ARUP

Whole life carbon assessments at global scale: A case study

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Foreword

The built environment stands at a critical juncture. It represents 37 per cent of global energy-related carbon dioxide emissions, and these emissions are still rising. It is urgent that we come together as a society, as businesses, and as governments to halve emissions from the built environment by 2030 and reach net zero emissions by 2050.

Through the Market Transformation Action Agenda for the Built Environment, we have identified the critical collective actions that must be prioritized to accomplish this task. This includes actions on the three critical levers for market transformation, including a focus on Whole Life Carbon (WLC) emissions in every building project, placing carbon alongside cost to inform decision-making, and transforming supply and demand relationships based on quantified carbon information.

The efforts outlined in this paper are a considerable contribution to the industry alignment behind the first Lever of the Market Transformation Action Agenda, to conduct Whole Life Carbon Assessments (WLCAs) in every project and share relevant data. We applaud Arup for making the commitment at COP26 to conduct WLCAs on all their projects, steering the entire industry to engage more actively on this critical lever.

Arup's case study reflects the complexity of such an undertaking and enables us to identify and embed learnings from their challenges, findings, and achievements. Harmonized WLCAs need to become the new normal in every building project around the world, otherwise we will not achieve our decarbonization targets. Arup has demonstrated what needs to happen at industry-level today and showcased the type of leadership actions we are aiming to unlock through the shared Market Transformation Action Agenda, co-developed with over 250 representatives from over 100 organizations across the built environment value chain.

I trust you will find this case study useful in transforming your business.

Peter Bakker
President and CEO
World Business Council for Sustainable Development

Figure 1. Timeline of Arup's Carbon Commitments

Introduction

The consequences of climate change weigh heavily upon us. From extreme weather events causing ever more chaos to the daily lives of millions around the world to heightened warnings from UN climate scientists, it is evident that global society is not close to taming the effects of the global warming our technological progress has caused. Climate scientists are clear that historical human-generated greenhouse gases (GHGs) in the atmosphere have caused our present conditions. What we do now determines our future.

The United Nations Framework Convention on Climate Change (UNFCCC) has determined the deep reductions in present and future GHG emissions that are necessary to avoid even more global warming and its detrimental effects on the stability of the world's life-sustaining ecosystems. Enshrined in the Paris Agreement is the goal of limiting global warming to 1.5ºC above pre-industrial conditions by 2050. The plan behind it heavily relies on converting as quickly as possible to an economy that is no longer releasing new greenhouse gases (GHGs) into the atmosphere. This is often called a net zero carbon economy, as carbon emissions are the most prevalent GHGs.

As a professional services firm devoted to the sustainable development of the built environment, Arup has made two key commitments to reduce the emissions under its influence or control: one associated with our business operations – achieving net zero as an organisation by 2030 – and one associated with the built outcomes of our design and consulting work.

Because Arup provides professional services that lead to significant construction material and energy use across a building's life, by virtue of the advice we provide to clients and the size of our business, we have influence over future global emissions at a scale far beyond the carbon footprint of our business entities. We wanted to know the scale of the impact associated with the outcomes of our work, and then to do what we could to reduce it. Clients were asking us how to reduce the carbon emissions of their asset portfolios and of new projects. Our goal was to be able to exert the greatest possible influence on future clients to engineer carbon emissions out of their assets, as regulation and policy increasingly demand. We also knew that we **should** be able to better understand where carbon was buried in our designs, and we were quickly confronted with the truth of the old adage: "You can't manage what you don't measure."

In November 2021, at COP26 in Glasgow, Arup committed to undertake whole lifecycle carbon assessments of all of its building projects both new and retrofit, clarifying in 2022 that the assessments were to be done in the service of aligning our design ambitions with the UN 2030 Breakthrough outcome for the built environment of net zero carbon operation and a cut in embodied carbon of at least 40%.

In so doing, we joined an industry-wide effort, mobilising the scale of our global buildings design portfolio as the sample pool for our research. The underlying expectation of our research is that collating more data across Arup's portfolio of buildings will lead to deeper insights that should help change design practice.

The architecture-engineering-construction (AEC) industry has been grappling over the last decade with creating measurement methodologies, setting standards, and gathering reference data to perform carbon assessments that take into account the expected emissions over the life cycle of a development – this is called whole life carbon assessment (WLCA).

Many non-profit organisations have been attempting to collate building lifecycle data from design and construction teams either from small geographic pockets or within certain trade or discipline-specific communities of professional practice. Many others in the industry are also performing lifecycle assessments on given projects, but there is no global standard or data structure for doing this in a way that allows comparisons.

We collaborate with organisations and campaigns seeking to galvanise whole value chain endeavours to standardise solutions, create tools and methodologies, accelerate built environment decarbonisation, and reduce data friction across the industry. Global initiatives such as the World Business Council for Sustainable Development's Market Transformation programme, the Open Data Institute's net zero data framework and the World Green Building Council's Advancing Net Zero programme all promote sharing, transparency and deep collaboration in the light of our common global challenge.

In this spirit, this case study details the activities we have carried out since making our WLCA commitment, the challenges we faced, and the pertinent lessons we learned. These related to a systemic transformation in:

– Data and digital architecture

– Global harmonisation

– Data quality

We are still on the journey to embed whole life carbon assessments as business as usual, to inform design choices on all projects. As the years race through this crucial decade for climate action, we at Arup have millions of square metres of floor area in design that is expected to open from 2030. As a firm and as part of a wider movement, we cannot afford to delay adoption of WLCAs as a metric for carbon performance.

With over 1,000 projects contributing carbon emission data over the last two years, we have chosen to share our story of challenges, successes, and lessons learned as a contribution to the ongoing conversations with like-minded stakeholders in the built environment industry. We offer our findings as one firm attempting a global task, in the hope that they will help the global AEC community tackle the challenges of quickly creating and adopting the comparable datasets needed to rapidly decarbonise property worldwide.

Erin McConahey
Arup Fellow, Director of the Arup Whole Life Carbon Initiative
February 2024

Figure 2. Arup's Whole Life Carbon initiative automation workshop, London, October 2023

Executive Summary

This document illustrates a case study of Arup's Whole Life Carbon (WLC) initiative that was launched at COP26 in November 2021. It provides a two-year status report on our commitment to collect whole life carbon assessments (WLCAs) from all of our buildings design portfolio. It is written by Arup and concerns our own activities.

The goal is to share progress, challenges and lessons learned with industry peers, specifically about its experience creating a digital WLCA data collection and visualisation platform (Zero). The case study describes the steps taken to create and use Zero to capture WLCA data for the work that Arup was contracted to carry out in over 800 buildings across 30 countries in 2023.

The case study provides, for context, a brief background on the urgent need for systemic change in the way the built environment is designed and operated, if UN trajectories towards a net zero carbon economy are to be achieved. It then describes how Arup deployed its ambition on a global scale, activating subject matter experts (SMEs) across 14 communities of practice to advise on software, database and content development.

As with any new endeavour, the value is not only in achieving a goal but in the learning, discovery, and advances made along the journey. The majority of the case study focuses on the steps taken to build and deploy Zero, including the challenges faced along the way. These included:

- Standardising a global WLCA data schema
- Resolving disparities between global and local reference carbon data sources
- Using digital technology to capture and store data
- Investing in learning and community building
- Planning for the maturing of project details and the associated improvement of data quality
- Addressing difficulties with data quality and extracting design recommendations from data analytics

In addition to sharing selected results from the data set, the case study provides highlights that may help others in the built environment industry attempting similar large- scale WLCA data collection exercises. Other examples of Arup's efforts to support market transformation under the WLCA framework are included.

The case study ends with a reflection on how the findings can be applied to industry-wide initiatives – be they governmental agencies considering mandatory reporting or non-profit organisations trying to extract insights from multiple contributors. The key observations are:

1. The goal of WLCA adoption is to achieve deep decarbonisation of the built environment, not necessarily data collection itself.
2. The WLCA has the potential to fulfil an urgent need to set a standard of global GHG measurement for the built environment – provided calculation and reporting methodologies are better harmonised across regions.
3. The greatest challenge for global industry-wide data collection is to establish which carbon-related values and metrics have the potential to deliver meaningful change, and then set guidelines to preserve data integrity for those levels of detail from the outset.
4. As noted by the Open Data Institute, "the concept of a carbon data strategy for a net zero economy, or a 'net zero data strategy', is still in its infancy".
5. Standardising carbon data management across all digital design, analysis and Building Information Management (BIM) tools would enable a faster embrace of WLCA to inform design.
6. The 'return on investment' of doing WLCAs must be clearly articulated to design practitioners across the industry, so that they are able to convey the results of low-carbon outcomes to their clients.

Urgent need for systemic change

It is clear that there is an urgent global need for systemic change in the AEC industry. This section summarizes some key concepts and industry trends to indicate the global context around Arup's specific WLCA story.

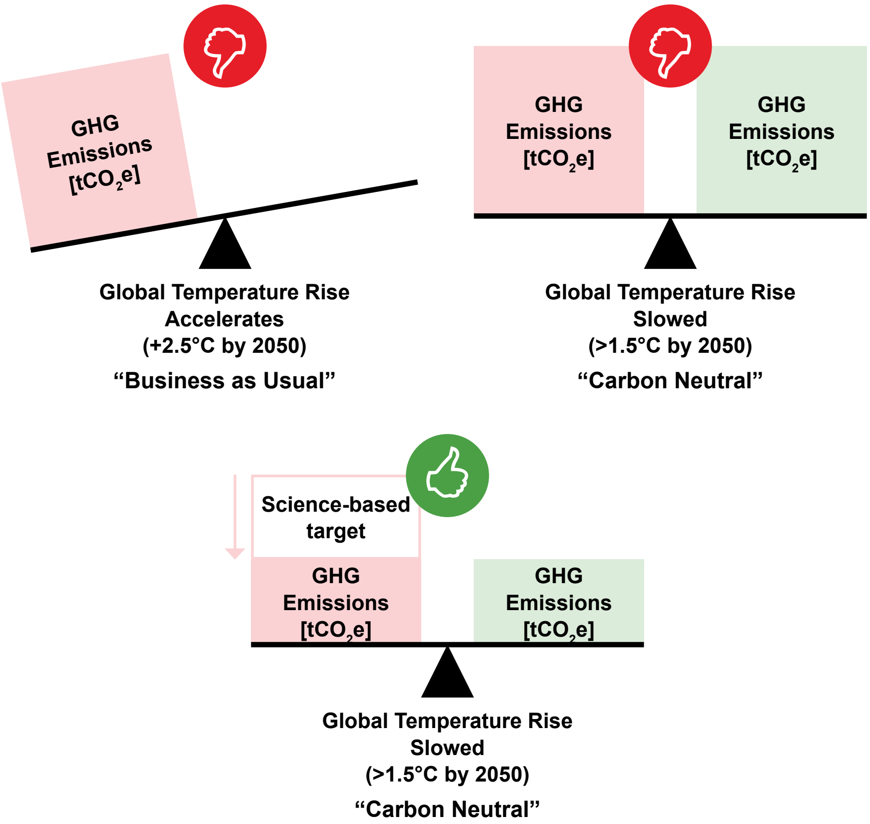

Figure 3. How Net Zero Carbon differs from Carbon Neutrality

The 2022 Global Status Report for Buildings and Construction from the UN Environment Programme showed that in 2021, the sector represented 37% of global emissions when fully accounting for energy and process emissions. This status fails to meet the critical decarbonisation trajectory towards a zero-carbon building stock in 2050, an essential element for achieving the goals of the Paris Agreement. Reducing emitted carbon now during the 2020's is essential, with the UNFCCC global stocktake noting "a rapidly narrowing window to raise ambition and implement existing commitments to limit warming to 1.5°C above pre-industrial levels" (p. 5).

Achieving net zero carbon on a building development means first achieving "science-based targets" for reduction of absolute emissions before resorting to carbon offsets. This is different from "carbon neutrality," which allows a large amount of GHGs to be released into the atmosphere with the promise that an equivalent amount will be removed. Much like what a doctor may advise for weight loss, science would advise first you must reduce the amount of calories consumed and then have the proper amount of exercise. It is quite similar for science-based targets for reducing GHG emissions in aggregate, except that the complexity of building construction means that it's hard to know which trade is responsible for reducing what amount of emissions.

For the building sector, the science-based near term targets have been set by the UN Climate Champions 2030 Breakthrough goal of "[a]ll new projects completed from 2030, are net zero carbon in operation, with >40% reduction in embodied carbon." Progress is tracked through two components summed for the whole building: embodied carbon and operational carbon, with reporting by lifecycle stage in a format called whole lifecycle carbon assessment (WLCA).

The complexity of building construction means that it's hard to know which trade is responsible for reducing what amount of emissions.

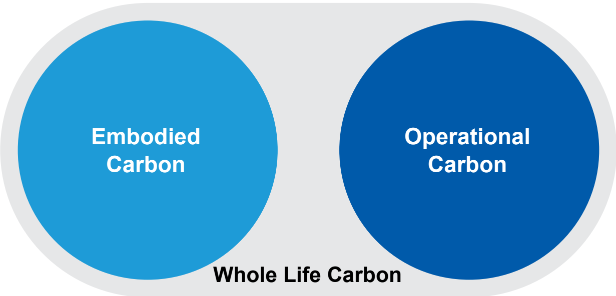

Figure 4. Components of Whole Life Carbon Emissions

Operational carbon

The indirect and direct emissions of carbon dioxide and other GHGs associated with utility energy and water consumption, on-site burning of fuels, and leaks of chemicals that cause global warming, such as refrigerants.

Embodied carbon

The indirect emissions associated with energy and the direct emissions of a variety of global-warming chemicals associated with raw material extraction, manufacturing, transport, installation and disposal.

Industry-wide, there is a growing recognition that systemic change is necessary to achieve these goals.

- The World Business Council for Sustainable Development (WBCSD) has identified market transformation levers calling for radical and deep collaboration across the value chain to align behind the notion of Whole Life Carbon, integrate carbon cost and pricing, and transform supply and demand dynamics.
- The Race to Zero coalition, with more than 13,000 non-state parties including over 1,000 cities, have made net zero commitments.
- Government regulations and incentives are on the rise, as evidenced by the EU Taxonomy Regulation and the U.S. Inflation Reduction Act.
- Greater transparency for investors has led to standardised reporting as defined by the Task Force on Climate-Related Financial Disclosure (TCFD).

Governments, corporations, nonprofits and civil society organisations are rising to the challenge of making net zero carbon commitments. The next step is to bring those pledges to life through high quality data analysis that helps building owners understand the GHG outcomes of design decisions. This same WLCA data can prove in the early stages that a project is on track to significantly reduce carbon emissions. This evidence can help to attract finance, ease regulatory compliance, and/or enhance an organisation's standing with the public.

Arup is part of the net zero carbon and WLCA adoption movement to help drive the transformation of the built environment with clients and collaborators around the world. The sections that follow describe some of the systemic change that we have had to consider.

Project: UTAS Forestry Building

The proposed redevelopment converts an existing Forestry building into a learning and teaching space for the University of Tasmania, a committed carbon neutral organization since 2016. The project has funding from Green Bonds that are linked to reductions in Upfront and Operational Carbon, elevating the need for detailed quantification.

The majority of the structure and the façade are already in place, representing significant savings in embodied carbon when compared with a new build equivalent. The project adopted an all-electric building services solution, a new timber framed roof, dematerialisation strategies, portland cement content reduction in concrete, low impact refrigerants, retained windows and facades, durra panel and hempcrete walls, and low impact carpets, flooring and acoustic insulation products.

With a client strongly focused on upfront carbon and circular economy, results were presented per discipline, demonstrating the value that each could bring to the project, rather than just stopping with the obvious benefits of an existing building and the timber roof. A deep and detailed dataset was fully coordinated with the project team, including rarer inclusions such as audiovisual systems and furniture, creating the reference thresholds for performance to protect the design during future value engineering exercises during construction.. With ambiguous criteria of success for the Green Bonds and other rating systems, extra rounds of analyses proved positive compliance against differing interpretations of boundaries and targets, ultimately allowing the client to manage risk and uncertainty,while improving credibility with the funder.

2023 Arup Carbon Transformation Award Winner:

– Judges Highly Commended Project

– Best data

– Notable mention for pushing boundaries of embodied carbon

The amount of new gross floor area within Arup's portfolio that will be completed in 2030 is substantial and will require attention now during design phases to ensure that it is on track with the UN 2030 Breakthrough targets.

