Final Report

for the Carbon Neutral Cities Alliance: Dramatically Reducing Embodied Carbon in Europe's Built Environment

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Contents

1 Introduction

Zero Waste Scotland was funded by the Carbon Neutral Cities Alliance (CNCA) to support the "Dramatically Reducing Embodied Carbon in Europe's Built Environment" project. This initiative, launched in 2021 with the financial support of the Laudes Foundation, has three main aims:

- To foster the adoption of ambitious embodied carbon and biobased material policies in 10-20 cities across Europe
- To advocate for national level policy adoption in at least five European countries
- To build a coalition of cities, national-level stakeholders, industry and civil society groups to advocate for EU-level policy adoption

Prior to collaborating with CNCA, Zero Waste Scotland's work on embodied carbon in construction in Scotland had included:

- The development of a Net Zero Public Sector Building Standard (NZPSBS) (see section 2)
  - sets net zero requirements against six objectives and helps public bodies to meet their net zero commitments for new build and major refurbished infrastructure projects.
- Research into policy and future regulation of embodied carbon in Scotland (final report pending)

To inform the development of any embodied carbon reduction targets and to allow progress to be monitored, it is necessary to develop an evidence-base to understand the amount of embodied carbon in current construction projects. Zero Waste Scotland was therefore keen to encourage an upturn in the number of embodied carbon calculations being carried out on new developments and retrofits in Scotland.

The workstreams agreed between Zero Waste Scotland and the CNCA were selected to support CNCA in the delivery of their project and to align to the next stages of the NZPSBS and Scottish policy development activities.

1.1 Activities & deliverables

The key activities delivered by Zero Waste Scotland and funded by CNCA, were:

- Stakeholder engagement
  - Identify and hold introduction sessions with relevant stakeholders in Scottish cities
  - Identify suitable developments for embodied carbon calculations
- Conduct embodied carbon calculations
  - Appoint a contractor to carry out calculations and circularity assessments on (approximately 10) selected developments
  - Final report
- Knowledge sharing
  - Findings to be shared with Scottish cities via Scottish Cities Alliance (SCA)

In addition, Zero Waste Scotland committed to carrying out the following "in-kind" activities:

- Provide training and upskilling in relation to the use and adoption of the Net Zero Public Sector Building Standard (as above)
- Engage with policy makers and ministers to adopt and progress the recommendations of the route map and embodied carbon reduction targets (as above)
- Engage with industry stakeholders on potential embodied carbon targets (e.g., Scottish Construction Leadership Forum)
- Promote the use of nature-based materials construction projects (with Construction Scotland Innovation Centre, Forestry & Land Scotland, academia, etc.) including Scottish timber, hemp, sisal, and wool

The contract commenced in May 2022 and the completion date was extended to end-September 2023.

1.2 Outputs & outcomes

Table 1: Outputs

Output	Number	Notes
NZPSBS training sessions	5	
Embodied carbon calculations	10	• Inverness: 1; Glasgow: 4; Perth: 1; Edinburgh: 3; Aberdeen: 1 • Cities not covered: Stirling, Dundee, Dunfermline • Healthcare: 3; Education: 4; Office: 3
Circularity assessments	4	• Completed as separate reports for the first four projects.
Final report	1	
Presentation to cities (via SCA)	1	• Presentation covered all findings relevant to clients and the slides have been made available to the group. • We have offered to present directly to each city's development team.

Zero Waste Scotland completed an additional two embodied carbon calculations. These were not city-based developments and were separately funded, therefore they have not been included within this report.

This project has been extremely valuable and has already had a meaningful impact on our work to address embodied carbon in Scotland's built environment. For example, it has allowed us to:

- Start generating an evidence base of embodied carbon in buildings being developed now
- Identify key issues that need to be addressed for embodied carbon to be robustly, consistently and routinely monitored
- Identify common areas where there are opportunities to improve circularity and reduce embodied carbon
- Engage with key industry players on the subject and increase their awareness and understanding of what is required
- Engage with key personnel in city authorities and increase their awareness and understanding of what is required

In addition to these impacts and the contracted outputs, there are several notable outcomes at sector level, national level and in relation to Zero Waste Scotland's commitment. These have been outlined in section 4.

