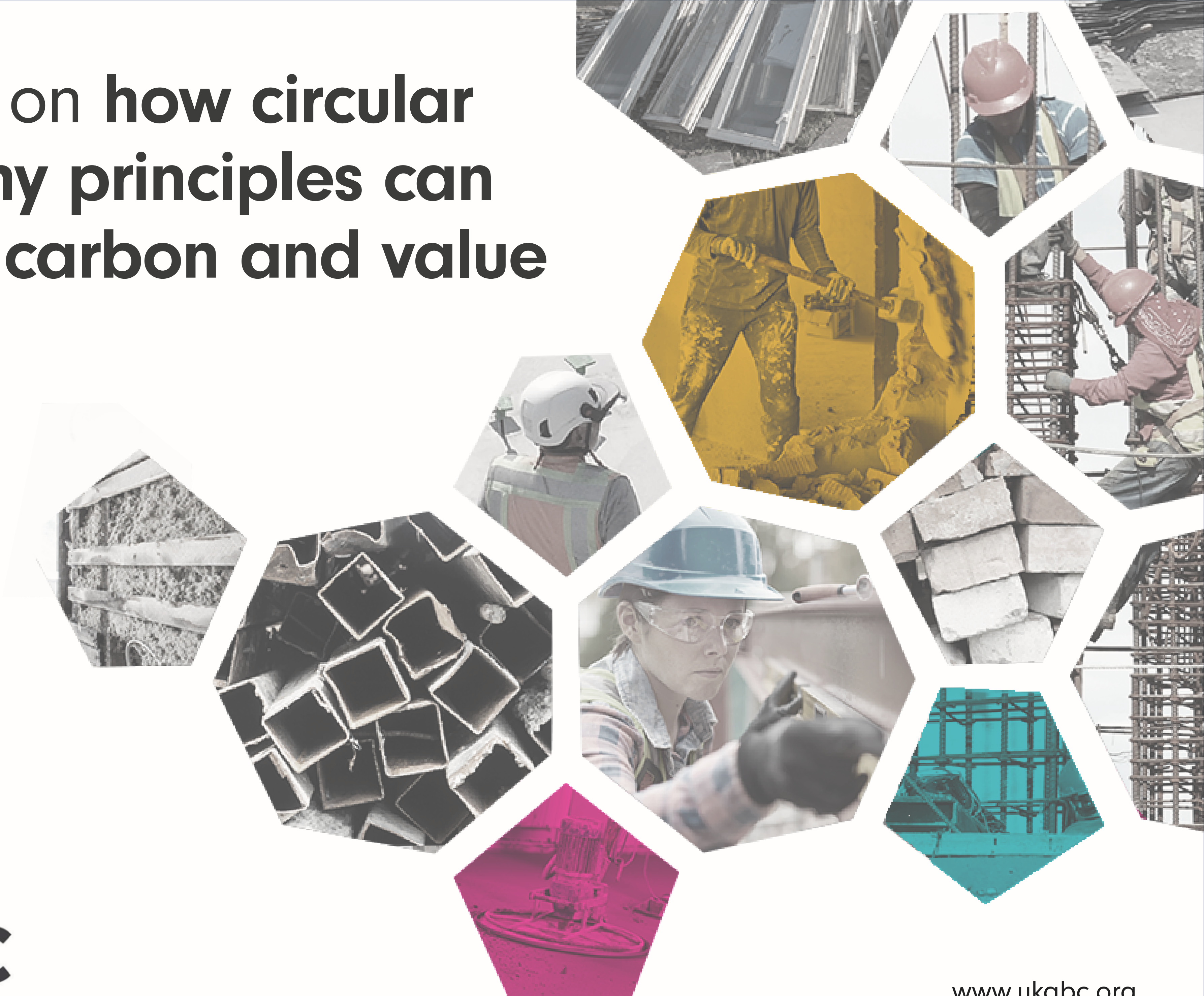
Insights on **how circular economy principles can impact carbon and value**

August 2022



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Executive summary

The Net Zero Whole Life Carbon Roadmap, published in 2021, demonstrates that the UK built environment can be net zero carbon by 2050. The modelling found that for this to happen, both embodied and operational carbon must be reduced to almost zero, and that the use of circular economy principles are an important part of the solution. Five such principles and how to apply them were set out by UKGBC in Circular economy guidance for construction clients, published in 2019.