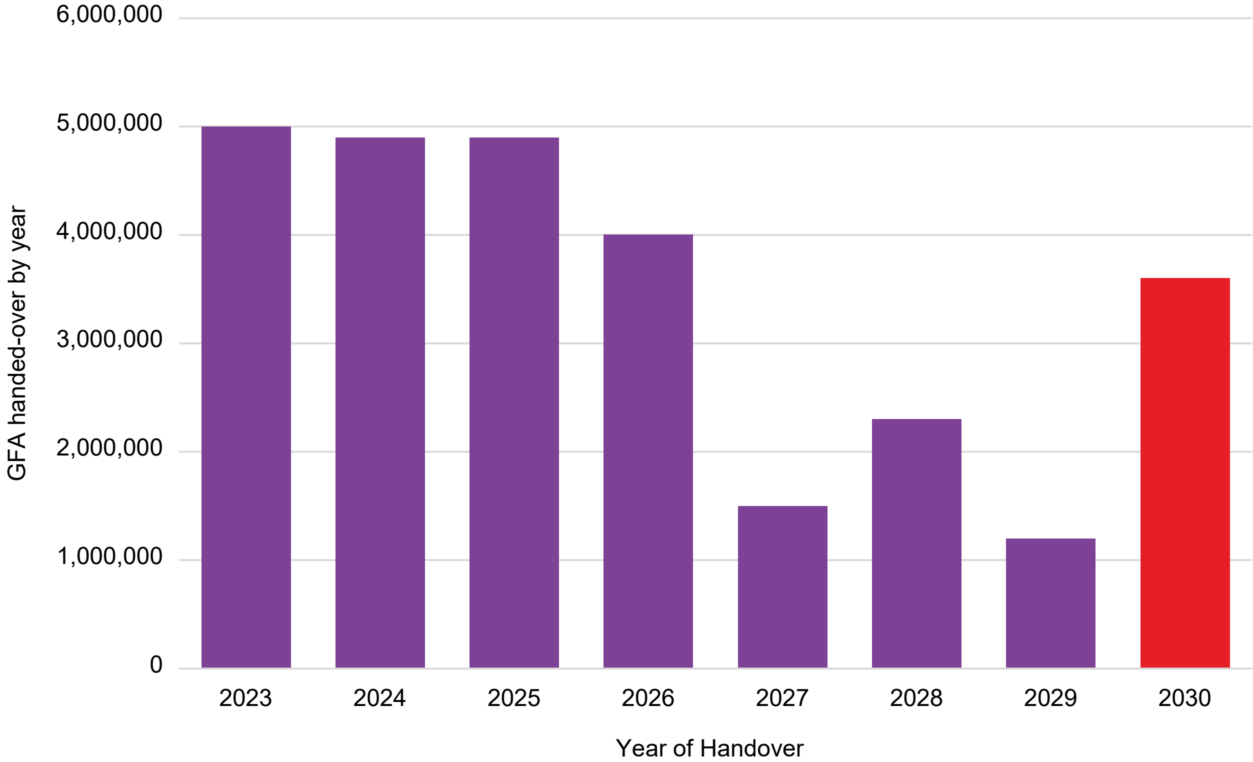

Figure 5. Gross Floor Area anticipated to complete construction per year from Arup's buildings design portfolio

Figure 6. Number of assets reported

2030 projects trending towards UN Breakthrough target but not reaching it yet.

Average GHG reductions of 40% in 2030 are apparent, with the majority of savings arising from the decarbonisation of the electricity grid. Net zero operational performance is not widespread in terms of recorded client commitment to renewable energy. Embodied carbon appears to be reducing, primarily from design decisions as opposed to predicted improvement in supply chain emissions. At the moment, environmental product declarations (EPDs) reporting material and product lifecycle carbon factors are fixed values associated with the year of reporting. With the exception of limited lines of net zero branded products already available, few manufacturers publish predictive decarbonisation trajectories for the emissions of their future products based on the companies' own fuel source decarbonisation pathways. Design teams could better predict further emission reductions if they were able to account for lower emissions associated with later procurement from the materials supply chain.

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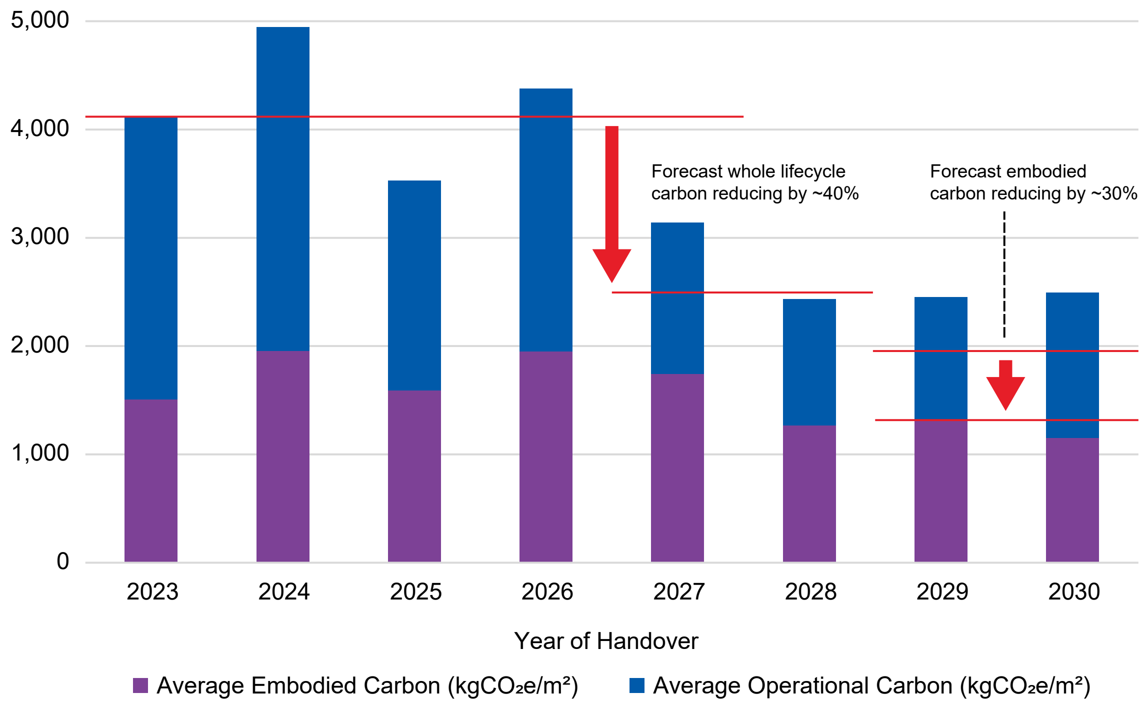

Figure 7. Forecasted Whole Life Carbon emissions reducing but not meeting UN Breakthrough Goal

Arup Working at Global Scale

Our starting point

When Arup committed, at COP26, to undertake WLCAs for all of its new and retrofit buildings projects, our project teams did not generally make whole life carbon assessments unless required by contract or by regulation. Our sustainability teams carried out WLCAs on projects for a small but growing minority of our clients with net zero carbon commitments. In addition, some early-adopting communities of practice within the company were carrying out assessments of their designs to add carbon performance to their understanding of best practice.

Structural	Public Health	Building Envelope	Decarbonisation & Sustainability
Fire Life Safety	Acoustics/AV	Lighting	Energy
Mechanical	ICT	Building Performance	
Electrical	Security	Architecture	

These calculations followed different methodologies and were being carried out to different regional standards or guidance, different levels of granularity and different trades to include, with building elements being grouped differently – depending on different software architectures. This is because there is not a common global standardised approach to GHG calculation and reporting in the building sector.

Moreover, digitally storing project-level reference data and calculation files in project folder structures created data silos, hindering our ability to leverage our global reach. Until the WLC initiative, there was no central database for standardising the collection of the detailed outcomes of design calculations across projects to make GHG metrics comparable.

Figure 8. Arup's Carbon Futures Workshop, London, March 2023

First steps

The first priority of the transformation programme was to set our goals.

1. Calculate the lifetime emissions of projects that complete construction each year, in order to compare them with our annual corporate operational carbon footprint, and to track trends in the emissions from our professional services.
2. Collect consistent, comparable data based on specific construction elements within procurement categories in order to link WLC emissions to a design decision made by a designer with trade- or discipline-specific expertise.
3. Analyse data to identify trends between design choices and WLC outcomes.
4. Create a database of carbon emissions in projects representing 90% of our buildings design revenue for the year.
5. Build a platform so simple and quick to use that project teams will want to use it in the early estimation phase.
6. Collate the results of single projects in a multidisciplinary database to allow comparisons and the discernment of trends by building type and system type.

Our starting point was to understand how Arup analysis teams around the world were approaching energy modelling and material lifecycle assessments (LCA). As a global multidisciplinary company, we engaged in our investigation effort subject matter experts (SMEs) from Arup's 14 buildings-related discipline-specific communities of practice to understand best practice in different countries.

The Whole Life Carbon initiative for buildings was led by a small group of representatives from each Arup region. This leadership team coordinated with an internal group of digital development and data science experts to create a data collection and visualisation platform called Zero.

It quickly became clear that we would benefit from collaborating across disciplines and regions to create a global data schema, a centralised repository of vetted reference data, and a common user interface for data collection. This would enable us to perform WLCAs across the world, to improve the speed and efficiency of our analyses, and to reduce the contractual risks associated with carbon estimates.

During the first year, an embodied carbon subcommittee led by LCA SMEs worked with the global communities of practice to collate emission calculation methods, material data reference sources, and any published benchmarks for historical emissions in each discipline.

An operational carbon committee incorporating energy modelling and sustainability SMEs similarly provided benchmarks on prevalent energy use intensity, utility carbon factors, and electrical grid decarbonisation trajectories. It also performed mass energy analysis of nine primary building types under a variety of design criteria to produce a set of mathematical functions that provide a building energy use estimate with only 14 user-provided design inputs.

Track trends in the emissions from our professional services.

Collect consistent, comparable data based on specific construction elements within procurement categories in order to link WLC emissions to a design decision.

Identify trends between design choices and WLC outcomes.

Collate the results of single projects in a multidisciplinary database to allow comparisons and the discernment of trends by building type and system type.

Collaborating across disciplines and regions to create a global data schema, a centralised repository of vetted reference data, and a common user interface for data collection... would enable us to perform WLCAs across the world, to improve the speed and efficiency of our analyses, and to reduce the contractual risks associated with carbon estimates.

Another committee was responsible for developing training and determining what other metadata, beyond lifecycle carbon emission characteristics, was needed to allow sorting and comparison in the future.

A fourth committee identified research priorities for influencing emissions throughout the value chain, whether by comparing effectiveness in net zero policy trends in city planning or the credibility of new developments in low-carbon materials.

A fifth committee gathered global stories of net zero case studies and service offerings, working closely with our business development teams to integrate them with information that meets client needs.

The first data collection campaign started seven months after the COP26 announcement.

In the first year, data collection was supported by over 150 regional skills coaches who helped project teams navigate their introduction to Zero, as well as to the concepts and elements of WLCA calculations. We accepted minimal input during the first year, to seed the database with benchmark data for each contracted discipline across the breadth of the buildings portfolio.

Improving the data

While continuing with regional skills coaches, in the second year the campaign focused on improving data quality by offering more pre-set material, product and assembly carbon factor data from the library in each discipline. It also engaged regional leaders in identifying projects where teams were still actively accessing the needed information.

SMEs focused on the quality of reference data sources and on an exercise to map the methodologies and tools used by Arup in LCA and energy modelling. Much to the surprise of the corporate digital technology team, more than 150 tools were being used on WLCA-related tasks. They ranged from spreadsheets to bespoke scripts and datasets embedded in other analysis tools, to methodologies integrated with building information models. Stakeholder engagement resulted in a commitment to focus on common workflows using a dozen third-party WLCA-related tools in order to normalise methodologies, improve efficiency, and reduce errors.

Reflections

The first two years were an investment in the process and digital transformation that enabled the action needed to achieve our objectives. The campaign helped improve awareness around net zero best practice – and WLCAs in particular. The WLC leadership team said that we were having to build the car while moving at high speed around the race track.

Year upon year, we have learned from successes and unfulfilled ambitions. We are sharing them now as we all continue to engage in the global Race to Zero.

Determin[e] what other metadata, beyond lifecycle carbon emission characteristics, was needed to allow sorting and comparison in the future.

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We were having to build the car while moving at high speed around the race track.

A Unified Plan for High-Quality Harmonised Carbon Data

To perform WLCAs at scale, our transformation needs to extend deep into the organisation through our projects, in learning for members, and in data management across the integrated digital ecosystem.

One of the most challenging aspects of our WLCA exercise has been the all-encompassing nature of our ambition: to engage our building designers on all stages of all building projects. This involves moving from sustainability enthusiasts promoting WLCA to the 'democratisation' of its adoption to achieve carbon insights with every client on every project in every discipline responsible for material or energy use.

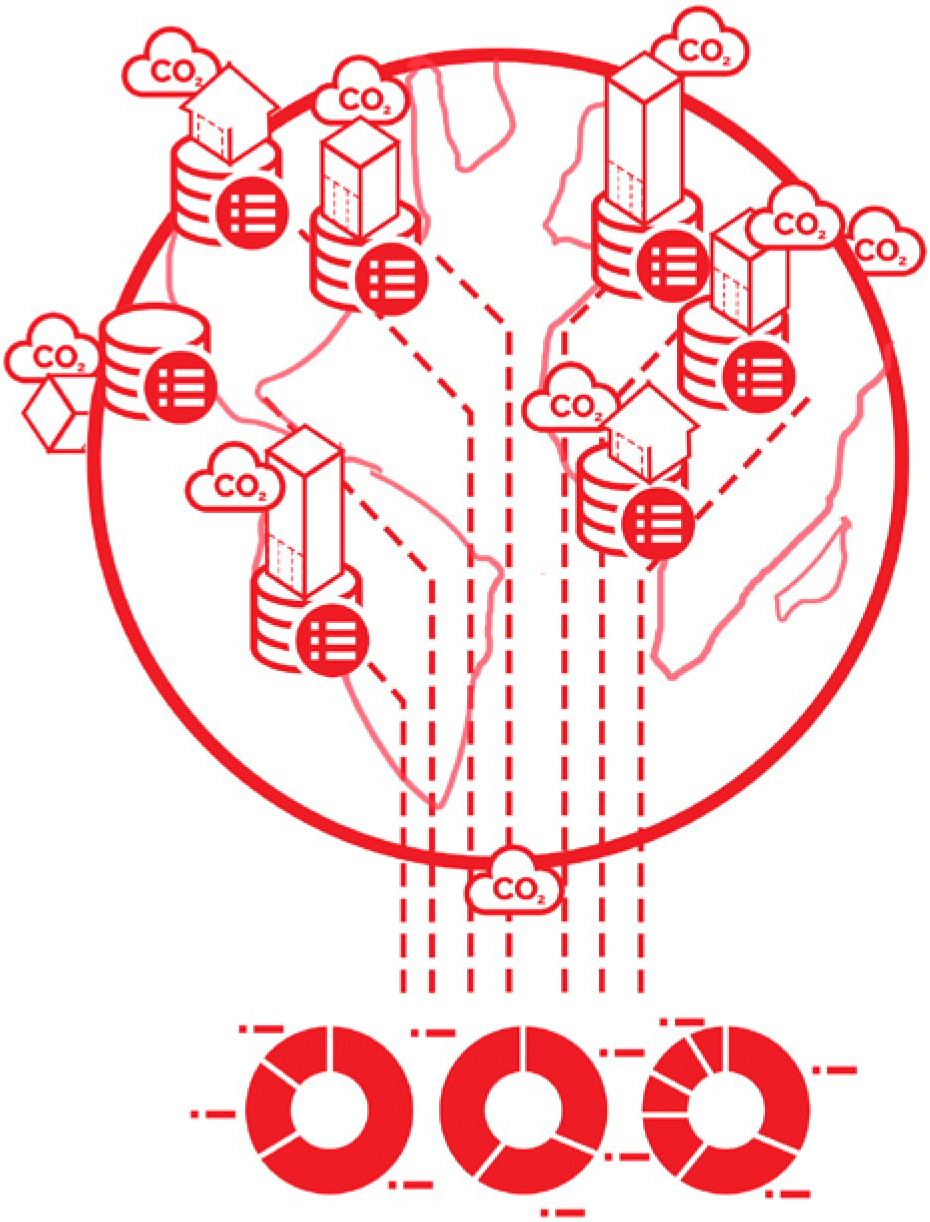

Figure 9. Harnessing and harmonising global data

While we sought to maximise participation from the outset, it was also important for the leaders of the WLC initiative to build the digital infrastructure that could mature into a process embedding accuracy, consistency and completeness.

This would enable us to meet the rigour of environmental, social and governance (ESG) reporting standards – the gold standard of measurement, improvement and reporting. Our clients require data reliability, and Arup's own ESG reporting is likely to include the emissions of our design outcomes, eventually.

For these reasons, the focus of the first two years has been on putting in place processes to support the creation of a gold-standard digital process, in the knowledge that much more work with the design teams and global value chain partners will be necessary to achieve trust and credibility at scale.

A unified plan for high-quality harmonised data

Our first goal was to create a unified plan for collecting and storing project GHG data in a consistent format and in a common location. This decision produced clear business benefits. For instance, one team's effort in finding valid reference data for material carbon factors could be shared with others to reduce the cost of research for all subsequent analyses. Also, once a project team has calculated the emissions for its structural system, the project manager can compare those results to similar projects around the world. The goal is to have a pathway towards high-quality data, with the ultimate goal of achieving accessibility and transparency for learning and interrogation purposes.

The diagram below shows the key steps of our unified action plan for harmonised data. While the steps are shown sequentially, steps 1 through 4 were developed in parallel.

Build the digital infrastructure that could mature into a process embedding accuracy, consistency and completeness.

Meet the rigour of Environmental, Social and Governance (ESG) reporting standards – the gold standard of measurement, improvement and reporting. Our clients require data reliability...

Much more work with the design teams and global value chain partners will be necessary to achieve trust and credibility at scale.

Create a unified plan for collecting and storing project GHG data in a consistent format and in a common location.

Have a pathway towards high-quality data, with the ultimate goal of achieving accessibility and transparency for learning and interrogation purposes.

Standardise
Create a uniform global data structure for operational and embodied emissions

Global & Local
Create a reference database to support nationally relevant carbon assessments

Capture & Store
Create a digital platform to collect and store data in a way that allows tracing and retrieval at any time, to monitor how design impacts evolve

Learning
Promote the engagement of more than 7,000 members globally

Report & Share
Provide continual review, analytics, insights, reporting and sharing analytics, insights, reporting and sharing

Figure 10. Arup's approach to harmonising WLCA data.

Standardise the data structure

Step 1 consisted in standardising a building taxonomy and carbon data schema that are aligned to procurement categories, allowing all of Arup's WLCAs to be captured in a common data structure. This resulted in a standard way of defining a building's function(s) – and whether its design is for core-and-shell and/or interior tenant improvements, and newly built or a refurbishment. Having established what the building is, the schema then accommodated data capture by lifecycle stage for seven major building systems (substructure, superstructure, mechanical, electrical, public health, building envelope, interiors). Within this framework, we introduced a deeper categorisation through 26 associated subsystems to better link the choice of subsystem with its emissions, and designers to their carbon-related responsibilities.