2 Net Zero Public Sector Building Standard - Training

During 2021, Zero Waste Scotland, SFT[1] and Health Facilities Scotland collaboratively developed the Net Zero Public Sector Building Standard[2] (NZPSBS). The standard sets net zero requirements against six objectives and supports public bodies to meet their net zero commitments for new build and major refurbished infrastructure projects. The second version of the standard is now live (as of August 2023) and has the additional scope of the "transition of existing buildings to net zero".

Figure 1: Structure and objectives of the NZPSBS[3]

Place	Objective 1	Inclusive Net Zero Economy Outcomes
Carbon	Objective 2	Construction embodied carbon
	Objective 3	Operational energy
	Objective 4	Other whole life carbon
Environment	Objective 5	Indoor environmental quality
	Objective 6	Environmental aspects

Objective 2 aims to reduce the embodied carbon impact of the project up to practical completion, requiring the use of Life Cycle Assessment (LCA) to assess the environmental impacts of the product and construction process stages. It seeks to influence projects and support the most significant reductions in embodied carbon during the early life cycle stages by considering the potential for reuse of an existing asset as opposed to new build and through considered material and product specifications. In support of best practice waste minimisation, objective 2 also sets requirements for circular economy principles and assesses how they have been applied during the design and delivery stages.

The standard has been formally adopted by the Scottish Government and Zero Waste Scotland, SFT and Health Facilities Scotland are engaging with public sector organisations across Scotland, and their contractors, to raise awareness and encourage its wider adoption. To that end, training materials have been developed which will upskill decision makers, carbon champions, and all those involved in construction (architects, planners, quantity surveyors, etc.). As part of this work with the CNCA, Zero Waste Scotland focussed initial engagement and training efforts on city-based stakeholders.

While currently optional, registration to the standard is a requirement for the Learning Estate Investment Programme (a £2bn grant fund operated by Scottish Futures Trust on behalf of the Scottish Government for public bodies). This is proving to be a successful driver and is a model that could be replicated with similar investment programmes.

The standard is also now signposted under the Scottish Government's funding and finance programmes for retrofit energy efficiency and decarbonisation: Scottish Central Government Energy Efficiency Grant Scheme, and Scotland's Public Sector Heat Decarbonisation Fund.

As the standard is rolled out across the Scottish public sector, it will be further developed to include all retrofit, and operational carbon and embodied carbon will be reviewed in the planned 2025 revision.

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[1] "Established by Scottish Government as a centre of infrastructure expertise, we provide additional skills, resource and knowledge to public sector organisations, supporting them plan, fund, deliver and manage their construction projects and buildings better" https://www.scottishfuturestrust.org.uk/

[2] https://www.netzerostandard.scot/

Standards developed for the public sector are often the forerunner for sector wide standards as they are seen as easier to implement and test. Therefore if the standard is successful, it is hoped that wider adoption by the sector will occur and that it may later become a requirement in Scottish Government policy/regulation. We hope that the standard will in time be the methodology that will deliver net zero buildings in the non-domestic market in Scotland.

2.1 Sessions delivered

North-east best practice in construction forum

Incorporating representatives from:

- Construction companies: Keir Construction, Balfour Beatty, Robertson Construction
- Local authorities: Aberdeen City Council, Aberdeenshire Council
- Other key city stakeholders: Robert Gordon University, Energy Transition Zone, University of Aberdeen, Aberdeen & Grampian Chamber of Commerce

Perth project team

- BAM construction
- Perth & Kinross Council
- Design team: DM Wilson, Baker Hicks, Rybka, JGA, Holmes Miller

University of Aberdeen

Aberdeen City and Aberdeenshire Councils

Mixed session

- City stakeholders: NHS Highland and The Highland Council
- Construction companies: Balfour Beatty
- Other participants included: NHS Ayrshire & Arran, and East Ayrshire Council

3 Embodied carbon calculations

Following a tendering process, Ricardo Energy & Environment was appointed to carry out the embodied carbon calculations and circularity assessments.

Calculations were carried out for the following developments.

Table 2: Calculations completed

City	Type	Circularity assessment
Inverness	Healthcare	Yes
Glasgow	Healthcare	Yes
Perth	Education / research	Yes
Glasgow	Education / research	Yes
Edinburgh	Education / research (a)	
Edinburgh	Office	
Glasgow	Office (a)	
Aberdeen	Healthcare	
Edinburgh	Education / research (b)	
Glasgow	Office (b)	

3.1 Methodology

The embodied carbon calculations were carried out using:

- OneClick software
- Royal Institute of Chartered Surveyors' (RICS) New Rules of Measurement[4]
- RICS Professional Statement (RICS PS) "whole life carbon assessment for the built environment"[5]
- British Standard EN 15978[6]

The British Standard EN 15978 defines the various stages in a building's life cycle, and these are shown in Figure 2 below.