The purpose of this report is to:

Increase understanding within the real estate sector of how circular economy principles can support whole life carbon reductions, and where there may be potential trade-offs; and

Provide greater clarity on how circular economy may be valued in relation to the whole life carbon impacts of buildings by translating these outcomes into financial and other value metrics.

Over 50 organisations kindly gave their time to help create this report, through a Task Group, provision of case studies, and reviewing the findings. The report is structured into three main sections, which start by introducing the relationship between whole life carbon and circularity, then explore via case studies how each of the five circular principles can impact carbon, financial value, and non-financial value, and finally information is provided on the 18 case studies used with five described in detail.

The report concludes that many new and existing building projects have already used circular economy principles and are able to evidence resulting reductions in carbon, especially in relation to the "Maximise reuse" principal. However, the other principles can help maintain quality and a market for reused materials and so act as enablers for reuse, even though it has proven difficult to assign the benefits to those principles specifically. A range of impacts on financial and non-financial value were identified across all the principles, thus demonstrating that circularity benefits not just carbon, but a much broader set of organisational, social, environmental, and financial aspects.

However, the case studies and task group also identified that measuring the impact created by the application of circularity is infrequent, inconsistent, and difficult. One solution identified was to have a commonly accepted and applied set of metrics and methods to measure both the whole life carbon and circularity of projects. Fortunately, many individuals and groups are working to improve clarity and consistency on these issues. This includes an upcoming update to the RICS Whole Life Carbon Assessment for the Built Environment and ongoing work by UKGBC members to identify a set of circular economy metrics.

Hopefully this report provides evidence and inspiration for designers, developers, owners, and occupiers, to put circular economy principles into practice. It should also lead to further collaborative work between stakeholders to improve the measurement and understanding of the multiple benefits that circularity enables.

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Introduction

Since the industrial revolution, the cumulative impact of human actions has increased global average temperatures by over 1°C, and this is on course to reach 4°C by 2100. This threatens to usher-in a new geological epoch characterised by greater climate instability and significant impacts on human life.[1] To limit global heating this century to below 1.5°C, greenhouse gas (GHG) emissions must be halved by 2030. To help achieve this, the UK has a legally binding 2050 net-zero carbon target.[2,3]

Climate change and the circular economy

In November 2021, UKGBC published the Net Zero Whole Life Carbon Roadmap ("the Roadmap")[4] which identifies that the UK built environment is currently responsible for 25% of total UK greenhouse gas emissions and is on course to fall well short of being net zero carbon by 2050. Both the embodied (covering construction, maintenance, and demolition) and operational emissions from buildings and infrastructure were assessed, including associated imported emissions.

The Roadmap provides a modelled trajectory and set of actions that demonstrate that a net zero carbon built environment is actually feasible by 2050, and that it need only require a relatively small amount of carbon offsetting due to the possibility of reducing operational emissions to almost zero and embodied emissions to around only $9MtCO_2$. It makes clear that this will only be achieved with a transformative shift in industry practices, including the adoption of circular economy principles.

Many individuals and organisations have been working over the last few years to embed circular economy thinking into the actions of the built environment industry. To help with this, in 2019, UKGBC published Circular Economy Guidance for Construction Clients, which set out five circular economy principles for use in project briefs and detailed steps on how to specify them, alongside solutions for addressing perceived challenges, and examples of projects applying the principles. This was followed up in 2020 with further detailed guidance on "Reuse" and "Products as a Service"[5]

Despite this, there is limited evidence regarding the amount of carbon reduction that the use of circular economy principles can and do result in. A recent IPCC report states that "circular economy initiatives have to date, made a limited contribution to climate change mitigation."[6]

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Report purpose and audience

UKGBC started a project in late 2021 in order to:

1. Increase understanding within the real estate sector of how circular economy principles can support whole life carbon reductions, and where there may be potential trade-offs; and
2. Provide greater clarity on how circular economy may be valued in relation to the whole life carbon impacts of building by translating these outcomes into financial and other value metrics.