The data structure allows any contracted discipline to independently enter data about its design without having to represent an entire building – it is rare for Arup to cover all design scopes in a single project.

Benchmark data for other disciplines is available to project teams to understand the relative contribution of Arup disciplines to the whole, but the emissions in uncontracted scopes are not attributed to Arup's professional practice. This approach allows users to interrogate their own project results to identify high-emitting subsystems for priority action while they input the information.

After submission, the data is available in the analytics platform, where a project team can compare its performance to peers and each discipline's community of practice can have data stored by subsystem for comparative analysis.

This taxonomy aligns with the prevailing alternative taxonomies, including RICS WLCA and cost taxonomies, OmniClass cost structures, EU Level(s), London Plan Guidance, Dutch MPG requirements, LEED Core and Shell. This allows calculations performed for those schemes to be translated directly into the Arup results database.

This global GHG reporting data schema has created a single place to capture carbon (and other) information on all our building projects at different levels of granularity, allowing us to:

1. Systematically assess our own data for risk management, future ESG reporting and internal knowledge development.
2. Support Arup's efforts to collate information in a standardised way so that teams can share knowledge, experience and insights.
3. Meet client- or project-specific requirements on how to visualise information.
4. Participate in regional sustainability initiatives such as the Building Embodied Carbon Database (BECD) in the UK or SE2050 in the Americas.

Standardising a building taxonomy... resulted in... defining a building's function(s)– and whether its design is for core-and-shell and/or interior tenant improvements, and newly built or a refurbishment.

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The data schema has been successfully applied for two years and now features 31 subsystems, after some were added during the second year in response to requests from the design teams. The discipline-specific structure and digital aggregating platform allow discipline experts on a project team to share the time burden of WLCA calculation. This puts the design experts in charge of their own carbon calculations and reporting. LCA SMEs of the past often had to rely on their own interpretation of drawings and a cost model's Bill of Materials (BoM) to obtain material quantities.

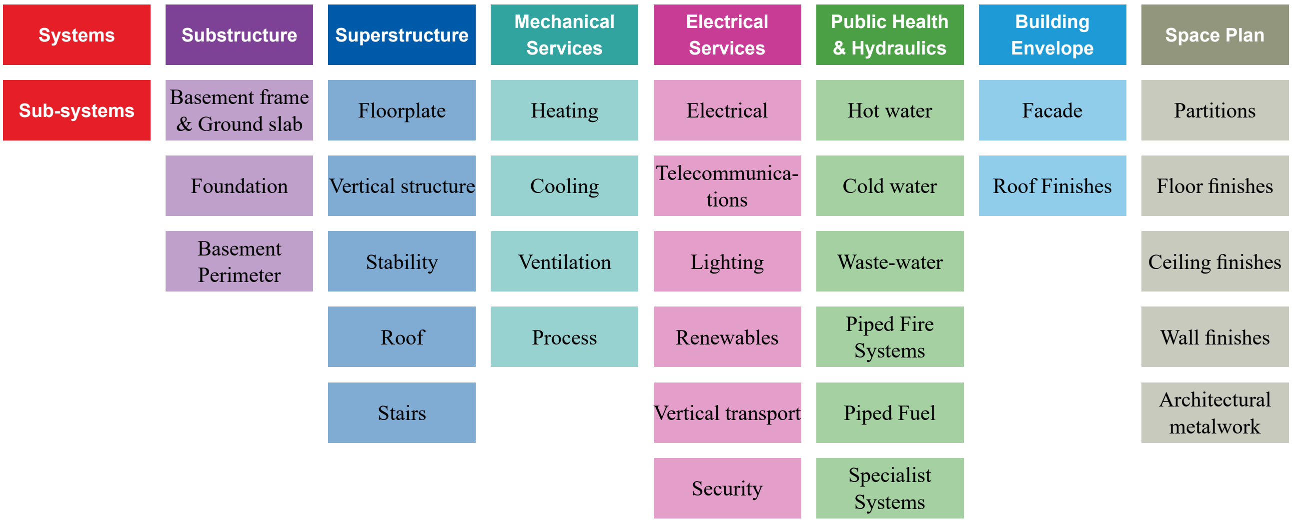

Figure 11. Arup Zero Building Scope Taxonomy

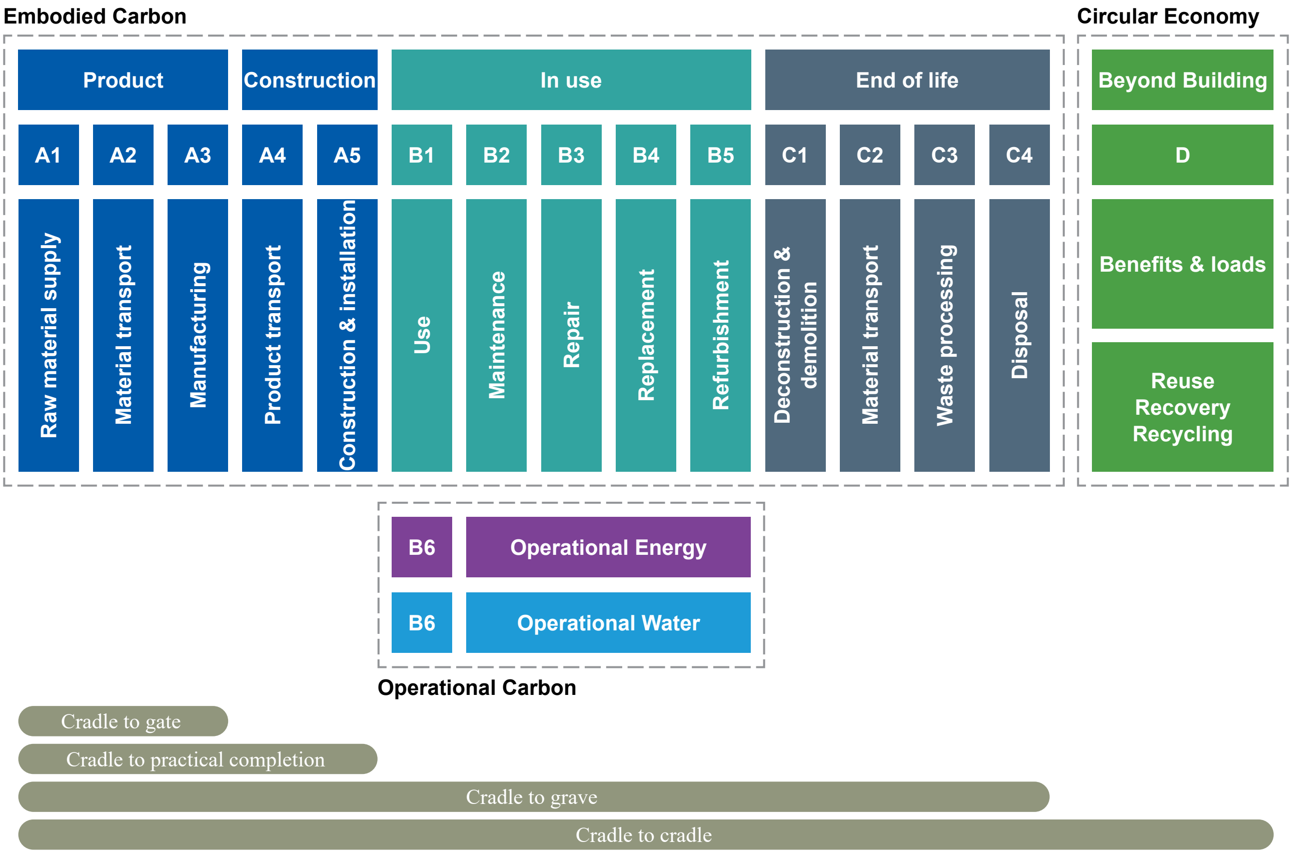

Figure 12. Mapping whole life carbon by building life cycle stage

Project: Dalkeith Road (Commercial)

This project is a deep retrofit of a historically listed 1970s office building stripped back to its original shell and adapted to become a more efficient commercial space. Taking a multidisciplinary design approach, the goal was to adopt the best package of sustainable solutions available, with aspirations for credentials across multiple green rating systems (including BREEAM, NABERS & WELL).

Beginning with a goal of retaining as much of the original structure as possible, the design team presented a mixture of structural and MEP carbon reduction strategies. Where new structure was required, we explored proposals for reduced material use, cement replacements, timber, and selective demolition for reuse of concrete or repurposing of steel. The MEP systems included generating electricity through the rooftop solar panels and designing a fossil fuel-free heating/cooling system for the building. All services are exposed, with no ceilings to mitigate further material embodied carbon.

WLCA sensitivity analyses of the net multidisciplinary carbon emissions status of each low-carbon proposal enabled us to identify the right package to move forward with strong support. Evidence in hand, the client was able to successfully present a very efficient and low-carbon retrofit project to the city planners and the heritage advocacy community. As the original structural design firm for the building, Arup is pleased that a new generation of designers have helped upgrade the empty property and bring it to new life as a highly desirable, sustainable grade-A offering.

2023 Arup Carbon Transformation Award Winner:
- Grand Champion
- Best in category
- Best in creating value
- Best in pushing boundaries of embodied carbon

The vital role of grid decarbonisation

Even without the facility within Zero to accommodate for future electrification to replace gas fuel sources, substantial reduction in total operational carbon emissions is apparent when global grid decarbonisation trajectories are applied. Design teams should therefore move to all-electric or electric-ready solutions and encourage clients to have a renewables procurement strategy in their capital plans and operational budgets.

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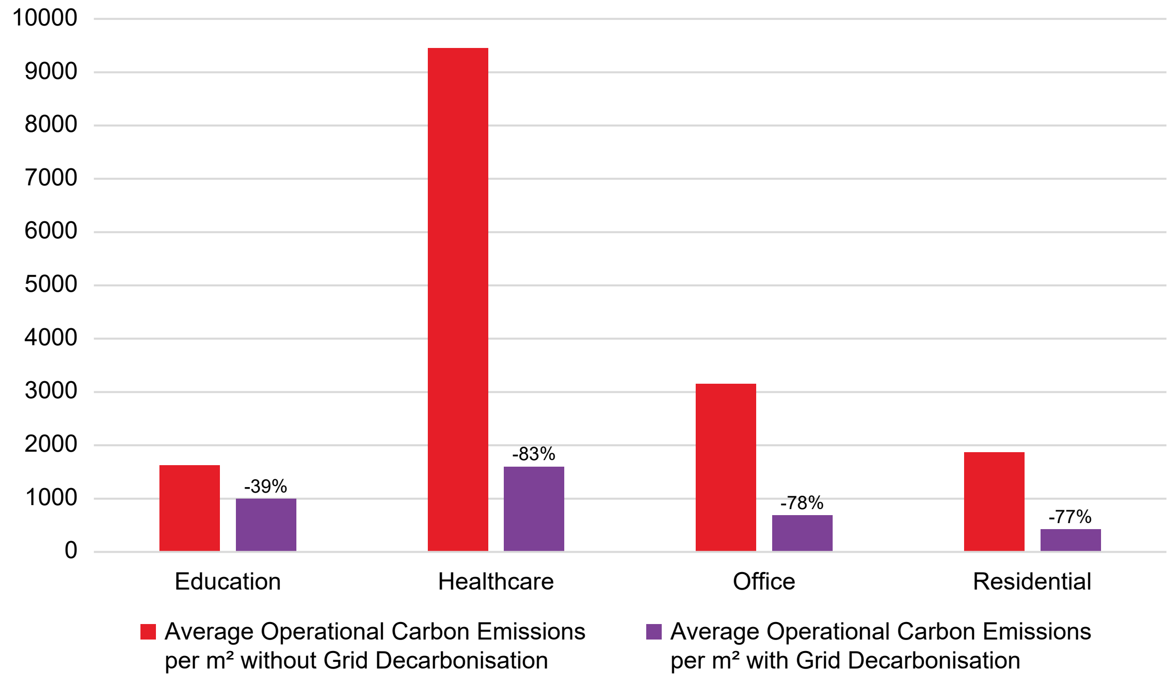

Figure 13. Influence of electricity grid decarbonisation on operational carbon

For mechanical, electrical and public health (MEP) systems, as operational carbon emissions decline due to grid decarbonisation, the challenge of embodied carbon looms larger

Embodied carbon as a performance metric will have increasing prominence in MEP system selection as grids decarbonise. MEP equipment manufacturers will have to be transparent with the embodied carbon factors across all product classes and sizes in order to inform system design selections.

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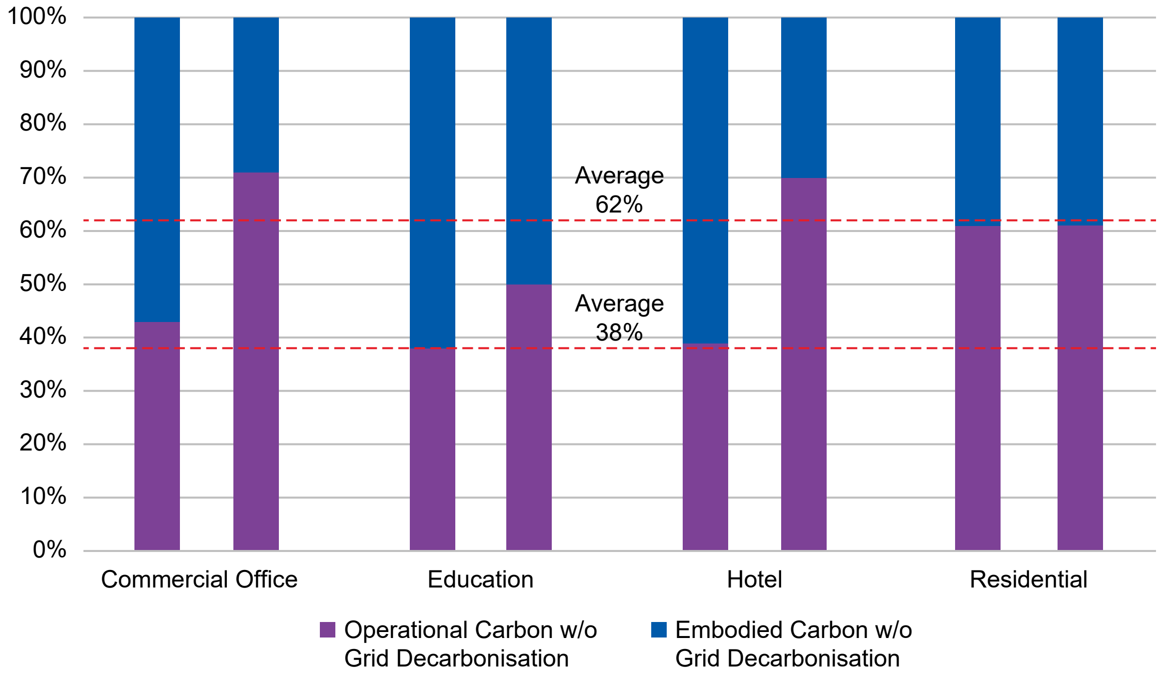

Figure 14. Grid decarbonization triggers the rise of influence of embodied carbon for MEP equipment

Globalise to localise the carbon reference data

Step 2 was to engage the discipline SMEs to canvas their global counterparts to vet and consolidate carbon reference data in a common structured location for materials, products, assemblies, utilities and building benchmarks.

Embodied carbon

For embodied carbon, the way the reference data for materials is structured allows the SMEs to pre-process it for designers to use during the early stages of a project. It is good digital practice to have a single source of truth, but we had to grapple with the reality that carbon emissions for the same kilowatt-hours (kWh) of energy or the same material are different depending on where you are building or where your materials are manufactured.

In the second year, Arup's material reference data database adopted a hierarchical structure in an attempt to reduce redundancy and improve long-term data management. The rationale is as follows:

1. Materials typically have an environmental product declaration (EPD) that may differ around the world.
2. When an EPD is not available, materials and quantities can be used to define manufactured products.
3. Materials and products – and their respective quantities – can be combined to make up assemblies.
4. Because material and product quantities are associated with the assembly's design function, they are agnostic to the carbon emissions of their components.
5. Representative products and typical assemblies reflecting design choices can be assessed on the basis of past design work and used in the early phases of a project to estimate quantities.
6. For early-phase design, a set of assemblies and products can be selected to represent a design intent without knowing its carbon emissions.

Materials are the basic building blocks of any system and will have a carbon footprint directly related to their production.

Products (manufactured items) are entities produced in a factory. In most cases, information on their carbon footprint is provided by manufacturers. If not, it can be calculated based on their material build-up.

Assemblies are generalised building components made up from quantities of products and/or materials. They provide a reference point for the carbon footprint of a component depending on the region, asset properties and construction date.