Figure 2: Life cycle stages included within the scope of the assessment

Product stage			Construction process stage		Use stage							End of Life stage				Benefits and loads beyond the system boundary
Raw material supply	Transport	Manufacturing	Transport	Construction	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Demolition	Transport	Waste processing	Disposal	Future reuse, recycling, or energy recovery potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
✓	✓	✓	✓	✓	x	x	x	x	x	x	x	x	x	x	x	x

The scope of this project was to conduct cradle to practical completion assessments (covering life stages A1 – A5), for projects at RIBA[7] Stage 5[8] and beyond.

The calculation process complied with the methodologies laid out in the RICS New Rules of Measurement, RICS Professional Statement whole life carbon assessment for the built environment, and British Standard EN15978. The assessment adhered to the principle of modularity, where processes that influence the products environmental performance during its life cycle have been assigned to the module in the life cycle where they occur. The system boundary was set following the "polluter pays principle" where the processes of waste processing are assigned to the product system that generates the waste until the end-of-waste state is reached.

[4] https://www.rics.org/profession-standards/rics-standards-and-guidance/sector-standards/construction-standards/nrm

[5] https://www.rics.org/profession-standards/rics-standards-and-guidance/sector-standards/building-surveying-standards/whole-life-carbon-assessment-for-the-built-environment. It should be noted that the document is currently being revised. Expected changes will cover benchmarking and alignment with taxonomy in ICMS 3 for classification of carbon reporting.

[6] BS EN 15978:2011 – Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method.

[7] Royal institute of British Architects

[8] The RIBA Plan of Work organises the process of briefing, designing, delivering, maintaining, operating and using a building into eight stages: 0 Strategic definition, 1 Preparation and briefing, 2 Concept design, 3 Spatial coordination, 4 Technical design, 5 Manufacturing and construction, 6 Handover, 7 Use. https://www.architecture.com/knowledge-and-resources/resources-landing-page/riba-plan-of-work#available-resources

Primary data (largely the bill of materials) specific to each development was supplied by the contractors. The calculation team then worked within One Click to select the most suitable datasets and assumptions, combining the material/process types and quantity data to perform the impact assessment calculation, the result of which is a value of potential carbon dioxide equivalents per building and per m^2 of gross floor area.

Additional details on the calculation methodology have been provide in Appendix 1.

3.2 Calculations summary

The results of the ten completed calculations are set out in Table 3 below. In all cases, we relied on the developers to provide data and therefore, we are unable to confirm the completeness or accuracy of the information we received.

It is important to note that there were varying levels of data availability and quality associated with each selected development. In all cases, assumptions have had to be made (more information on the methodology is provided in Appendix 1) and this reduces the accuracy of the results.

Ultimately, due to the data availability and quality issues encountered, it has not been possible to meet all the mandatory requirements set out in the RICS PS in all cases. However, at this stage we are relatively confident in the majority of the results and despite these issues, the results are of considerable value at a starting point for Scotland.

Table 3: Results

Project	Building total[9] (t CO_2 eq)	Total per m^2 (kg CO_2 eq / m^2)	Comparison to benchmark[10]
Inverness, Healthcare	2599	277	-54%
Glasgow, Healthcare	5087	477	-21%
Perth, Education / Research	2941	691	+15%
Glasgow, Education / Research	4022	504	-16%
Edinburgh, Education / Research (a)	5175	749	+25%
Edinburgh, Office	6520	459	-24%
Glasgow, Office (a)	15625	434	-28%
Aberdeen, Healthcare	4259	775	+30%
Edinburgh, Education / Research (b)	6103	558	-7%
Glasgow, Office (b)	12132	578	-4%

[9] The overall calculated embodied CO_2 of the building in terms of carbon dioxide equivalents. Based on data provided by the contractors – we cannot attest to the completeness of the data submitted.

[10] The NZPSBS sets an embodied carbon benchmark of 600kg CO_2 eq/m^2 for stages A1-A5.

3.3 Circularity assessments summary

The purpose of these assessments was to provide a snapshot of how circular economy principles have been incorporated into the processes at each building site, as well as provide high-level recommendations on how best practices can be embedded in future projects.