The findings within this report are intended to enable project decision-makers and key built environment stakeholders to strengthen the business case for implementing circularity. This includes developers, owners, and investors in real estate, as well as design, construction, and consultancy teams advising real estate clients on their new and existing developments.

Project methodology

To deliver these aims, a task group was formed with over 40 individuals who represented a cross-section of the built environment value chain. Four working groups were established, each looking at one or two circular economy principles in detail relating to the carbon impact, trade-offs, costs, and value generated from their deployment. Desktop research and a series of workshops were used to collate and discuss information.

An industry survey, with follow up interviews, was conducted in order to identify case studies utilising circular principles. These case studies are used within this report to illustrate the actual or expected carbon impacts and value from CE principles on projects. The Task Group and a number of external supporters and reviewers have also reviewed and provided feedback on this report during its creation, with further details in the Acknowledgements section.

Report structure

The focus of the report is on non-domestic and domestic buildings, though we believe that the findings are relevant to infrastructure as well. The focus is on individual built assets, not impacts at an organisational level. This report does not cover how to implement circular design strategies, for which there are many other publications, including the UKGBC Circular Economy Guidance for Construction Clients.[7]

After the introduction, the report is structured into three main sections:

1. **Exploring Whole Life Carbon and Circularity:** This introduces the main concepts used in this report, along with how they link to each other.
2. **Impacts of Circularity on Carbon and Value:** The section is split into the five UKGBC circular economy principles, along with the impacts on carbon reduction and financial and non-financial value that were identified through the case studies. Potential challenges to implementing and their potential solutions are also provided.
3. **Case Studies:** This section provides a detailed overview of five projects and links to a further 13 case studies that are housed on the UKGBC Solutions Library webpages.

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Exploring whole life carbon and circularity

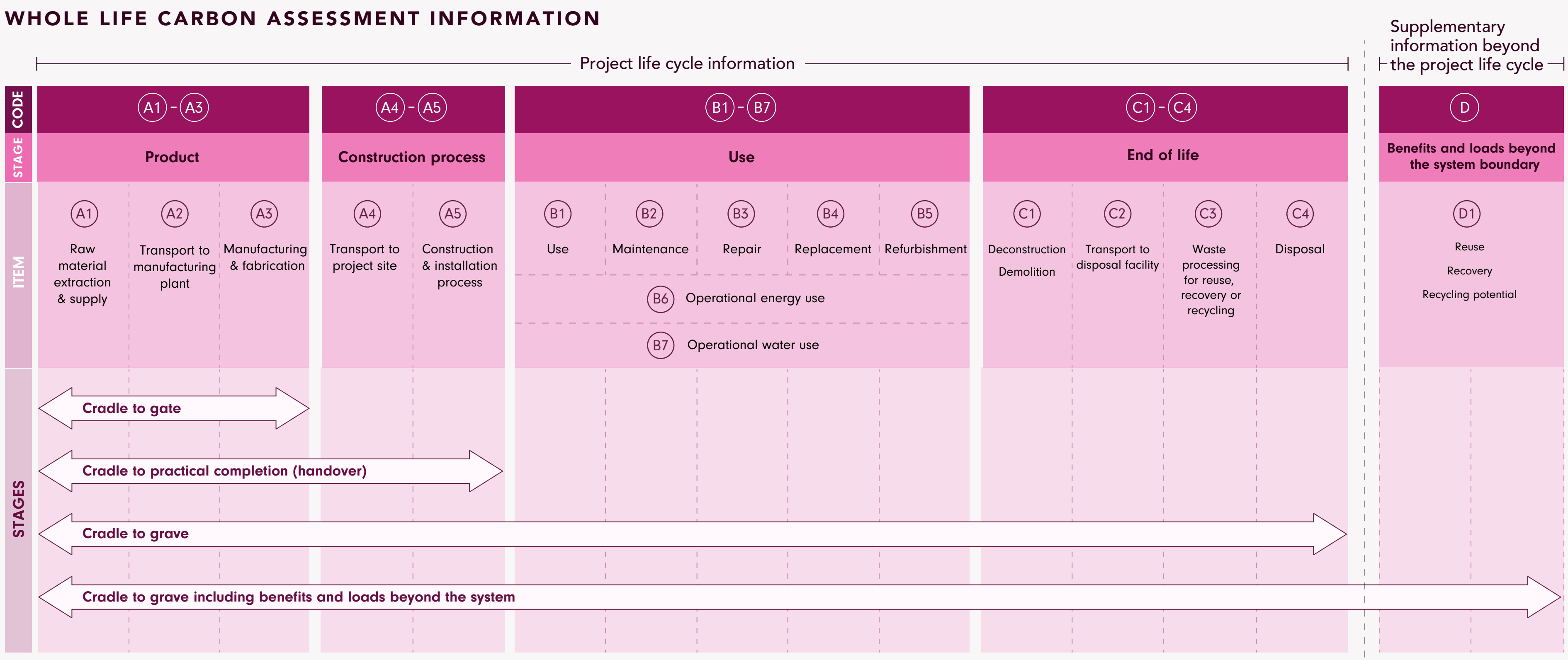
This section includes brief introductions to the concepts of whole life carbon (WLC) and circular economy (circularity) and how they relate to each other. This is followed by a short exploration of the challenges to identifying the impacts from using circular economy principles and some of the identified drivers for implementing circularity.