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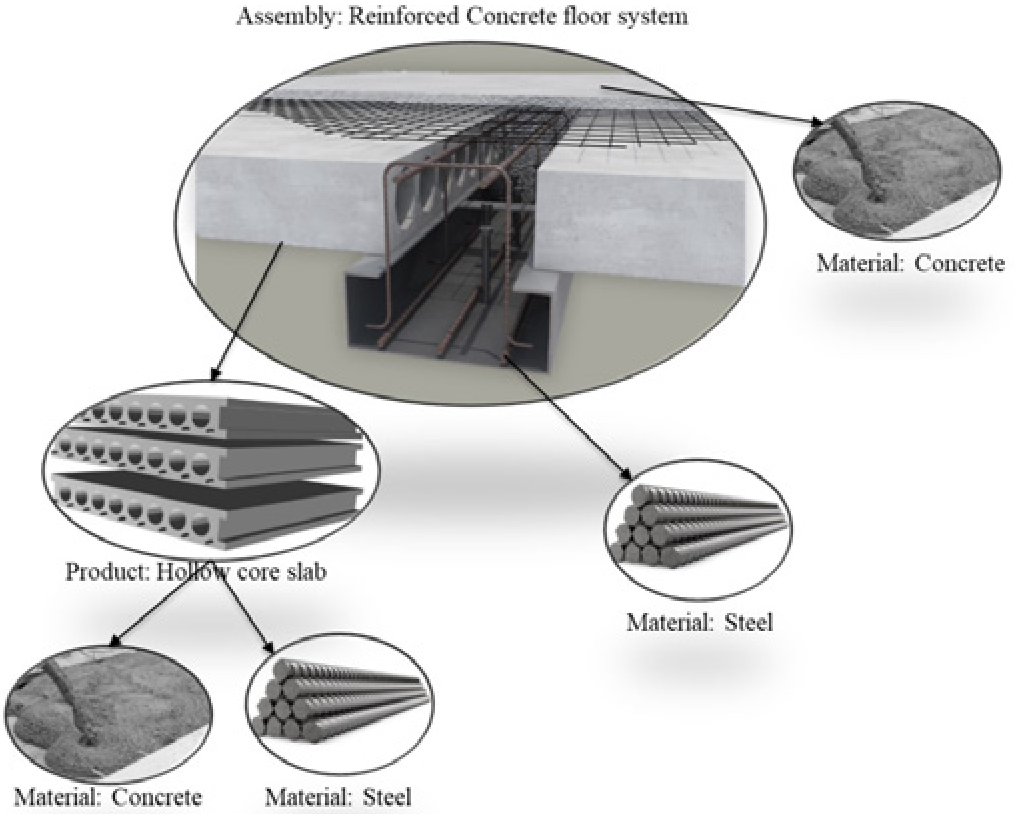

Figure 15. Hierarchy of material carbon information stored in reference database

The assembly quantities are digitally stored independently from the carbon emissions associated with their sub-elements, using an algorithm that calculates aggregated emissions for the unique geography requested.

There are several benefits to this approach:

1. It makes it easier to localise data without recreating quantities, as the same assemblies are re-run for the material factors and assumptions appropriate to the relevant geography.
2. It records the process of assembly build-up and makes it transparent. Educated users can dig into the aggregated assembly to discern the specific materials and product types, and quantities used.
3. It makes it simple for discipline users to add new assemblies. In fact, an 'assembly builder' digital tool was provided for this purpose and used during the collection campaigns to create new assemblies at the request of designers.
4. As the tool will continue to be used in the future, this approach will make it simpler to understand changes – whether they relate to discipline developments, availability of new or different products, changes in carbon calculation methodology, or changes in carbon factors and assumptions.
5. It provides a reasonably comprehensive library of concept/scheme-level carbon emissions information, collating in one multi-disciplinary space information previously held in separate design guides by each community of practice.

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Record the process of assembly build-up and make it transparent.

Provide a reasonably comprehensive library of concept/scheme-level carbon emissions information, collating in one multi-disciplinary space information previously held in separate design guides by each community of practice.

Operational carbon

Another example of the power of the global SMEs was the data gathering exercise for a comprehensive database of published decarbonisation pathways of electricity grids across the world, compared to 2019 UNFCCC emissions data by country. This database allows project teams to anticipate operational emissions savings derived from external sources when considering investment decisions during design. Again, the centralised exercise allows project teams to focus on the quality of their energy modelling, while the digital platform sources the carbon factors appropriate to the project location.

Anticipate operational emissions savings derived from external sources when considering investment decisions during design.

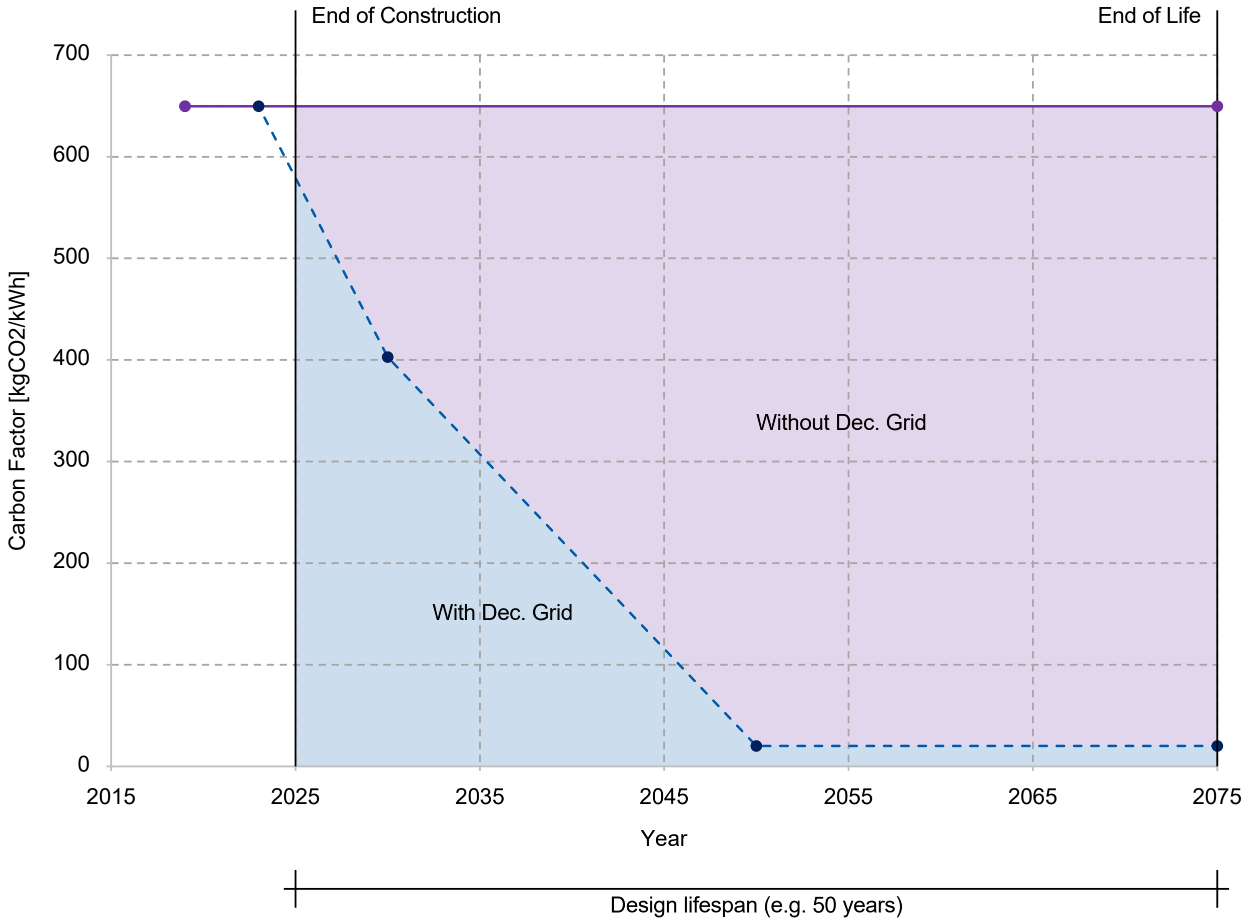


Figure 16. Anticipated decarbonization pathway for electricity for an asset completing construction in Germany in 2025

Using digital technology to capture and store data

– Step 3 focused on creating the digital architecture to manage all of the newly generated WLCA data to support the goals of reporting and sharing. Because Arup's interest is to gather data on carbon emissions over which it has influence, the data collection covered Arup-contracted disciplines on active projects in design or under construction. The digital infrastructure to capture WLCA data had to accommodate anything ranging from a single design to a multi-asset campus.

– Arup created a suite of digital products under the name of Zero. The scalable modular approach of the Zero software architecture has the following components:

– The Zero platform user interface for simultaneous multi-user data entry and viewing of project-level results.

– The Veracity carbon factor reference database, which includes items such as carbon emission factors by geography for materials, products and assemblies; collated benchmarks by discipline; electricity grid emissions inclusive of published decarbonisation pathways.

– The building/project information database, with user inputs for all assets and access permissions.

– The carbon emissions database with results by lifecycle stage within each system or subsystem, as applicable.

– The Zero analytics user interface for viewing aggregated results.

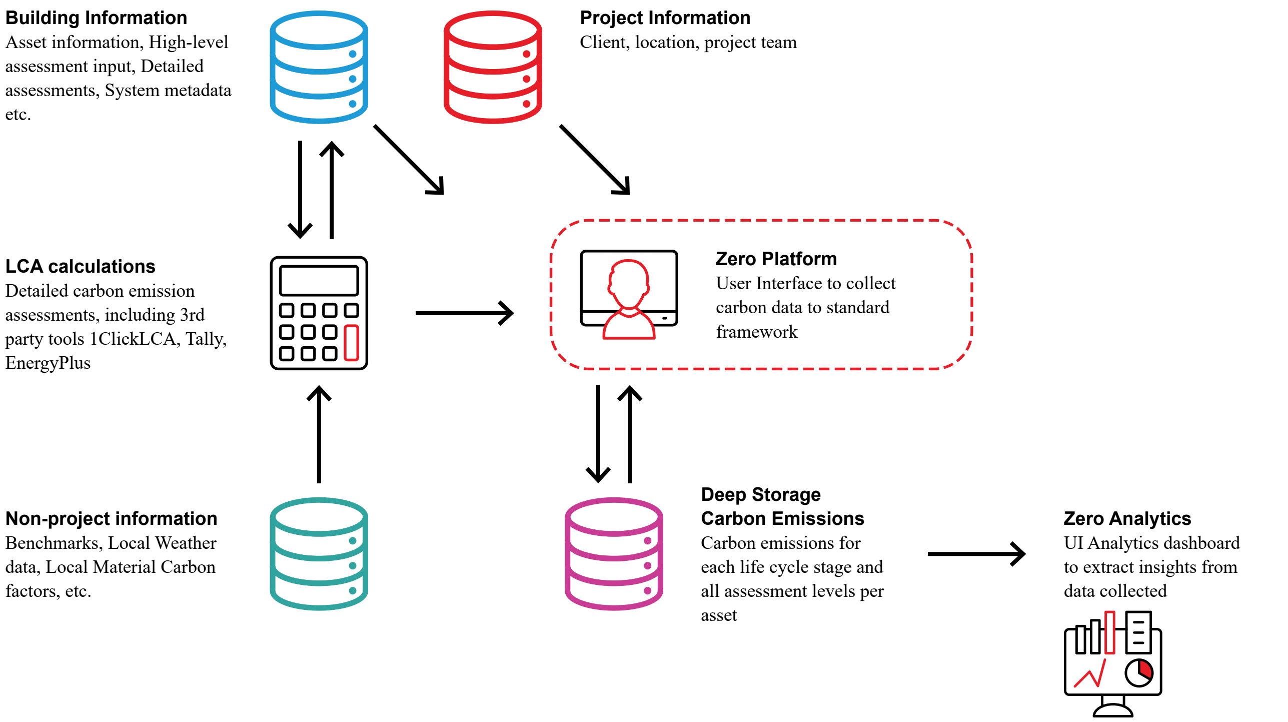


Figure 17. The Zero suite of digital products

Zero is a data collection and collation platform. It does not execute detailed LCA or energy modelling calculations unique to a project. It can only pull information from the databases that the SMEs have created to deliver benchmarks or to pair carbon factors with assemblies, materials, products or fuel use – based on the user input for each building location. At the detailed data entry level, it can structure how data is displayed to match the standard reporting format of each construction category and lifecycle stage.

After two years of data collection, the WLC initiative's leadership and the SMEs recognize that the manual manipulation of design data to obtain quantities and material values continues to hamper adoption of WLCAs.

A recent workshop mapped the 'ideal' workflow from building information model (BIM) through analysis prior to data entry in Zero. It found that it is necessary to enrich data beyond the raw information currently stored in models. Arup intends to build upon its existing global BIM data taxonomy to ensure that access to significant metadata (information about the data) is retained during the data handling processes as information passes through multiple software applications, databases, and visualisation packages.

One insight was that a key cost of WLCAs is the production of a trustworthy and complete Bill of Materials (BoM) from BIM across multiple disciplines. In an ideal automated workflow, systemic digitalisation of the measurement and export processes can deliver efficiencies and better consistency, especially if materials can be cross-referenced to the central database to retrieve their carbon factors. Efforts continue to be made to look at the potential of automation, including conversations with non-profit organisations, software and BIM partners, as well as like-minded collaborators, given that this is an industry-wide barrier.

Structure how data is displayed to match the standard reporting format of each construction category and lifecycle stage.

The manual manipulation of design data to obtain quantities and material values continues to hamper adoption of WLCAs.

Ensure that access to significant metadata (information about the data) is retained during the data handling processes as information passes through multiple softwares, databases, and visualisation packages.

A key cost of WLCAs is the production of a trustworthy and complete Bill of Materials (BoM) from BIM across multiple disciplines.

Systemic digitalisation of the measurement and export processes can deliver efficiencies and better consistency...

Figure 18. Arup's Carbon Futures Workshop, London, October 2023

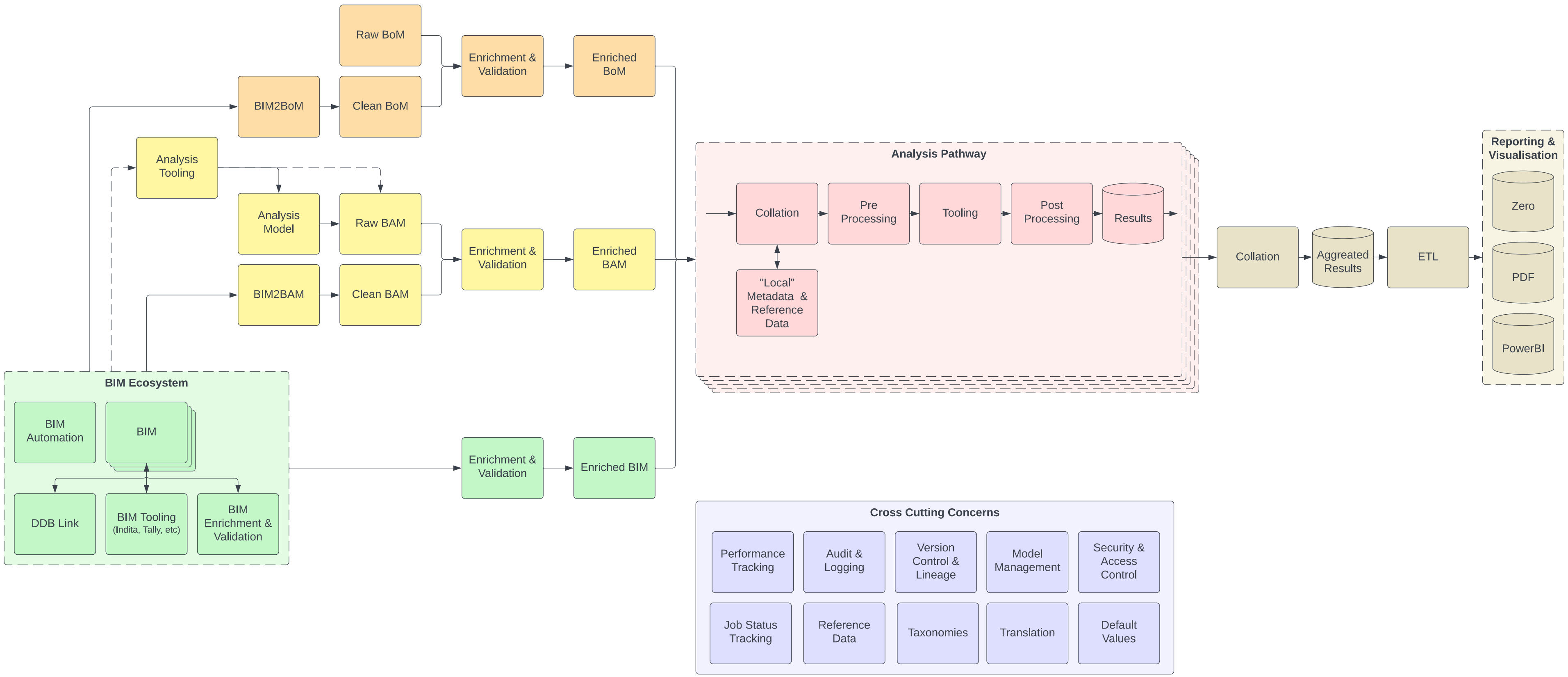


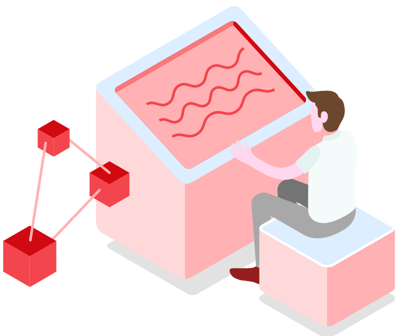
Figure 19. Idealized WLCA common BIM to BoM and analysis workflows

Data resolution appropriate to project evolution

A key feature in the development of Zero was the ability to accommodate progressive stages of design and the improvement of data resolution to account for project evolution. This would create the conditions for every project team with an eligible design project to participate – even during the first year – under the principle of 'learning by doing'. It would also chart a path for the improvement of carbon data quality in individual disciplines as design decisions were agreed with the client.

Data is collected via one or more of the three interrelated layers of granularity:

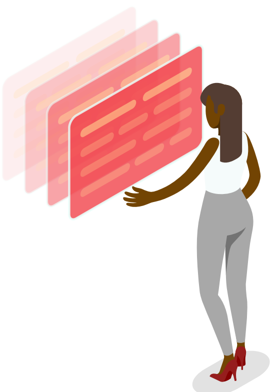
Accommodate progressive stages of design and the improvement of data resolution to account for project evolution.



Level 0: Benchmark Mapping

Carbon benchmarks are rates of emission per square metre which Arup's sustainability experts consider to be the minimum achievable for assets and systems by region, sector and discipline.

In Zero, benchmarks are automatically mapped against the gross floor area of any added asset to provide a view on what good looks like.



Level 1: High level Assessment

High-level assessments result from applying recommended values for products, materials and utilities against asset design information. They provide a target of what should be achievable through a high-level assessment of an assembly, asset or system.