Assessments were carried out using Zero Waste Scotland's Circular Economy Assessment Tool and focussed on the processes, materials and procurement policies applied from project inception through to the date of the assessment.

The assessment consists of 14 questions covering three themes and six subcategories (further details provided in Appendix 2). Responses to each question were qualitatively scored according to the following criteria:

- Good: Evidence that some circular principles have been applied
- Average: Largely business as usual approaches indicating low circularity
- Low: No/minimal evidence of circularity
- Unclear: Unclear or more information required
- N/A: Not applicable - this is where client specifications and/or procurement criteria prevent the implementation of circular principles

Through this method a score for each subcategory, theme and ultimately the overall project, was calculated.

Table 4: Summary of scores

Project	Good	Average	Low	Unclear or n/a
Inverness, Healthcare	15%	28%	37%	19%
Glasgow, Healthcare	28%	30%	38%	4%
Perth, Education / Research	10%	30%	60%	0%
Glasgow, Education / Research	32%	26%	42%	0%

3.3.1 *Common opportunities and recommendations*

Table 5: Resources theme

Sub-category	Recommendations
Retain in use	Retrofit existing assets • Use Greater London Authority (GLA) decision tree[11] to assess technical feasibility of retaining existing components onsite • Refer to Interreg guidance[12] to assess the feasibility of reuse where there are doubts concerning the energy efficiency and quality standards of assets or building materials that could be reused/retrofitted
Source responsibly	Salvaged materials: • Set clear procurement specifications for reuse performance in the project brief • Refer to Interreg toolkit[13] and Zero Waste Scotland guide[14] as required Recycled content: • Set out clear procurement specifications for recycle content • Material categories identified as a priority are aluminium, concrete aggregate, steel, and glass Low impact materials: • Set out a clear preference for the use of low impact materials, such as natural fibre insulation and low VOC (volatile organic compound) paints

[11] Further guidance on circular best practice for the built environment by the GLA can be found here: Mayor of London, *Design for a Circular Economy Primer*: link

[12] Interreg, *Reuse Toolkit: Procurement strategies – integrating reuse in large-scale projects and public procurement* (2021): link and Interreg, *Reuse Toolkit: Material sheets* (2021): link

[13] Interreg, *Reuse Toolkit: Procurement strategies – integrating reuse in large-scale projects and public procurement* (2021): link and Interreg, *Reuse Toolkit: Material sheets* (2021): link

[14] Zero Waste Scotland, *Maximising re-use of materials on-site guidance* (2017): link

Sub-category	Recommendations
Design out waste	Manage wastage of materials: • Embed waste reduction clauses within project briefing and tendering documentation • Clients and contractors work together to define clear waste reduction targets as KPIs at the start of a project • Clients should appoint a waste champion responsible for coordinating with the contractor and monitoring progress against indicators Manage construction site waste: • Active communication and collaboration between contractors, clients and sub-contractors at the inception of a project to standardise practices for waste minimisation strategies • Provide suitable facilities (space, equipment, etc.) for onsite segregation of materials leading to high-value recycling • Use Zero Waste Scotland's Site Waste Reduction Protocol[15] as a way to monitor onsite waste generation General considerations: • Most opportunities to embed circularity require decisions at the design and planning stages • Clients should lead engagement and collaboration with the delivery team throughout these stages giving all available options due consideration • Decisions to be clearly communicated through all links in the project delivery chain

Table 6: Components theme

Sub-category	Recommendations
Standardise manufacture	Modular Components: • Set clear preferences in procurement specifications for modular components, offsite prefabrication and adaptable designs
Extended producer responsibility	Servitisation of components: • Set clear procurement specifications for "product as a service" systems. Products identified as a priority are lighting, carpet tiles, raised flooring systems and ceiling tiles • This action should be supported through active market engagement with companies that do (or could) provide these services (see UK Green Building Council implementation packs[16])

[15] Protocol, summary, CWIC calculator, user guide and case studies available to download from https://www.zerowastescotland.org.uk/resources/site-waste-reduction-protocol#:~:text=What%20is%20the%20Site%20Waste,all%20of%20your%20construction%20sites

[16] https://ukgbc.org/resources/circular-economy-implementation-packs-for-products-as-a-service-and-reuse/