Whole life carbon

It is important to consider carbon across the life of a building as focussing on just one area could lead to decisions which actually create a larger carbon impact in another stage of the building lifecycle. *The RICS Professional Statement: Whole life carbon assessment for the built environment*[8] is the most commonly used WLC assessment guidance for buildings in the UK. The RICS guidance uses the EN 15978[9] modular life cycle approach (Figure 1) for assessing carbon emissions that arise from various built assets, including commercial and residential buildings. It is applicable for the assessment of both new and existing buildings as well as refurbishment, retrofit and fit-out projects.

In this report, when it is possible, carbon impacts are referred to by where they fall within the life cycle modules. The term *Upfront carbon* is also used to refer to emissions in the A1-A5 stage.

Figure 1: WLC assessment modules as per BS EN 15978



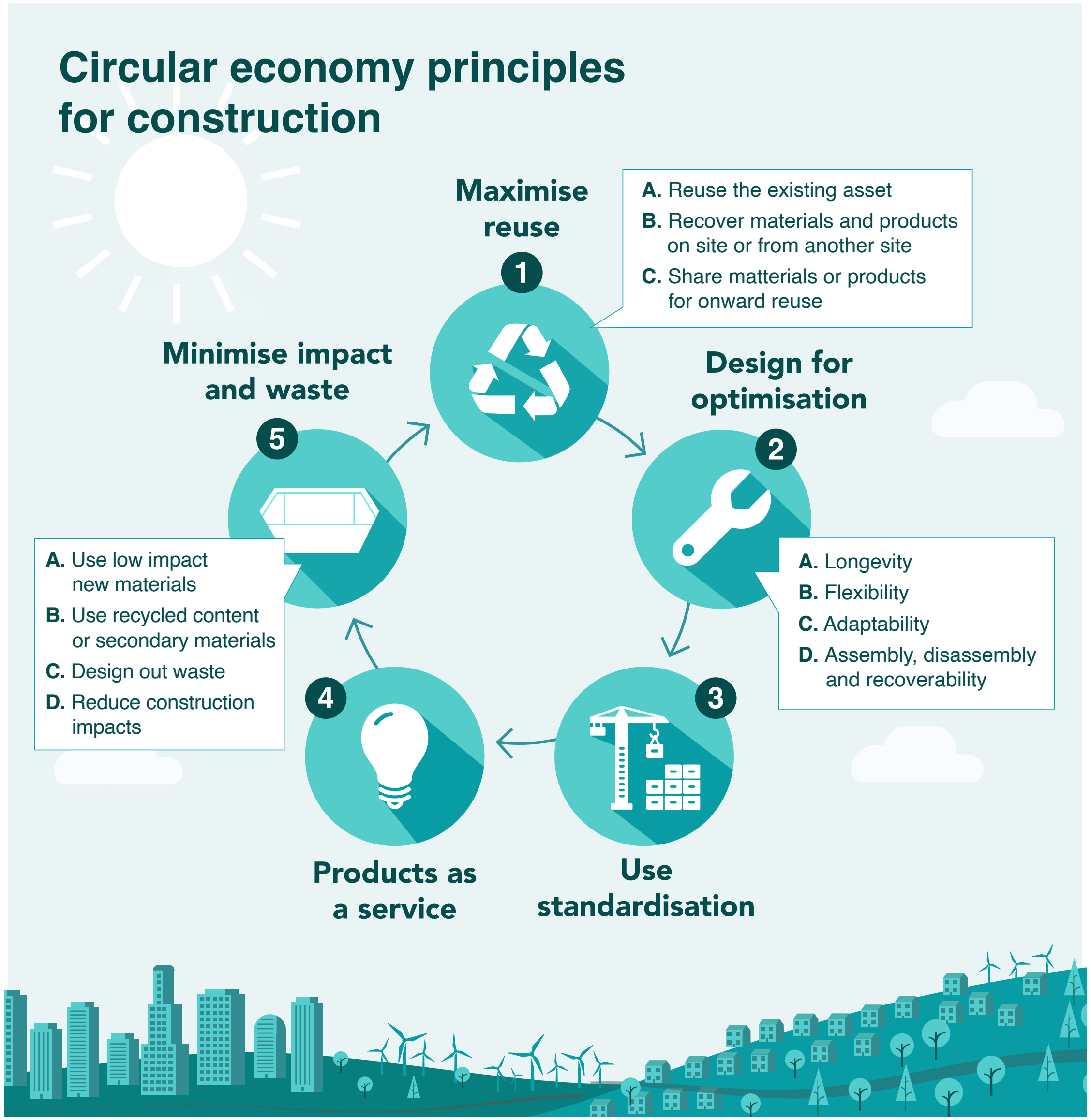
Circular economy

In contrast to a linear 'take-make-dispose' economy, a circular economy builds overall system health by gradually decoupling economic activity from the consumption of finite resources. The Ellen MacArthur Foundation defines circular economy as *"A systems solution framework that tackles global challenges like climate change, biodiversity loss, waste, and pollution. It is based on three principles, driven by design: eliminate waste and pollution, circulate products and materials (at their highest value), and regenerate nature."*[10] Therefore, circular economy methods aim to have a positive impact on the environment beyond carbon reduction, such as protecting biodiversity and water quality.

The circular model distinguishes between technical and biological cycles, where biologically based materials and building components are generally designed to feedback into and regenerate living systems; while technical cycles recover and restore products, components, and materials through strategies like reuse, repair, remanufacture or (as a last resort) recycling.

