCAs, but it is important to note that EcoInvent is widely considered to be one of the most up-to-date and complete databases on the market. In the absence of more specific data, these data were deemed appropriate for use in the meantime.

All other emission factors used (transportation, energy, disposal) were provided by publicly available DEFRA 2009 guidelines on GHG conversion factors. This latest update gives emission factors in CO_2e, and is deemed to meet all data quality requirements. Waste benchmarks were provided by the BRE Smartwaste model, which gives an average of waste production for hundreds of projects throughout the UK for the last three years and is therefore representative for this type of project.

A final source of uncertainty is the expected lifetime of building components. Most of this information was based on standards, documentation and discussion with engineers. Since a design lifetime cannot be accurately determined, this represents a source of imprecision to be taken into account in the interpretation of the results. Nevertheless, this is tackled by using a normally distributed approach to the likelihood of replacing building components.

APPENDIX B

Treatment of recycled content and recyclability

With respect to recycled content, since steel is used in such great quantities for construction, it was particularly important to address the allocation of recycled content burdens. Generally, there are two possible routes to account for recycling in LCA: one is to look at the recycled content used in the material, and second is to predict the future recyclability based on current recovery rates. GHG emissions factors can reflect either under EN ISO 14044.

dcarbon8 uses the recycled content route when calculating GHG emissions, which is recommended by the UK Building Research Establishment (BRE), University of Bath International Centre for the Environment (Bath ICE) and PAS 2050 Carbon Standard. The main difference of this approach is that it does not require any future proofing and is considered by dcarbon8 to be more conservative – there is no guarantee that currently achievable high recovery rates for steel will be the same when the building is demolished in 60 years time.

It should be noted that Corus uses the recyclability route, suggesting that between 60 to 85 percent of steel is currently recovered from UK building demolition sites.

When including the recycled content of steel during GHG accounting calculations, it is generally advised (by BRE and Bath ICE) that an average global recycled content value should be used, regardless of the percentage of scrap iron used by individual steel manufacturers. The reason for this is that since recovery rates of steel are so high (generally greater than 90 percent), the net benefits of sourcing recycled content are minimal. (i.e. sourcing high recycled content steel only means that the recycled content must decrease elsewhere to accommodate this.)

Cut-off criteria

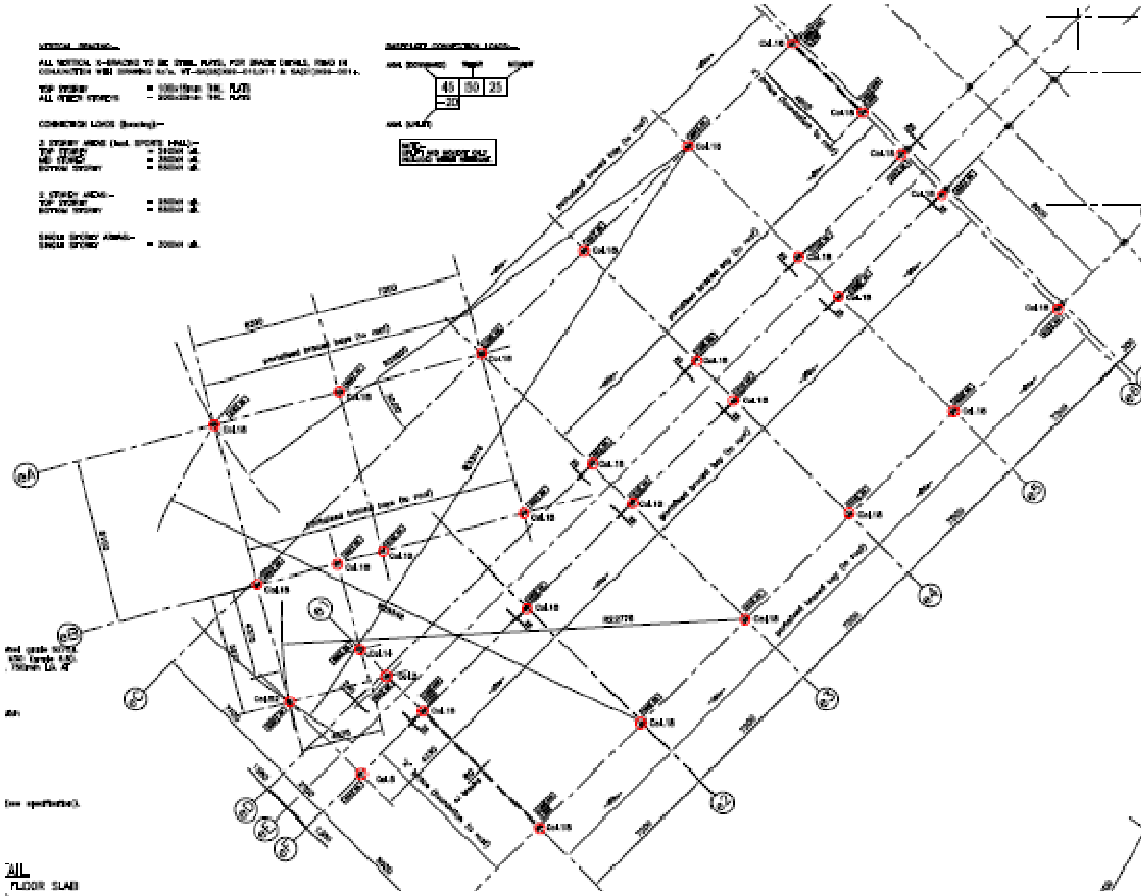
The following cut-off rule was applied during the inventory compilation stage of the study: mass flows that on aggregate contribute less than 2% of inputs to a life cycle stage may be omitted from the inventory analysis.

Ideally, cut-off criteria will be based on environmental relevance. However, it is often impractical to define cut-off criteria based on environmental impact, since data for a process need to be collected in order to understand the environmental impact of that process. A more practical approach is to base cut-off criteria on mass or energy, as has been taken in this study.

It is dcarbon8's belief that the cut-off criteria defined above do not have an effect on the final results. Care was taken when excluding processes from the inventory where inputs under the 2% mass threshold could have a significant environmental impact.

APPENDIX C

Typical layout of the school design



Grid of 7.2m x 8.0m, Live Load of 5kN/m²