Level 2: Detailed Assessment

Zero allows users to upload the results of detailed lifecycle assessments completed by designers or consultants in verified tools at the end of a design phase.

By uploading these assessments, Zero allows Arup to achieve the data quality needed to improve the data tables within Level 0 and Level 1 for the next year.

Figure 20. Levels of WLCA assessment within Zero

The Zero platform allows project teams to:

1. Log estimates of carbon emissions at early phases based on minimal input.
2. Compare them to representative historical benchmarks.
3. Upload the post-processed results of detailed third-party energy models and Life Cycle Assessments derived from detailed construction documents, contractor submissions, or post-occupancy evaluation.

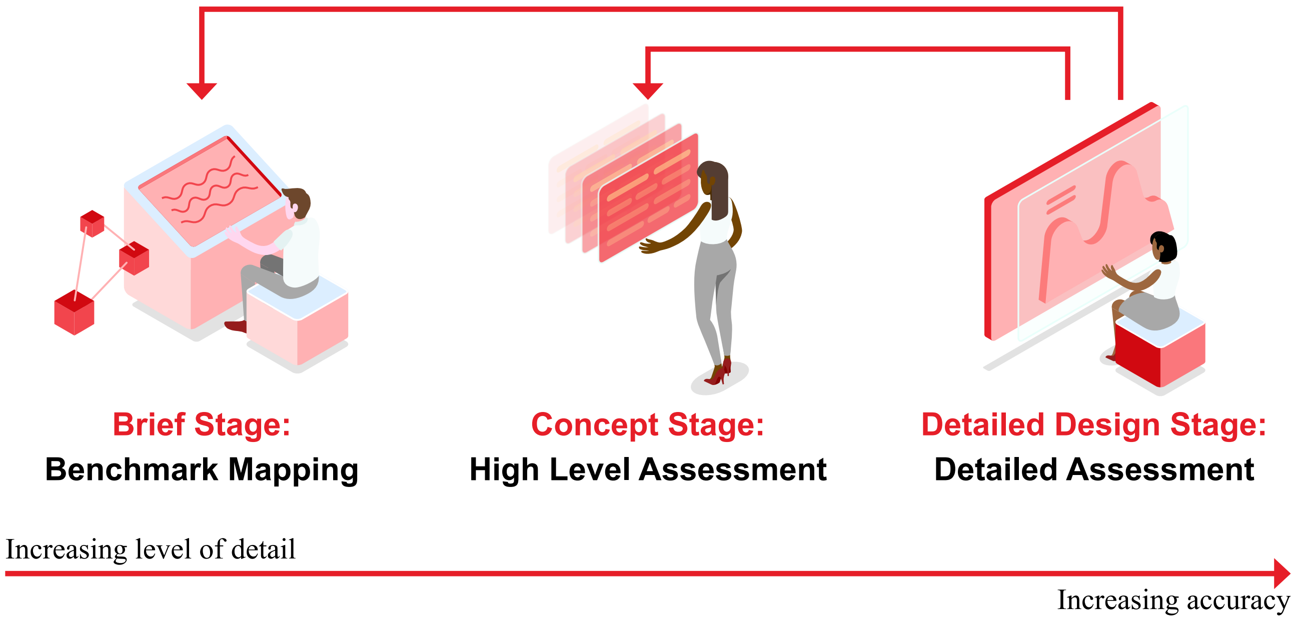


Figure 21. Harmonising data across design stages, with anticipated feedback loops for improvement of early phase estimation

Benchmarks for embodied carbon are primarily derived from the UK-based Low Energy Transformation Initiative (LETI) and London City information. Benchmarks for Operational Carbon derived from taking the output data from the American Society of Heating Refrigeration and Air-conditioning Engineers'(ASHRAE) Standard 90.1 template compliance models, created by the US Department of Energy (USDOE). These were scaled by climate zone and building type based on the US Energy Information Administration's 2018 Commercial Buildings Energy Consumption survey.

Functions representing the results of hundreds of parametric runs of the USDOE energy models were used to estimate energy performance for nine building types (Office, Warehouse, Retail, School, Restaurant, Hospital, Outpatient Health Care, Hotel, and Apartment). As all of these template energy models historically incorporated natural gas for heating, their usefulness in supporting all-electric outcomes is decreasing. Many projects already use energy modelling during early phases to inform design optimisation, so moving away from a bespoke level 1 operational carbon pathway and encouraging level 2 energy model pathways will support a more accurate representation of operational carbon in the future.

Over time, data analytics from detailed outputs will inform the carbon factor library used to generate estimates and set viable carbon targets, superseding historical benchmarks. Project data tagging allows cross-comparison by building function, geography, project development stage, new build vs alteration construction type, and disciplines involved.

Over time, data analytics from detailed outputs will inform the carbon factor library used to generate estimates and set viable carbon targets, superseding historical benchmarks.

Learning and community-building

Step 4 focused on education and awareness-building across the 7,000+ buildings-related designers within the firm to support the transformation of practice in order to make WLC calculations business-as-usual by the middle of the decade. Over the two years, central global sources provided online real-time learning and asynchronous training videos to introduce whole life carbon as an idea, as well as the steps to navigate Zero. Detailed modules were developed progressively to address the needs of:

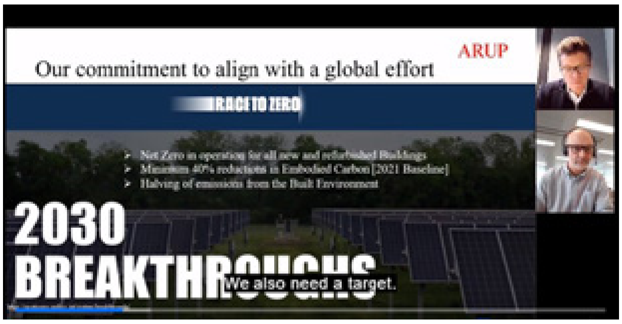


Figure 22. Image from UK training webinar, one of many conducted by WLC initiative leaders within thierhomes May-June 2023

- Regional Leaders, Project Directors and all participants in Zero
- Project Managers
- Technical Expert on Project Team
- Skills Coaches

Project managers assigned a team member per discipline to be responsible for uploading the data in Zero. This resulted in approximately 10% of buildings-related staff entering data in Zero.

Teams of SMEs in each discipline were activated in each region to act as 'skills coaches' to the project teams. These 150+ local coaches have been indispensable in helping colleagues new to WLCA navigate the information they needed to collect and how to process the data for the appropriate level in Zero.

Moving forward, the responsibility for overview training will transfer to the discipline communities of practice under the oversight of the Decarbonisation and Sustainability community of practice. Regions will have standing teams of skills coaches to support a rolling data collection process to increase the number of project-level participants performing WLCAs in future years. Now that a limited number of digital tools will be supported in the digital ecosystem, more expansive training on selected third-party tools will be pursued as appropriate to the geography or market needs. This will help move towards fully detailed assessments with the newer projects.

The buildings WLC effort represents the most significant systematic global collection of data on Arup's project designs. Leaders of parallel initiatives have already inquired on how to use the materials reference data store and project data collection structure to begin to gather information on other sustainability metrics such as water footprint, physical climate resilience risk, or aspects of circularity.

Arup Carbon Transformation Awards

Launched in conjunction with the 2023 data collection campaign, the Arup Carbon Transformation Awards (CTAs) recognise and celebrate those who are moving Arup forward towards our decarbonisation goals by reducing whole life carbon emissions to bring value to clients. The CTAs are an internal initiative to raise attention, promote best practice and identify and celebrate the best of the best, so Arup designers know what good really looks like.

Participants submitted WLCA information through Zero and answered a short questionnaire to capture the story of how the design team used the WLCA to reduce emissions for clients.

Winning entries (included in panels throughout this report) were featured in an awards webinar where they presented to over 150 peers. Top entries received a stipend to continue research, engage with industry-wide WLC standards initiatives, and attend conferences on net zero. The global grand prize winner presented to approximately 300 senior leaders at the Arup Group Annual Meeting.

Recognise and celebrate those who are moving . . . forward towards . . . decarbonisation goals by reducing whole life carbon emissions to bring value to clients.

Raise attention, promote best practice and identify and celebrate the best of the best, so . . . designers know what good really looks like.

The plan for reporting and sharing

Step 5 of the unified plan for high-quality data was reporting and sharing. This could only take place when data collection was completed. Most WLCA reporting schemas are commonly structured to report the emissions of a project across a standard set of lifecycle stages, which Zero is able to do for the detailed Level 2. To help project teams, Zero is also able to comparatively report a project's performance by system across each level for operational and embodied carbon.

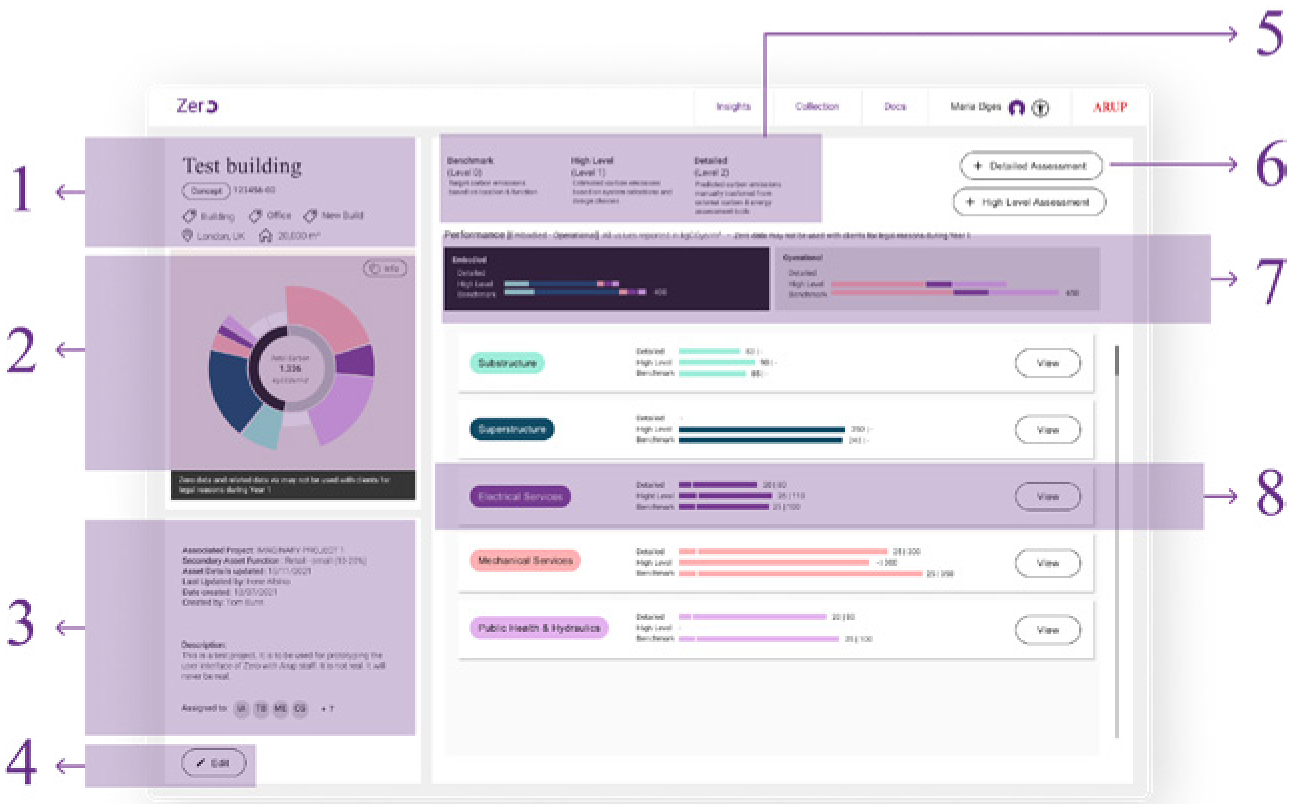


Figure 23. Zero project level results landing page

1. Asset Key Information 1

Essential asset information including asset title, work stage, associated job number, asset function, size, location.

2. Summary Donut

Displays the Asset Performance Summary for this asset. This is also visible on the My Collection page site.

3. Asset Key Information 2

Further asset information including dates of asset changes, description and responsible people.

4. Asset Edit

General asset information entered during asset creation can be updated via this 'Edit' button.

5. Level legend

Brief description of the different levels of assessment.

6. Upload data

Click here to upload High Level (Level 1) or Detailed (Level 2) Assessment data.

7. Asset Performance Summary

Overview of the estimated carbon emissions for this asset, displayed by embodied/operational, assessment level and system. The same information is in the diagram to the left of the page.

8. System Breakdown

Each system within Arup scope has an area like this. The estimated carbon emissions are displayed for each assessment level completed so far, split into embodied (left bar and number) and operational (right bar and number). This feeds into the Asset Performance Summary. To view this information, click the 'View' button on the right. In this asset example no detailed assessment of superstructure has been complete.

Process-level results from the first two years

The principles of a unified approach to Steps 1 to 4 meant that Arup was able to launch its first global data collection campaign seven months after the COP26 announcement. The second year's data collection period began in May 2023, with a future plan for converting to a rolling digital data collection at the end of each project stage.

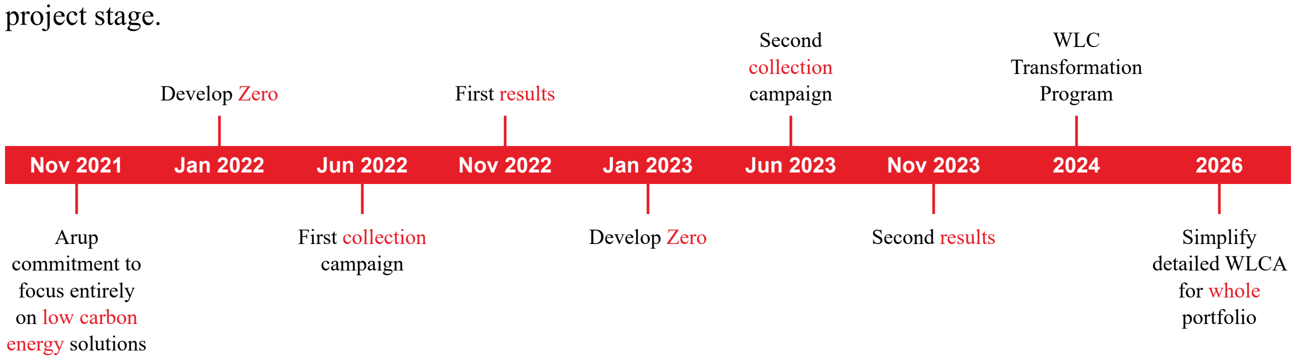


Figure 24. Timeline of Arup WLCA initiative

With the first two years of data, Arup has been able to compile information on over 1,000 projects, having more than 1,400 building assets in over 50 countries. The results database is able to note over 20 building typologies and take a whole building WLC approach with the breakdown of data by lifecycle stage across more than 20 subsystems.

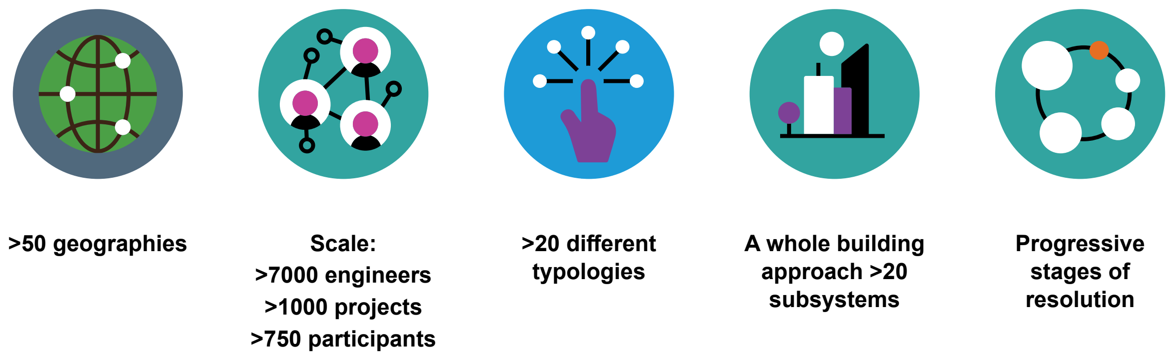


Figure 25. High level outputs of two years of WLCA data collection

One of the process insights is that the estimated whole life carbon emissions arising from Arup's building designs completing construction in 2023 is over 100 times greater than Arup's own carbon emissions for the year. As evidence of process improvement, the reporting this year included the prospect of grid decarbonisation, and is thus about one-third of the equivalent value estimated in 2022.

Clients will want to know the range of risks associated with reliance on grid decarbonisation when considering ESG future risks, the long-term costs of purchasing green energy or the opportunity costs of installing onsite renewables. However, when considering global data aggregation, many methodologies do not allow for this future grid decarbonisation benefit. This is a standardisation question to be resolved by industry.

Estimated whole life carbon emissions arising from Arup's building designs completing construction in 2023 is over 100 times greater than Arup's own operational carbon emissions for the year.

Clients will want to know the range of risks associated with reliance on grid decarbonisation when considering ESG future risks, the long-term costs of purchasing green energy or the opportunity costs of installing onsite renewables.

Another improvement to celebrate is the increase in both Level 1 and Level 2 data during the 2023 data collection campaign. Level 0 benchmarks were not accepted as a project's annual submission unless a project was just starting. Improvements to the carbon factor library content encouraged participants to supply more high-level assessments, bringing participation up to 80% of the eligible assets.

Adding the facility to upload data via a semi-automated spreadsheet helped to increase participation in the Level 2 detailed assessments during the second year. Within Zero, users can download an energy model or LCA spreadsheet template and manually fill in the spreadsheet with the standard export values from third-party energy modelling and LCA tools, tagging the data into the correct subsystem or energy use category. This allowed us to jump from 9% to 27% participation at the detailed assessment level for at least one discipline per asset.