Table 7: Future value theme

Sub-category	Recommendations

Design to preserve value	Design for deconstruction:
	• Set clear preferences in procurement specifications for adaptable designs which enable deconstruction. For example, those featuring:
	  ○ mechanically fixed rather than adhesive-fixed systems
	  ○ bolted connections rather than welded approaches
	  ○ reduced or weaker chemical or mortar bonds (e.g. lime mortar for brickwork)
	• Require a deconstruction plan to be included in the project tender process.
	• Use and update deconstruction plans throughout the project and provide this to the client at handover for future reference
	• Ensure the future owner of the BIM model (e.g. the client's facilities manager) has training on use of the BIM for deconstruction
	
	Design to Preserve Value:
	• Require a Circular Economy Plan, demonstrating how circular principles have been incorporated across a building's design, to be provided at project inception phase

3.4 Lessons learned

Carrying out this project and delivering the embodied carbon calculations has been a valuable exercise for all parties involved (the developers / construction companies, the contractor carrying out the calculations and ourselves). Following completion of the first four calculations, Ricardo produced a lessons learned report to capture the key issues and their wider implications, and to set out recommendations to address these challenges for the remaining six calculations and more broadly. The report was updated following completion of all ten calculations and the key findings are presented below.

3.4.1 Challenges and solutions

3.4.1.1 Material data availability and quality

Challenges / lessons	Solutions / actions
Bill of quantities (BoQ) and extraction of data from Building Information Management (BIM)	
• Time-consuming with data requiring significant review, extraction and reformatting to be submittable to LCA calculation software	• Direct supply of BIM models to the calculation team • Contractors should consider data format requirements in early project stages and build these into supplier and sub-contractor reporting commitments • Systems, such as digital design and material delivery recording, should be integrated to allow 'one source of truth' so the data is kept up to date at any stage in the development cycle • See "contractual requirements"
"As built" records	
• RICS PS recommends that for existing buildings, "as built" records should be used as a data source to maximise accuracy of calculations • None of the contractors used / provided this information during this project either because they preferred to use detailed design dataset for speed and due to staff familiarity or they did not have "as built" updates incorporated into project BIM models	• 'As-built' records should be used for maximum accuracy • See "contractual requirements"
Existing embodied carbon ambitions	
• Where a contractor and an associated project already have embodied carbon or environmental accreditation targets or ambitions, data collection was easier (as the relevant information is collected with such calculations in mind from the outset) • Such ambitions tend to be client driven and most contractors do not collect this type of information as standard	• Encourage greater uptake of the NZPSBS to increase public sector client-led requirements in this area • Engage private sector clients would help to deliver the necessary critical mass to see contractors adopt the necessary data processes as standard / Business-as-usual (BAU)

Challenges / lessons	Solutions / actions
Contractual requirements	
• A lack of contractual requirements to collect or analyse embodied carbon data means that it is not always collected or recorded consistently • Data may be collected consistently by a contractor, but not necessarily by sub-contractors leading to issues with consistency, availability and quality	• Clear requirements for embodied carbon data capture and analysis should be written into all contracts and sub-contracts (between the client and the contractor, and between the contractor and their sub-contractors). This should include: • Prioritisation of material delivery / "as-built" records, then BIM model data, then Bill of Quantities (to align with EN 15978) • Formatting requirements to align with the chosen LCA software • Access to data "owned" by different parties is adequately addressed within contracts and sub-contracts • Data collection, reporting and approval processes should be initiated as soon as possible • All relevant personnel at the contractor and sub-contractors should be made aware of the requirements and contract monitoring / management processes used to ensure that the requirements are adhered to

In summary, there are two main issues with data: availability and accuracy. Confirmation of data, calculation and reporting requirements as early as possible in the project will allow all parties to set up appropriate processes to meet these requirements from the outset and will help to ensure that the relevant type and granularity of information is recorded through the project lifecycle.