The circular economy principles referred to throughout this report, and illustrated in Figure 2, are those identified within the 2019 UKGBC report *Circular economy guidance for construction clients.* Definitions are provided in the next chapter.

Figure 2: Circular Economy Design Principles



The link between circular economy and whole life carbon

The Net Zero WLC Roadmap demonstrates the importance of applying circular principles in order to create a near-zero carbon-built environment by 2050. The Roadmap requires that embodied carbon will form over half of built environment emissions by 2035, that 25,000 new homes per annum will be delivered via change-of-use conversions from 2025, that improved utilisation of existing building stock will create a 10% reduction in new office and residential demand by 2040, and that there will be a 10% reduction in material demand by 2040 due to increased material reuse. These projections are directly related to the use of circular principles in building design.

Whole Life Carbon Assessments (WCLA) as per BS EN 15978 (Modules A-D) are increasingly required, either legally (e.g., GLA London Plan) or via stakeholders' own corporate commitments. While certain circular design principles may be able to reduce upfront carbon (Modules A1-A5), others may only see a benefit in reducing emissions during the use or end of life treatment (Modules B-C) of a built asset and its components. Others still might have a benefit in future projects (Module D). There is also potential that the application of circular principles may result in higher carbon at certain stages. Better understanding of this relationship will be critical to reducing any unintended impacts from these design choices.