There is still a data gap between our present level of participation and our aspiration for detailed WLCAs to be business as usual by 2026, but we acknowledge the progress across a multi-year transformation plan. We anticipate that upcoming automation workflows advocated in the industry will further support improvements at the detailed assessment level by ensuring easier pathways from BIM to BoM (Building Information Model to Bill of Materials).

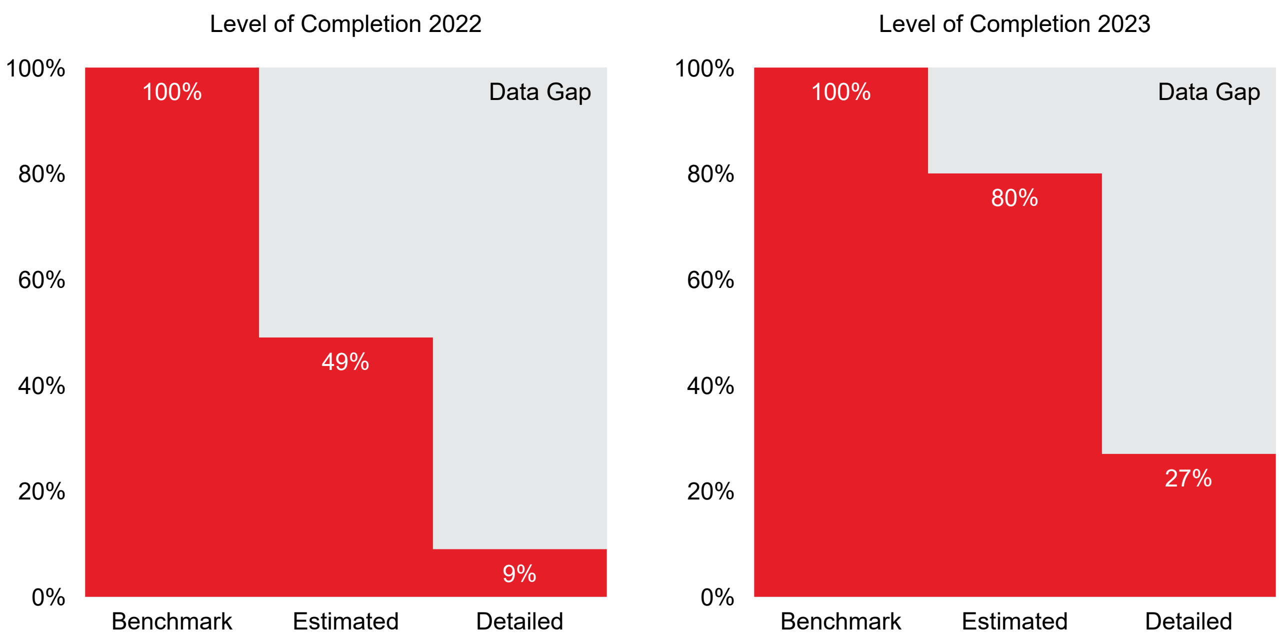


Figure 26. Data Gap has decreased during the second year of data collection, reflecting more design-specific information being entered into Zero

Data quality challenges

The data analytics process has been difficult. Much of the data analytics period after the close of the campaign was spent in 'cleansing' the data and removing errors or interrogating outliers. A review of the individual entries appears to reveal quantification errors in the easier early-phase path of the high-level assessments. As systems can be built from assemblies, products and raw material components, it is not always possible to associate the materials with a particular floor area or even a particular system type during SME review. We can only see outliers by looking at a variety of visualisations in the data analytics dashboard. The future use of algorithms within the dashboard can help to highlight the areas of concern through comparisons with peers at the building and discipline level, now that we have more comparative data and know better which visualisations are most likely to reveal the errors.

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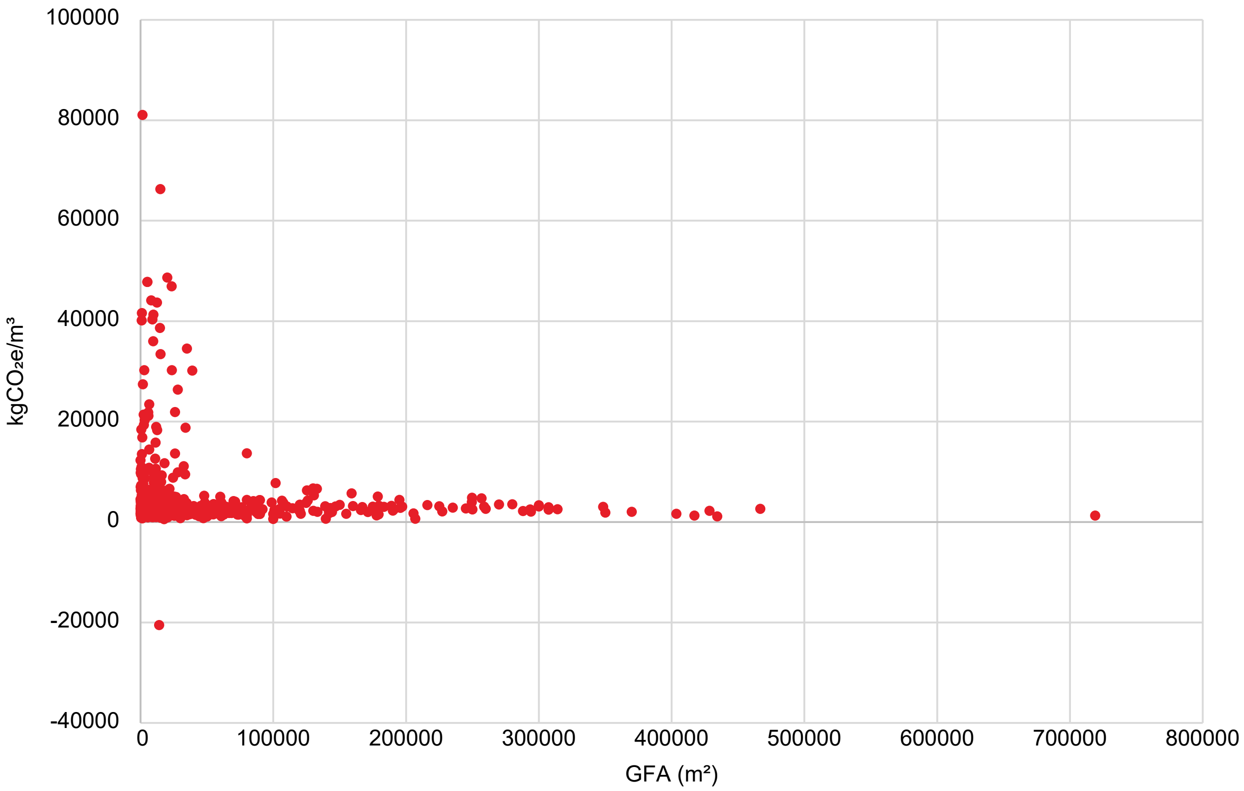

Figure 27. Aggregation of global data highlights outliers for investigation as to whether errors must be corrected by project teams

Within the analytics dashboard, project teams can find where their project performance (pink star) stands against peers – the central two quartiles (in purple) – within a building typology and/or geography. Upper and lower fences represent two standard deviations from the mean.

Figure 28. Example output from analytics platform to show project in comparison with peers

We are exploring user interface (UI) methods of providing warnings during data entry to catch such errors, now that we know what the most common ones are. The issue highlights the need for automated workflows that interrogate BIM models to produce a common set of measured areas for use by all disciplines so that human error is designed out of the quantity transfer process.

There is insufficient data to determine if current trends by phase indicate 'carbon creep' or just higher-intensity historical design practices.

Design teams are familiar with 'cost creep', when a greater level of detail of the same intention leads to higher cost at later stages of design and construction. Based on aggregated data from the campaign, SMEs suspect that carbon emissions may follow a similar trend, but we cannot confirm this yet for the following reasons:

1. The current construction and in-use stage data comes from projects designed without a prevailing net zero paradigm.
2. Future emissions of current early-phase projects may be offset by the absolute reduction in an element's carbon emissions arising from grid decarbonisation or other competitive modifications to the manufacturing process.

In the upcoming year's data collection, the capture of data for the same asset at different phases should allow us to determine whether project teams are remaining within the originally identified carbon budget. Subsequent data analytics aggregating projects' stages will allow us to determine whether there is an ongoing risk of 'carbon creep'. In addition, for fast-tracked projects, we should be able to cover multiple phases within the same year.

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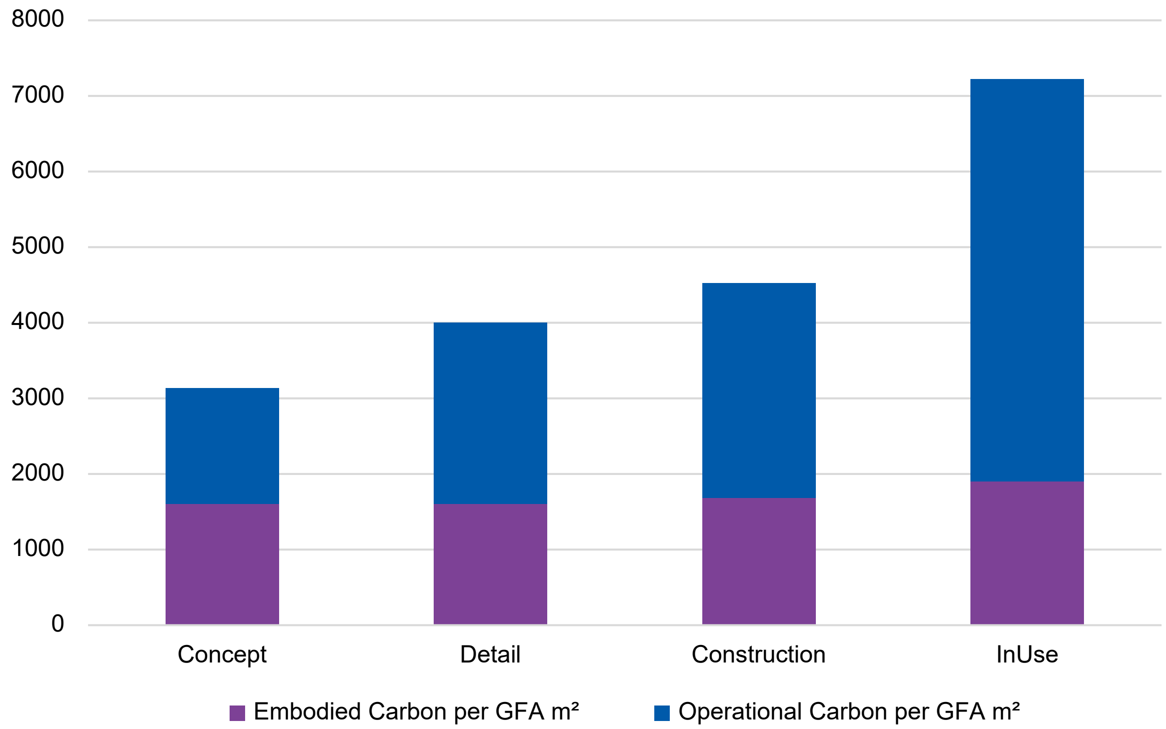

Figure 29. Carbon emissions by project stage

Carbon emissions of competing structural systems do not vary widely

We are learning from our estimation of full structures and the work with the material build-up to assemblies that there is great complexity in the choice of structural material, which is heavily dependent on its load-bearing capacity. While a cubic metre of concrete, steel and timber without load would often reveal timber to have the lowest passive emissions, for the same structural load-bearing performance, the relative volumes of materials have to be taken into account to create a functional system. There are no silver bullets: it is more effective to choose the right scheme for the loading characteristics and anticipated load paths, and then optimise to reduce material use further as a means to reduce carbon emissions.

While a cubic metre of concrete, steel and timber without load would often reveal timber to have the lowest passive emissions, for the same structural load-bearing performance, the relative volumes of materials have to be taken into account to create a functional system.

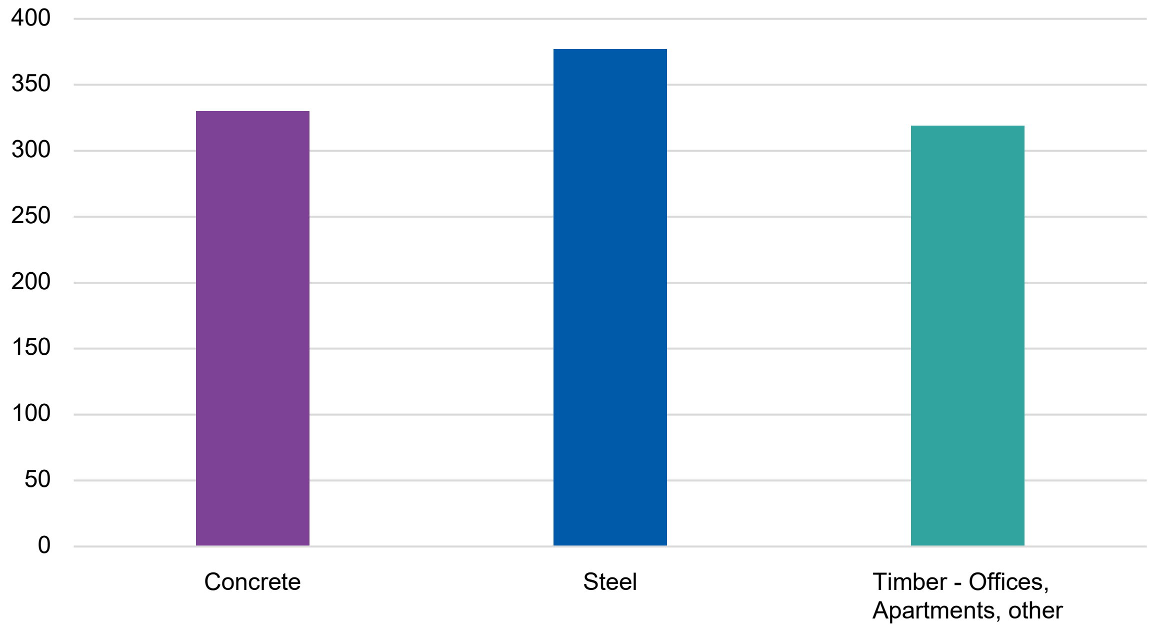

Figure 30. Comparison of primary superstructure materials within the portfolio shows less than intuited differentiation

Decoupling design intent from data

The original goal of a unified approach to Steps 1 to 4 was to create an environment where the data collection efforts by the project team result in insights for the individual designer that could reasonably link a design choice to its carbon emissions.

Emerging best practice techniques tell us which individual elements can benefit from a material change extrapolated across a building's volume. And project teams could use the Zero sandbox or reference data from Veracity to test alternate approaches in early phases.

But Arup's design teams and the communities of practice want to know how one discipline's low-carbon decision may affect the other disciplines, and what the body of data tells us about "what good looks like".

Emerging best practice techniques tell us which individual elements can benefit from a material change extrapolated across a building's volume.

Communities of practice want to know how one discipline's low-carbon decision may affect the other disciplines, and what the body of data tells us about "what good looks like".

Reporting meaningfully cross-project insights exploiting scale has been one of the most difficult aspects of the entire initiative because the more detailed and subdivided the quantity and emissions information becomes, the farther away it is from implicit information about the original design choice. For instance, an assembly from the carbon factor library inherently has descriptive design-based metadata in its name. If a designer selects a pre-set concentric braced frame of a certain steel strength and column-to-column spacing for lateral resistance, the data analytics can associate the emissions with the fact that it was a concentric braced frame, allowing the dashboard to compare the carbon emission performance of all concentric braced frames to all timber shear walls used for lateral resistance.

When we move to obtaining the higher accuracy raw lifecycle stage data exported into Zero Level 2 from third-party LCA tools, the outputs are often aggregated by common material or exported as multiple lines of individual elements. This more detailed data, by virtue of existing at the component rather than assembly level, becomes divorced from the assembly it was designed to be, and therefore unsuitable for comparison without additional metadata.

Better data is dumber data.

It would seem inconsistent with the promise of AI and machine learning, but the initiative revealed that the current data collection template misses the interpretative metadata to identify design intent. In other words, it lacks what an AI human trainer would have provided: “that’s a reinforced concrete wall”, or “this collection of components is a chilled beam system”, or “that generator is a backup”. The most vulnerable area of intelligence loss is in the process of capturing design intent metadata within BIM, and when data moves from BIM to BoM and BIM to BAM (Building Analysis Model).

The two cycles of data analytics with in-house expert digital analysts have shown the need to augment our processes and taxonomies to capture this subsystem characterisation data proactively when quantities and measurements are originally generated from the design documents. A recent SME workshop has generated a list of additional business metrics and system descriptors that will be reviewed for inclusion in future versions of Zero and the project database.

Reporting meaningfully cross-project insights exploiting scale has been one of the most difficult aspects of the entire initiative because the more detailed and subdivided the quantity and emissions information becomes, the farther away it is from implicit information about the original design choice.

More detailed data, by virtue of existing at the component rather than assembly level, becomes divorced from the assembly it was designed to be, and therefore unsuitable for comparison without additional metadata.

The most vulnerable area of intelligence loss is in the process of capturing design intent metadata within BIM, and when data moves from BIM to BoM and BIM to BAM (Building Analysis Model).

Capture... subsystem characterisation data proactively when quantities and measurements are originally generated from the design documents.