3.4.1.2 Other

Challenges / lessons	Solutions / actions
Carbon impact datasets	
• Material data needs to be matched to carbon impact datasets to complete embodied carbon calculations. The most accurate of these, Environmental Product Declarations (EPDs), do not exist for may built environment products and materials • The current embodied carbon landscape in Scotland does not sufficiently encourage manufacturers to produce EPDs except for their best performing products	• Consider how a policy and regulatory regime could be structured so a higher number of (if not all) construction products have EPDs • Explore what technical or financial assistance may be required to deliver this
Resourcing and time commitment	
• Difficulties in costing and planning calculations work where those carrying out the calculations have not been involved in the project from its early stages • Calculations team require ongoing input from project delivery team regarding data leading to delays and resource / availability issues	• Ensure that the calculations team have an opportunity to speak with the project team regarding data. This will allow them to understand what type and how much data is available from the EN 15978 hierarchy of preference
Communication	
• A lack of appreciation or understanding of the importance of accurate, consistent data collection and recording • Can lead to poor quality or incomplete data which has knock-on impacts for the accuracy of embodied carbon calculations	• Clear communication between carbon calculation teams and the relevant design and supplier teams to develop a common understanding • Standardisation of requirements which will spread from project to project, team to team, and eventually support the development of an industry-wide standard for consistent, carbon calculation focussed data reporting • See “contractual requirements”

3.4.2 Strategic messaging

Based on the challenges, lessons, solutions and actions outlined above, the following strategic messages have been identified. These will support positive contributions from contractors, clients, industry bodies and policy makers in addressing the challenges and making embodied carbon calculations easier, more efficient, and more accurate.

Topic	The importance and benefits of setting embodied carbon targets early in the project lifecycle
Audience	Clients
Result	This approach is adopted in an increasing number of projects, eventually becoming standard practice. This will result in the collection of more accurate, consistent and appropriately granular data as business-as-usual
Roles	**Policy makers and industry bodies**: Communications identifying of the climate benefits of embodied carbon reduction. Promotion of the NZPSBS and dissemination of the updated RICS PS and its requirements. **Contractors**: Engage clients during the early project stages to communicate these benefits and demonstrate that the industry is serious about tackling the climate crisis and is therefore keen to carry out embodied carbon calculations as standard practice.
Topic	**The benefits of proactively developing and deploying integrated data systems** (a demonstration of willingness to tackle embodied carbon and the wider climate crisis, improved accuracy of data leading to robust calculations and a genuine understanding of current performance)
Audience	Contractors
Result	An increasing number of contractors use integrated data systems leading to improved data availability, improved data quality, more robust calculations, a better understanding of current performance, identification of areas for improvement, and an ability to monitor progress towards any future targets.
Roles	**Policy makers & industry bodies**: Encourage and support contractors, share best practice, consider financial and technical support mechanisms.
Topic	The benefits and importance of integrating material data collection and reporting requirements for projects at the procurement stage
Audience	Clients
Result	An increasing number of procurements include data requirements in the specification leading to improved data availability, greater consistency, improved quality and helping this practice to become business-as-usual.
Roles	**Policy makers and industry bodies**: Share best practice on how to integrate suitable material data collection and reporting requirements into procurement specifications. **Contractors**: Take a leadership role by deploying and sharing best practice in relation to data

4 Outcomes and impacts

Overall, this project has been extremely valuable and has already had a meaningful impact on our work to address embodied carbon in Scotland's built environment. For example, it has allowed us to:

- Identify key issues that need to be addressed for embodied carbon to be accurately monitored
- Identify common areas where there are opportunities for improvement in circularity and reducing embodied carbon
- Engage with key industry players on the subject and increase their awareness and understanding of what is required
- Engage with key personnel in city authorities and increase their awareness and understanding of what is required
- Start developing a baseline understanding of embodied carbon in buildings being developed now

In addition to these impacts and the contracted outputs, there are several notable outcomes at sector level, national level and in relation to Zero Waste Scotland's continued commitment:

- Sector level
  - Interest from the Scottish Futures Trust in integrating embodied carbon into the Scottish public sector development register
  - Data needs and issues associated with embodied carbon measuring have been identified and are now better understood by the industry, their clients and Zero Waste Scotland
- National level
  - Findings have provided evidence to inform our work in support of the Scottish Government's Circular Economy Route Map
  - Informed a briefing to Scottish ministers on circular principles and embodied carbon in the built environment
  - Findings are being used to update the Scottish Government's building standards technical handbook to include embodied carbon
  - The intelligence gathered on data needs and issues will be used to inform policy, engagement and guidance to address the challenges, enable more accurate measuring of embodied carbon in Scotland's built environment and allow for progress to be better understood and monitored
  - While accepting that there are limitations to the calculations carried out due to the issues outlined, this project has started the development of a national dataset which in turn will support the development of embodied carbon targets
- Zero Waste Scotland commitment
  - This work has been crucial in helping us to understand the barriers and challenges which currently prevent embodied carbon calculations from being carried out robustly, consistently and routinely. As a result of the findings, Zero Waste Scotland has committed additional budget for the 23/24 financial year to conduct further research into these issues as well as potential solutions. This research will lead to further engagement with the sector, policy makers and clients to implement solutions which will drive progress in relation to embodied carbon
  - The Net Zero Public Sector Building Standard will be updated to include retrofit, and operational carbon and embodied carbon will be reviewed in the planned 2025 revision. We will develop online recordings of all training modules which will be freely accessible from the newly launched, dedicated website and will continue to run live sessions for organisations that have registered with the standard

Appendix 1 – Embodied carbon calculation methodology

The embodied carbon calculations were carried out using:

- OneClick software
- Royal Institute of Chartered Surveyors' (RICS) New Rules of Measurement[17]
- RICS Professional Statement (RICS PS) "whole life carbon assessment for the built environment"[18]
- British Standard EN 15978[19]

Scope

The British Standard EN 15978 defines the various stages in a building's lifecycle, and these are shown in Figure 3 below.

Figure 3: Modules included within the scope of the assessment

Product stage			Construction process stage		Use stage							End of Life stage				Benefits and loads beyond the system boundary
Raw material supply	Transport	Manufacturing	Transport	Construction	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Demolition	Transport	Waste processing	Disposal	Future reuse, recycling, or energy recovery potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
✓	✓	✓	✓	✓	x	x	x	x	x	x	x	x	x	x	x	x

The product stage (A1-A3) relates to the processes and impacts associated with the upstream extraction and processing of raw resources (A1), their transport to a material production site (A2), and the energy/utilities associated with converting these resources into the required building materials (A3). Life cycle inventory data, in the form of various sources of datasets available in the One Click tool database, have been used to represent the impacts of each material used. One Click software does not enable impacts for stages A1 to A3 to be reported separately and therefore amalgamated results are reported for the product stage (A1-A3).

The construction process stage (A4 – A5) covers the transport of these building materials to the construction site (A4), plus the impacts associated with constructing the building (A5) e.g., energy usage, disposal of generated waste.

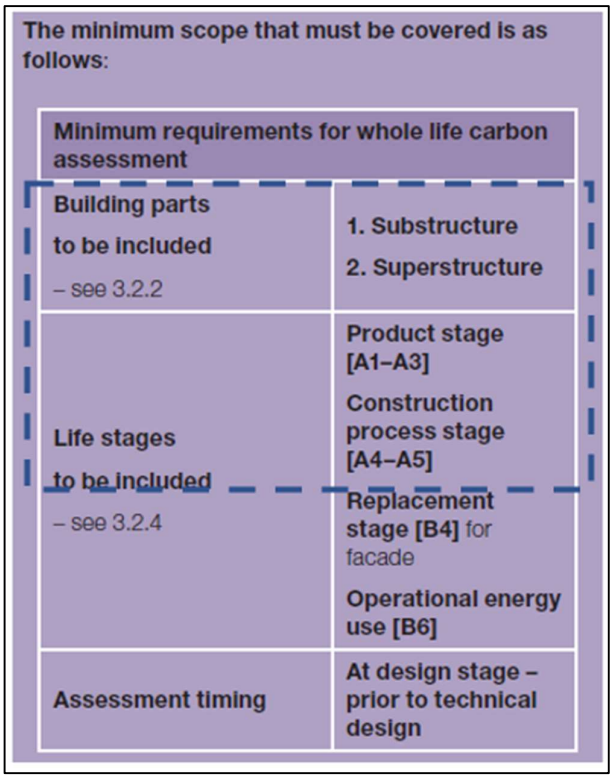
[17] https://www.rics.org/profession-standards/rics-standards-and-guidance/sector-standards/construction-standards/nrm

[18] https://www.rics.org/profession-standards/rics-standards-and-guidance/sector-standards/building-surveying-standards/whole-life-carbon-assessment-for-the-built-environment. It should be noted that the document is currently being revised. Expected changes will cover benchmarking and alignment with taxonomy in ICMS 3 for classification of carbon reporting.

[19] BS EN 15978:2011 – Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method.

Figure 4 below shows the defined minimum requirement for a whole life carbon assessment. The scope of this project was to conduct cradle to practical completion assessments (covering life stages A1 – A5), for projects at RIBA Stage 5 and beyond. The minimum requirements to deliver this scope have been outlined in blue in the figure.