Other observations during the analytics process include:

1. The same element performing the same function is not always called the same thing around the world.
2. There are few pure single-system buildings from the perspective of a single discipline. Beyond knowing how to handle mixed-use facilities, therefore, we also need the capacity to handle mixed-system designs in order to attribute quantities of the same kind of materials to different system types – for example, steel used for a lateral system versus that used for a floor framing system.
3. It is not possible to reverse-engineer WLCA data from a completed design to how it could have been done better. Buildings have unique site conditions or project constraints that make each one an original. The best way to build an early-phase database of 'what could have been' is to capture all of the results of the 3-5 design alternates' WLCA calculations in Zero to build a richer database for analytics. This would help choose between options. We are currently reviewing how to digitally support multiple instances of the same asset, not only across phases but also within a phase with different system types.
4. Few geographies publish historical benchmark data at a system or subsystem level by building typology, so the available databases that support Level 0 embodied carbon have a European design bias and the calculations that support Level 0 operational carbon have. a U.S. design bias. As a placeholder, reductions from historical code-based benchmarks reflect efficiency measures and the partial adoption of renewable energy. For embodied carbon, the historical benchmarks function as a guide for what we aim to halve. Given that the UN Breakthrough target of >40% embodied carbon reduction does not establish the original value of baseline emissions, transformative practice should set emissions targets for embodied carbon as absolute values, based on material availability and scientific information, rather than try to estimate from a limited representation of past performance.
5. No matter how large the carbon factor and assembly library, there will always be outliers that cannot be represented for the Level 1 high-level assessment process. Requests from SME stakeholders have led to thousands of assembly and product options to maintain for accuracy. It is desirable to develop easier methods of full-scale WLCA calculation through automated processes that support the availability of options.
6. The adoption of standard approaches that reflect the decarbonisation of the grid and track the planned electrification of end-of-life equipment requires better representation in initial WLCA estimates, even though these may not be allowable in voluntary and regulatory reporting schemes.

The same element performing the same function is not always called the same thing around the world.

Beyond knowing how to handle mixed-use facilities . . . we also need the capacity to handle mixed-system designs in order to attribute quantities of the same kind of materials to different system types.

It is not possible to reverse-engineer WLCA data from a completed design to how it could have been done better.

Capture all of the results of the 3-5 [early phase] design alternates' WLCA calculations . . . to build a richer database for analytics.

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The adoption of standard approaches that reflect the decarbonisation of the grid and track the planned electrification of end-of-life equipment requires better representation in initial WLCA estimates.

One emission target does not fit all

Building typologies appear to have distinct clusters of carbon emission intensities. Projects can be compared to their peers in their own geography but additional key performance metrics such as material type/quantity and energy use intensity may need to be tracked, in addition to emissions, to determine best practice. Data centres, in particular, sway the portfolio's performance with an intensity that requires reporting them independently and addressing their performance with appropriate renewables as quickly as possible.

One emission target does not fit all. Building typologies appear to have distinct clusters of carbon emission intensities.

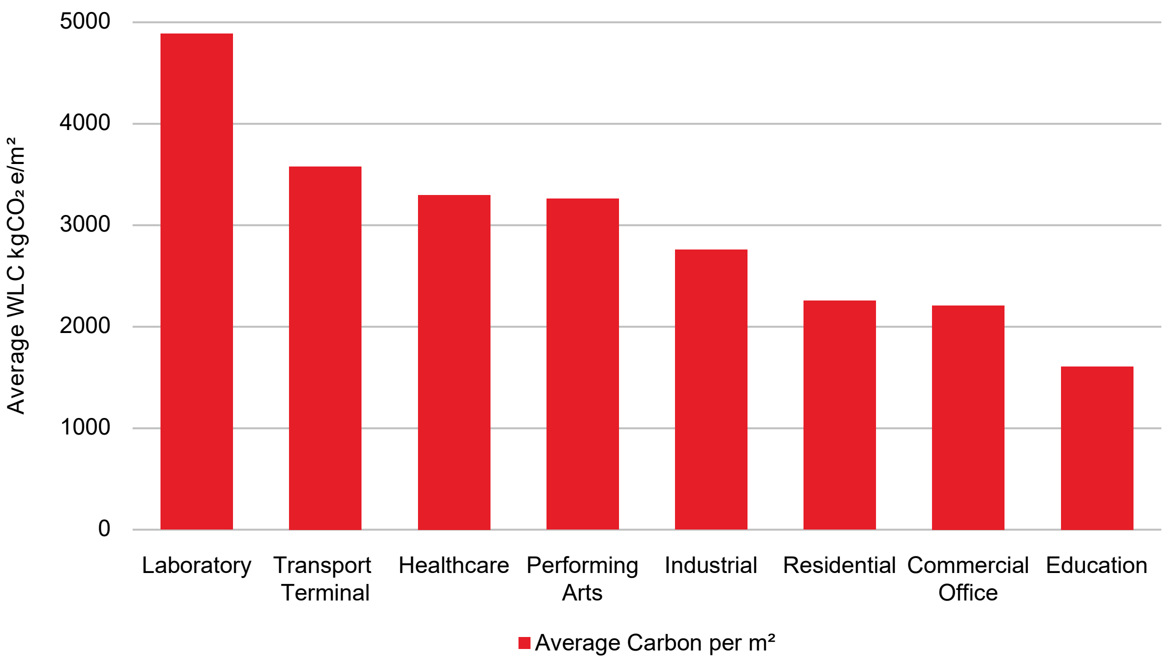


Figure 31. Emissions by Asset Function

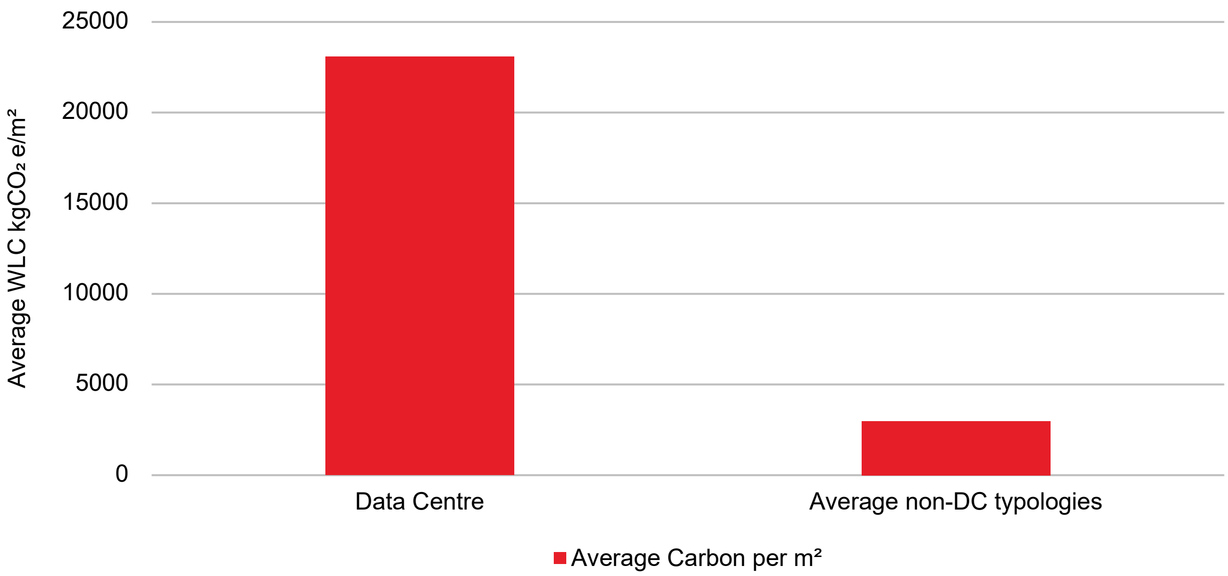


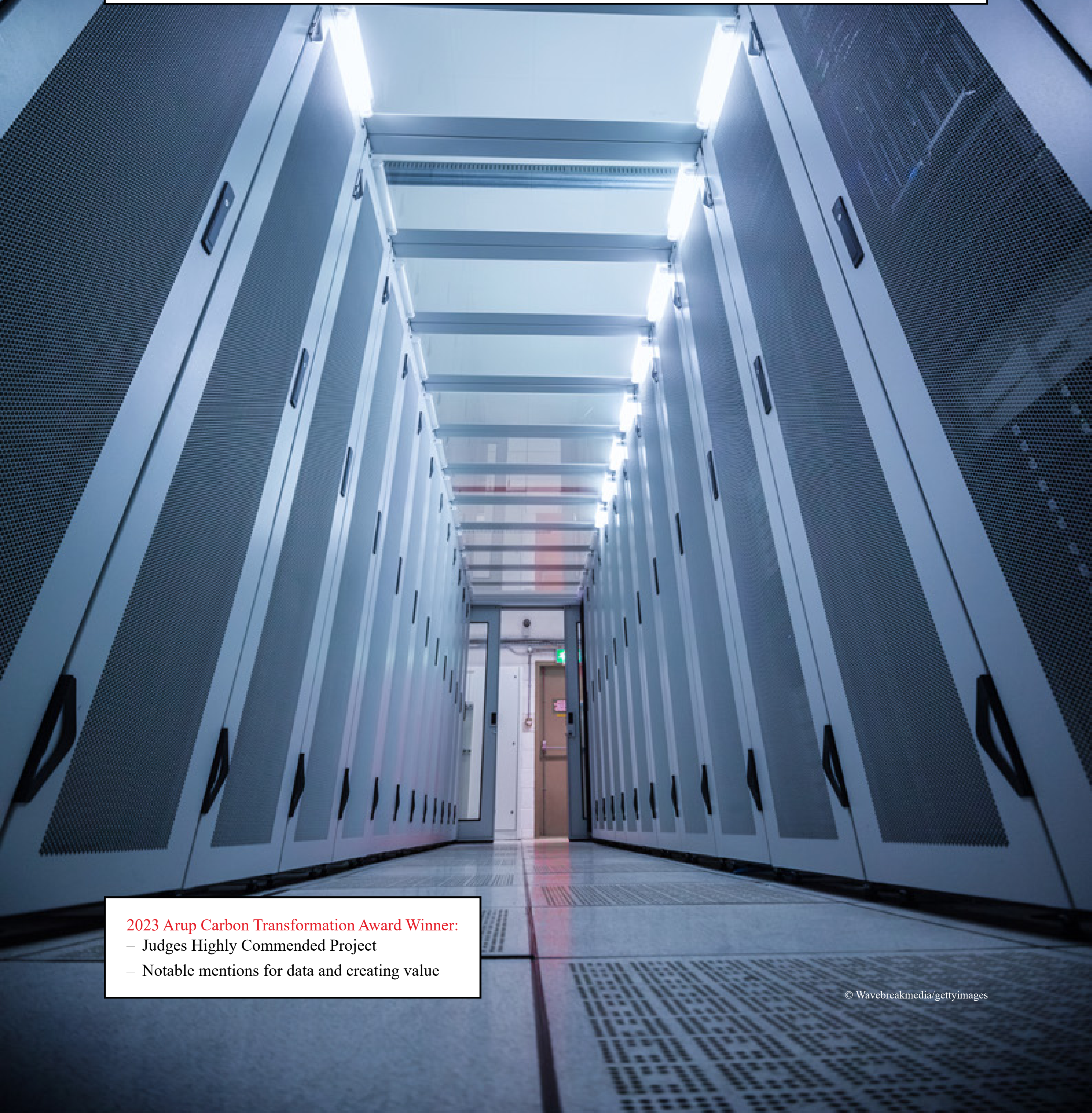
Figure 32. Comparison of carbon emissions of data centres versus all non-data centre typologies

Project: Data Center MEP Embodied Carbon Analysis

A life-cycle assessment (LCA) had already been done for civil, structural, and architectural (CSA) elements and the client was keen to understand the upfront product-level LCA for mechanical, electrical, and public health (MEP) services at the existing facility, given the significant quantity of MEP items within a data centre. The carbon challenge was to understand where in the reference design the MEP elements/systems with the highest embodied carbon reside.

Due to the distinct lack of information in the industry about many of the system components, it was imperative to develop and use a mix of published benchmark information, manufacturer's product-specific environmental product declarations, and material-buildup carbon emission estimation methods following the TM65 guidance published by the Chartered Institute of Building Services Engineers (CIBSE). A guidance note captures this data hierarchy to illustrate the precision in the LCA data, so that information gathering can be more straightforward during future assessments by the same client.

The LCA exercise allowed MEP benchmarks to be produced for life cycle stages A1-A3 (product stage/ cradle to gate), helping the client understand the quantum and location of embodied carbon within their reference design. The value for the client is that this in-depth knowledge about MEP product procurement allows for evaluation of alternative typologies and sensitivity analyses that may support prioritised GHG reduction goals.



2023 Arup Carbon Transformation Award Winner:

- Judges Highly Commended Project
- Notable mentions for data and creating value

Contributing to Market Transformation

In addition to in-house efforts to collect and compare global whole life carbon data, Arup has been working with industry partners to produce thought leadership and research pieces that support the market transformation and the definition of net zero carbon pathways for the built environment. In our industry engagement, we find common challenges, some of which we have attempted to solve along our journey and others that will require significant transformation across the value chain. Arup is committed to being part of the solution and being transparent on the lessons learned along the way.

Drawing from our portfolio and research, Arup has published a series of reports produced with the World Business Council for Sustainable Development (WBCSD) to share knowledge and insights with the wider industry as a basis for guidance and advocacy. These include: Net-zero buildings: Where do we stand?, Net-zero buildings: Halving construction emissions today, and Net-zero operational carbon buildings: State of the art.

In addition, we promote with other industry groups the need for whole life carbon data quality, standardisation and sharing mechanisms:

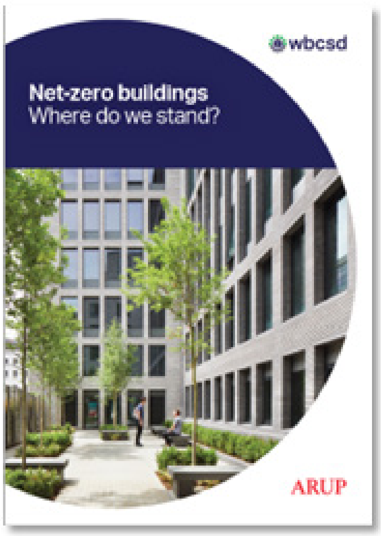
- We have a six-person team supporting the expert advisory committee for the Net Zero Carbon Standard, developed by the UK industry, setting out a certification procedure to demonstrate compliance with net zero requirements and avoid greenwashing.
- We have supported the UK Green Building Council (UKGBC) in developing what we believe is the first global set of guidance and advice to the building sector on good-quality offsetting strategies that justify the claim of netting off unavoidable emissions through carbon removals.
- We provide technical support to the UN Climate Champions initiative.
- We sit on the technical advisory board supporting the Science-based Targets Initiative with its guidance to the built environment setting out how stakeholders should account for carbon emissions through their commitments, reducing fragmentation and improving the drive to produce data. This initiative provides organisations guidance on GHG emission reduction pathways that are aligned with what the latest climate science has determined is needed to achieve a limit to global warming of 1.5ºC above pre-industrial levels.
- We have supported the introduction of UK embodied carbon regulations in a proposal, known as Part Z.
- We are part of the European Working Group for the development of a "Roadmap for the reduction of whole life carbon emissions of buildings" under the Directorate-General for Environment at the European Commission.
- We have contributed with data and reviews to the white paper by the Carbon Risk Real Estate Monitor (CRREM) on "Embodied carbon of retrofits: ensuring the ecological payback of energetic retrofits", which calls for a robust WLC approach as the embodied carbon of building retrofits is normally only evaluated from an operational carbon perspective.
- We have been founding members and part of several working groups of the Materials & Embodied Carbon Leaders' Alliance (MECLA), which is defining the agenda for embodied carbon in the public and private sector in Australia.
- We have been involved with the National Australian Built Environment Rating System (NABERS) and the Green Building Council of Australia to support a new embodied carbon rating scheme.
- We participated in a peer review of the Australian National Construction Code for the 2022 update on carbon.
- We have launched the Centre for Climate Action in Cities with the Singapore Economic Development Board.
- We have co-authored the "State of Decarbonization: Progress in U.S. Commercial Buildings 2023" report by the U.S. Green Building Council.

– We have contributed to the development of the “SE 2050 Beta Database and User Guide” for the U.S.-based Structural Engineering Institute.

– We have provided technical support to the North American standard “Evaluating Greenhouse Gas (GHG) and Carbon Emissions in the Building Design, Construction, and Operation”, under joint development by the American Society of Heating, Refrigeration, and Air-conditioning Engineers and the International Code Council.

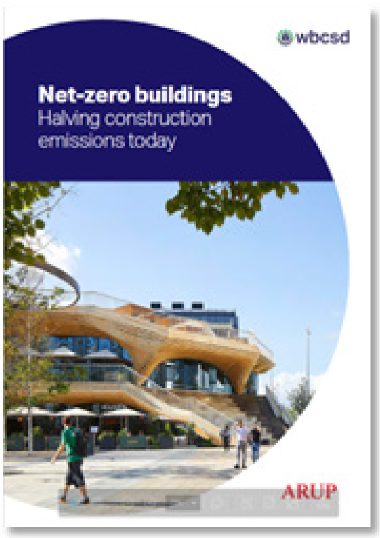
– We have been working closely with the Open Data Institute (ODI) to promote the development of global data strategies for the built environment, seeking to make carbon data universal and interoperable – just as money is in the currency markets.

– With our clients’ permission, we share their data with free-to-use repositories of WLCAs of built assets such as the Built Environment Carbon Database (BECD) in the UK and the structural engineering database SE2050 sponsored by the Structural Engineering Institute.



This report looks in detail at the results of six WLCA case studies using the WBCSD Building System Carbon Framework. It illustrates some of the challenges, barriers and opportunities related to the building industry’s carbon footprint. The aim is to provide an insight into the industry’s current performance and compare it with possible net-zero trajectories.

The authors, World Business Council for Sustainable Development (WBCSD) and Arup, encourage stakeholders from across the built environment to conduct whole life carbon assessments of their projects and openly publish the results to create a body of evidence and foster shared learning.



This report by the World Business Council for Sustainable Development (WBCSD) and Arup sets out how we can halve construction emissions in buildings by adopting the principle of doing more with less.

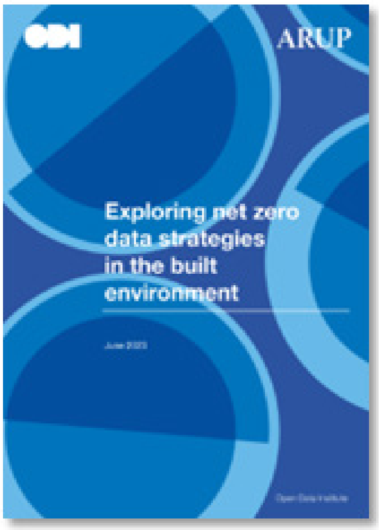
The built environment accounts for nearly 40% of global energy-related carbon emissions. Global decarbonisation trajectories indicate a need to reduce these emissions by 50% by 2030 if the industry is to reach net zero by mid-century and meet the climate goals of the Paris Agreement.

The report outlines strategies and actions to achieve the necessary rapid systemic changes, starting today.

Under the UN’s High-Level Climate Champions 2030 Breakthrough Goals, 100% of building projects completed in 2030 must be net zero in operation. However, as this publication illustrates, several areas are hindering progress, including the absence of consistent definitions of a net-zero building and a lack of national policies in this area.

This report by the World Business Council for Sustainable Development (WBCSD) and Arup aims to address these issues. It demonstrates the absence of clear direction to drive the necessary change in behaviours for progressing towards net zero.

It reviews the current situation, highlights areas where progress is being made, and identifies key gaps that need to be addressed.



This report, developed by Arup and the Open Data Institute, aims to bring together the best knowledge from the data and built environment professions to address the urgent needs of the global transition to net zero carbon performance.

It highlights that the concept of a carbon data strategy for a net zero economy is still in its infancy and identifies the building blocks of a strong data infrastructure, including governance, literacy and ethics practices that enable data collection, use and sharing. It also identifies hotspots to prioritise interventions that improve the tracking of carbon emissions across stakeholders industrywide. This is part of a cultural change that values data assets in parallel with physical assets across the value chain.

Arup was part of the working group that supported the UK Green Building Council (UKGBC) in the development of this comprehensive guidance on voluntary carbon offsetting and pricing strategies specifically tailored for built assets (both new and existing). This aims to help those who purchase offsets or make investment decisions at building asset or organisational level to align with their climate goals and accelerate the transition to net zero.

This report highlights how carbon pricing can be used as a powerful mechanism to accelerate the decarbonisation of built assets and the wider industry.

It sets out steps for creating an ambitious carbon offsetting plan and assists real estate developers and investors in taking a more holistic approach that goes beyond basic procurement of voluntary offset credits.

Conclusion

As we conclude the first part of our journey, we hope that the lessons learned from our global data collection and harmonisation efforts can inform the industry at large, whether governmental agencies considering mandatory reporting or non-profit organisations trying to extract insights from multiple contributors.

Returning to the adage of "you can't manage what you don't measure", WLCA has the potential to set a global standard for GHG measurement, if reporting and calculation methodologies are harmonised across regions. Data collection on embodied carbon may serve a temporary purpose for the AEC industry to improve supplier transparency by normalising "what good looks like" through mandatory targets for embodied carbon emissions in materials. The collection of operational carbon data may justify additional support for faster decarbonisation of the electricity grid, as well as incentives to support electrification. It will be important to understand what data regional policymakers will need from the industry to support bold action.

The goal of our WLC initiative is the deep decarbonisation of the built environment, not data collection itself. We believe that this is also true of the global WLCA adoption movement. But at present there is insufficient data transparency or evidence in the industry to radically change design practice. It is easy to build ever-growing data structures and 'data swamps' that no one ever visits. It has taken us a few attempts to "know what we would like to know" from the collected data.

Mass collection of WLCAs with no recorded design intent and without allocation of responsibility for emissions may do little to support change. Our insights on the need to standardise assembly and system type metadata, and diversify business metrics, exemplify a requirement we could not anticipate when we started. Our annual collection commitment is a valuable exercise as we can ask project teams to provide more information each year. The greatest challenge for global industry-wide data collection will be to determine which carbon-related values and metrics are meaningful for change, and to set guidelines to preserve data integrity for those levels of detail from the start.

Our experience of the last two years is a microcosm of what a global whole building, whole life carbon data collection digital approach might look like. Our process and our data are not yet perfect because, as we noted, we had to build the car while racing. We have learned about the limitations of the data we inherit from others, and we still process a lot of data manually. There is a significant cost related to overcoming software interoperability issues to support an efficient WLCA process because there is no digital WLCA standard adopted by our vendors. Standardising carbon data management across digital design, analysis and BIM tools would enable the faster embrace of WLCA to inform design.

As the Open Data Institute has noted, "the concept of a carbon data strategy for a net zero economy, or a 'net zero data strategy', is still in its infancy". Current reporting schemes require the submission of a single asset at a single time. Our experience with three levels of assessment shows the complexity of developing data structures that can be applied worldwide to track multiple instances of the same asset maturing over time in a way that allows for accountability to earlier promises. Our experience with trying to trace digital provenance back to the original material or product EPD reference has illustrated the challenges of maintaining a vetted carbon factor database across so many disciplines.

No case study can be considered complete if it does not highlight what was missing. The following represent the most frequently requested new features for our platform:

– Can the platform tell me the cost of my project to go with its calculated carbon emissions?

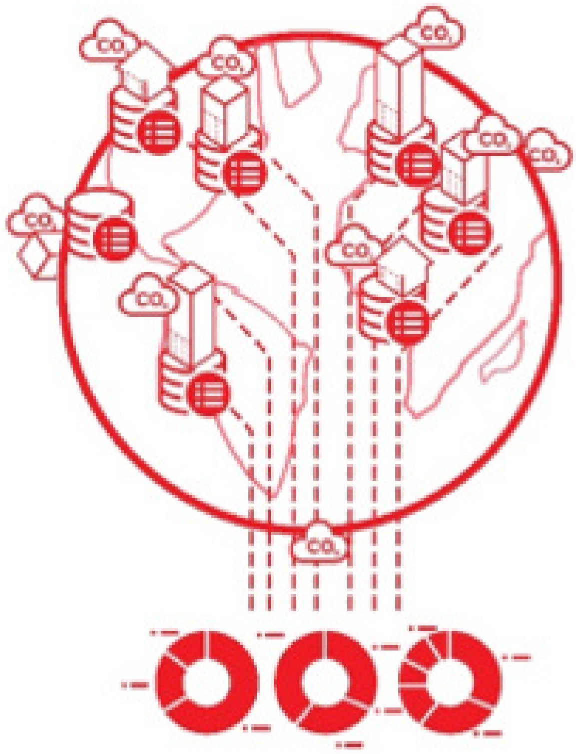
– Can the platform tell me if I pass [name of WLCA standard]?

– Can the platform tell me where to start or where I could have cut carbon emissions from my design?

These are big asks from a data collection platform. These questions indicate an ambition for excellence and foresight with a customer focus. The questions also highlight the need for the industry to clearly articulate the 'return on investment' of WLCAs to design practitioners, who in turn can use WLCA results to convey a 'return on investment' message for low carbon outcomes to their clients. Bolstering data quality and meaning, empowering early-stage designers with robust carbon estimates from peer-provided data, and tracking success against recognised metrics are key for us all to stay on track towards the UN 2030 Breakthrough Outcome. We look forward to what the next year brings in learning, insight and engagement with like-minded collaborators to accelerate industry-wide systemic change as quickly as possible.

Erin McConahey, February 2024

Appendix A:
Summary Description of Zero



Zero is Arup's global whole life carbon (WLC) software platform. It gathers embodied and operational carbon emission values for buildings to create an international and multidisciplinary structured data set.

The Zero platform allows project teams to:

1. Log estimates of carbon emissions at early phases based on minimal input.
2. Compare them to representative historical benchmarks.
3. Upload the post-processed results of detailed third-party energy models and Life Cycle Assessments derived from detailed construction documents, contractor submissions, or post-occupancy evaluation.

Over time, data analytics from detailed outputs will inform the carbon factor library used to generate estimates and set viable carbon targets, superseding historical benchmarks. Project data tagging allows cross-comparison by building function, geography, project development stage, new build vs retrofit/alteration construction type, and disciplines involved.

Zero's scalable modular approach to software architecture is configured with the following:

– The Zero platform user interface for simultaneous multi-user data entry and viewing of project-level results.

– The Veracity carbon factor reference database, which includes items such as carbon emission factors by geography for materials, products and assemblies; collated benchmarks by discipline; electricity grid emissions inclusive of published decarbonisation pathways.

– The building/project information database, with user inputs for all assets and access permissions.

– The carbon emissions database with results by lifecycle stage within each system or subsystem, as applicable.

– The Zero analytics user interface for viewing aggregated results.

The Zero user interface currently accommodates data captured by lifecycle stage for seven major building systems (Substructure, Superstructure, Mechanical, Electrical, Public Health, Building Envelope, Interiors) and their 31 associated subsystems. This comprehensive data allows users to interrogate the platform to identify high-emitting subsystems for priority action. In addition, the common data framework allows to compare peer projects at asset or system level via the Zero analytics interface.

The data is stored in the results database for auditable provenance and transparency of access, as past results are accessible by year of data entry.

There is no international standard for calculating or reporting whole life carbon. Arup has created a global data architecture of whole building WLC to reflect the need for such data, to influence the supply chain, and to help transform professional practice.

Arup built the Zero platform to have insight into its own portfolio of work, with more than 1,400 projects across 51 countries participating in the initiative over the past two years. Unique in the industry, the infrastructure has the potential to serve the industry at large.

Zero is a cloud-based whole building, whole life carbon emission aggregator supporting international data gathering and harmonisation.

Appendix B:
Glossary of Terms and Organisational Abbreviations

Glossary of terms

AEC	architecture-engineering-construction
BAM	building analysis model(s)
BIM	building information modelling/model(s)
BoM	bill of materials; a list of material descriptions and associated quantities
community of practice	a group of practitioners committed to sharing knowledge
COP26	a UN climate change conference held in the Glasgow, UK in 2021
CTAs	Carbon Transformation Awards, an Arup recognition programme
discipline	a specialized branch of knowledge typically learned in higher education
embodied carbon	The indirect emissions associated with energy and the direct emissions of a variety of global-warming chemicals associated with raw material extraction, manufacturing, transport, installation and disposal
EPD	environmental product declaration; a document that provides information on the environmental impact of a material or product across its life cycle
GHG	greenhouse gas
LCA	lifecycle assessment; the expected emissions over the life cycle of a material of product
MEP	Mechanical, Electrical, Public Health
operational carbon	The indirect and direct emissions of carbon dioxide and other GHGs associated with utility energy and water consumption, on-site burning of fuels, and leaks of chemicals that cause global warming, such as refrigerants
SME	subject matter expert
WLC	whole life carbon
WLCA	whole life carbon assessment; the expected emissions over the life cycle of a development

Organisational abbreviations

BECD	Built Environment Carbon Database
CIBSE	Chartered Institute of Building Services Engineers
CRREM	Carbon Risk Real Estate Monitor
MECLA	Materials and Embodied Carbon Leaders' Alliance
NABERS	National Australia Built Environment Rating System
ODI	Open Data Institute
Race to Zero	an initiative of the UNFCCC Climate Champions programme
TCFD	Task Force on Climate-Related Financial Disclosure
UKGBC	UK Green Building Council
UN 2030 Breakthroughs	an initiative of the UNFCCC Climate Champions to set near-term targets for emissions reduction across the real economy
UNFCCC	United Nations Framework Convention on Climate Change
WBCSD	World Business Council for Sustainable Development

Appendix C: Acknowledgements

We wish to acknowledge the contribution of over 400 experts across Arup, closely involved in developing and testing Zero's capabilities, offering insights and critical feedback, which has been essential to helping us achieve the progress we are making.

The nature of the Zero program is to connect with thousands of Arup Members, to support design teams with WLCAs and to gather data from around the world and it is with regret that it has not been possible to acknowledge everyone contributing to the program.

Aaron Tabares, Abdul Shaick, Adam Buchanan, Adela Tablas, Adrian Ryan, Agnes Narita, Alan Glynn, Alborada Delgado, Alex Chen, Alex Flash, Alex Hespe, Alexa Hinves, Alexander Bacon, Alexej Goehring, Alexia Velev, Ali Brit (Alena Dolzhenko), Alice Frostick, Alice Xu, Alina Alvariez, Allison Tsai, Almudena Rodero, Amalia Ekasanti, Amir Ahadi, Amparo Galvan Nieto, Ananth Iyengar, Andrew Goodfellow, Anrew Jones, Andrew Mole, Andrew Pettit, Andrijana Grkovic, Andy Belcham, Andy Lui, Andy Mathieson, Ann Dalzell, Ann Jiras, Anna Dombrowski, Anna Sutherland, Antonietta Canta, Ariana Forsythe, Arnon Dienn, Autumn Qu, Azqa Singh, Barbara Lane, Begoña Pérez de Colosia, Ben Brannon, Ben Hussey, Berlina Winata, Beth Richardson, Bex Porter, Bhaven Mistry, Brandon See, Brian Carman, Brian Luster, Brian Stacy, Brigitte Danks, Brittany Tse-Swanstrom, Bruna Frydman, Bryan Barrow, Callum Fox, Camila Colhado Gallo, Carin De Beer, Carl Mclean, Cassandra Mitsinikos, Chan York-Lin, Charlotte Graves, Charlotte Thompson, Ching Hui, Chloe Ballington, Chris Carroll, Chris Pountney, Chris Rush, Chris Taylor, Chris Tidball, Chris Watts, Christine Tiffin, Christopher Fung, Christy Chow, Cibele Romani, Clare Wilding, Colin Copeland, Conor Black, Conor Hayes, Cormac Deavy, Cory Abramowicz, Craig Irvine, Craig Sturzaker, Cristian-Gerard Cornea, Daeun Yoon, Dan Clipsom, Daniel Balding, Daniela Azzaro, Daragh Anderson, David Almond, David Davies, David de Koning, David Littler, David Lanceta, Deborah Blass, Diana Redding, Dobromila Pierzchala, Dom Egginton, Ed Hoare, Edie Pearse, Eduardo Mouhtar, Elia Galatolo, Elizabeth Dawe, Ella Brennan, Ellen Fox-Davies, Ellena Marli, Emily Walport, Enrico Zara, Eric Ota, Erin Gill, Erin McConahey, Ethan Zhang, Evan Zhu, Eve Chillcott, Evey Jiang, Farhad Khandan, Felipe Flores, Felix Chan, Fernando Ruiz, Fernando Soler, Filippo Cefis, Fiona Cousins, Florence Bassa, Frances Yang, Francesca Galeazzi, Franklin Kwan, Frazer Plumb, Freddie Eldridge, Gary Davies, Gemma Grant, Gemma Reed, Genevieve Graham, Geoffrey Iwasa, Gerasimos Kounadis, Gerrit Lebbink, Gigi Kam, Giulia Cavallari, Giuliana Galante Casazza, Giulia Santoro, Giulia Strallo, Giulio Antonutto-Foi, Goman Ho, Grace Di Benedetto, Grace Hahnel, Grace Pownall, Greg Waring, Guarav Kumar, Guo-Ju Li, Haico Schepers, Hailey Kim, Hannah Frost, Hannah Jury, Hau Han You, Helen Campbell, Henry Chan, Hugh Pidduck, Iain Smart, Ian Ferre, Ian Lumsden, Ian Rogers, Ingrid Chaires, Irene Albino, Irene Martin, Ivy Graham, Jack Beattie, Jack Cook, Jack Daley, Jack Lo, Jackie Wei Green, Jaco Kemp, Jacob Richardson, Jake Cherniayeff, Jakki Artus, James Flattery, James Hare, James Norris, James Smith, James Ward, James Wei, James Zeibarth, Jamie Risner, Jared Stock, Jason Burke, Jasper Hilkhuijsen, Jasper Riikonen, Jee Wei Tan, Jeff Guo, Jen Workman, Jenessa Man, Jeremy Edwards, Jerry Chung (X), Jesus Moracho, Jill Leung, Jim Johnson, Jimmy Chan, Jimmy Li, Jo da Silva, Jo Spencer, Joby Wong, Joerg Tonndorf, John Bynum, John Noel, John.F McCarthy, Jolie Lau, Jon Hurcombe, Jon Palmer, Jonathan Ciulanti, Jonathan Peart, Jordan McSharry, Joseph Hewlings, Joseph Kaylor, Juan LaFuente Cilla, Justin Szabo, Ka-Man Miu, Kaitlyn Wignarajah, Karma Barfungpa, Kasia Piontas, Kate Adlington, Kate Fletcher, Katie Hodge, Katie Nute, Kelly Knopp, Kelvin Nair, Ken Wynne, Kentaro Suga, Kerem Pakyurek, Kerry Lockwood, Kerryn Coker, Kevin Coeffe, Kevin Cressy, Kimberley Pepperell, Kimberly Avelar, Krishna Gotur, Kristen Garibaldi, Kristian Steele, Kristjan Nielsen, Lachlan Miles, Lap Fong, Laura Craft, Laura Solarino, Laura Young, Lauren Howe, Lauren Wingo, Lauryn Zoryk, Léa Silvestrucci, Leyla Sadigh, Li-Anne Sayegh, Linde van Beers, Ling-Fei Wang, Ling-tao Liu, Liu Chang, Louisa Wan, Ludovica Pototschnig, Luis Gay Tarazona, Luis Strengari, Lydia Stensberg, Mabel Aguerre, Mai Kakikawa, Marc Easton, Maria Benazzo, Maria Elges, Mark Lusis, Marta Kolonko, Martin Simpson, Mathijs van Heumen, Matt Carter, Matthew 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William Wong, Xavier Zhou, Xin Jin, Yar Ming Chong, Yolande Alves de Souza, Zach Postone, Zara Fahim, Zak Kostura, Zhiang Zhang, Zoe Keates.

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