Figure 4: Whole life carbon assessments minimum requirements[20]



Life cycle impacts beyond the construction process stage (B1-B6, C1-C4 and D) were excluded from the assessment.

Process

The calculation process complied with the methodologies laid out in the RICS New Rules of Measurement, RICS Professional Statement whole life carbon assessment for the built environment, and British Standard EN15978. The assessment adhered to the principle of modularity, where processes that influence the products environmental performance during its life cycle have been assigned to the module in the life cycle where they occur. The system boundary was set following the "polluter pays principle" where the processes of waste processing are assigned to the product system that generates the waste until the end-of-waste state is reached.

Primary data (largely the bill of materials) specific to each development was supplied by the contractors. The calculation team then worked within One Click to select the most suitable datasets and assumptions, combining the material/process types and quantity data to perform the impact assessment calculation, the result of which is a value of potential carbon dioxide equivalents per building and per m^2 of gross floor area (GFA).

[20] From RICS Professional Statement

Three different categories of data can be used in the LCA:

1) Specific data (primary data)

2) Selected generic data (secondary data)

3) Proxy data (secondary data)

To explain the distinction between these categories, specific data directly refer to the specific make of material under investigation. An example of this is an EPD for the specific material or component used for a building element (i.e., Ordinary Portland Cement produced by manufacturer 'X').

In cases where specific data is not available, generic data (secondary data) was selected. Generic data refer to the same type of material, but are not specific to the manufacturer, i.e. average UK Ordinary Portland Cement.

Where data for a material cannot be sourced through either of the above routes, proxy data is sought. Proxy datasets do not directly refer to the material under investigation but to similar materials; they are therefore used only as a last resort in the absence of selected primary or secondary data.

Specific data in terms of the carbon emissions used for the materials can only be used if the specific manufacturer and product type used is known and if there is a published EPD available.

A significant amount of data was provided by contractors. This was condensed into a set of standardised materials which were then used for the data mapping exercise.

Appendix 2 – Circularity assessment methodology

An assessment of the project's circularity was carried out by Ricardo using Zero Waste Scotland's Circular Economy Assessment Tool. Circular construction aims to minimise the environmental impact of projects by using less virgin material, creating less waste and enabling those materials which are deployed to be kept in as high a value use as possible, for as long as possible. It is important for clients to be aware of circular construction principles and options, as many of the decisions which have significant impact on a project's circularity, and therefore long-term environmental performance, are best made as early as possible in the planning and design process.

The purpose of the assessment is to provide a snapshot of how circularity principles have been incorporated into the processes at each building site, as well as provide high-level recommendations on how best practices can be embedded in future projects.

Scope

The scope of the Circularity Assessment is focused on the processes, materials and procurement policies applied at the development from project inception to the date of the Circularity Assessment interview.

Methodology

The Circularity Assessment consisted of 14 questions that can provide insights on three themes and six subcategories as defined in Table 8.

Table 8: Themes, sub-categories and descriptions

Theme	Description	Sub-categories
Resources	Applies the reduce, reuse, recycle mantra to the use of resources; retaining items in use or salvaging them for reuse; using materials with recycled/reprocessed content or otherwise of low impact; reducing resource use by minimising waste and maximising recycling during the construction process	Retain in Use, Source Responsibly, Design out Waste
Components	Manufacture and ongoing management of components, including Extended Producer Responsibility, especially where regular maintenance or frequent replacement is likely.	Standardise Manufacture, Extended Producer Responsibility
Future value	Design strategies to preserve future value of the building and components; maximise usable life by durability and flexibility; ensure materials can be salvaged at demolition	Design to Preserve Value

For each project, semi-structured interviews were carried out with representatives of the design, procurement and site management teams. Interviewees were asked to provide details on how circular approaches were applied for each building layer where appropriate (i.e., site, structure, skin, etc.). Where feasible, additional evidence, including designs, photographs and additional documentation was requested to support and/or clarify any of the insights gained during the interviews.

Responses to each question are qualitatively scored according to the following criteria:

- Good: Evidence that some circular principles have been applied
- Average: Largely business as usual approaches indicating Low Circularity
- Low: No/minimal evidence of circularity
- Unclear: Unclear or more information required
- N/A: Not applicable - this is where client specifications and/or procurement criteria prevent the implementation of circular principles

Through this method a score for each subcategory, theme and ultimately the overall project, was calculated.

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