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The challenges of identifying impacts from circular economy actions

The Task Group workshops, case study research, and interviews, identified that measuring the specific impact of circular design principles is very difficult and instead they must be considered within the wider sustainability strategies applied to buildings. There are several reasons for this:

- **Circular design principles are rarely applied in siloes:** This can make attributing direct impact difficult. Ultimately, this is likely to result in a positive outcome as the most significant carbon, financial and non-financial value will often be generated when these principles are used together and in tandem with other 'sustainable' design strategies (e.g., nature-based solutions). These other sustainable design strategies can also make the overall case stronger when there is perhaps a lower upfront carbon or cost value in applying circularity.
- **Circularity and non-financial value are not measured consistently:** While the case studies always identified some sort of carbon, financial, or non-financial value, this was not always measured. This is partly due to some of the benefits occurring at a future date, resulting in the value being attributed to future tenants or owners rather than the organisation undertaking the development. This provides little incentive for the development team to set up robust measurement processes. Greater measurement of circularity and value on projects must be encouraged to form a larger evidence base.
- **Inconsistent Whole Life Carbon Assessments:** It is difficult to compare case studies on a like-by-like basis. The tools commonly used within the industry, as well as internal company measurement tools, rely on different assumptions and boundaries of what's included and LCA experts themselves may use different assumptions, such as on replacement cycles. The RICS Professional Statement is the clearest interpretation to date of the BS EN 15978 WLC methodology, and it will be updated in 2023.
- **Whole Life Carbon Assessments are not yet the norm:** This is the case for many complete projects today, many of which will have started when circularity and WLCAs were in their infancy. However, cities like London now require WLCAs and circular economy statements for referrable schemes and companies are increasing their commitment to provide these assessments. WLCAs are likely to become more normalised over the next several years, leading to a greater evidence base but companies must be encouraged to do so.

The case study examples and discussions aim to inspire action, displaying direct examples of carbon impact and value in practice. From a pure carbon accounting perspective, the strongest evidence for carbon reduction can be seen through the Reuse principle. Nevertheless, while other principles might not have as significant upfront carbon savings, they must be considered in light of their full life-cycle impact and the additional benefits they may provide for clients, occupants, and wider society in the context of a climate emergency. This can include:

- Financial value through cost savings and programme reductions
- Marketing value because of the building having sustainability credentials
- Benefits to nature and biodiversity
- Wider health and well-being impacts etc.

Drivers for circularity

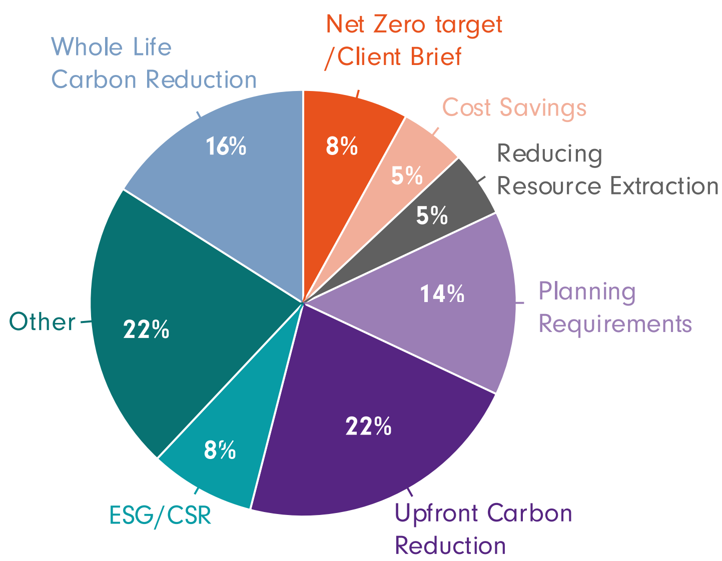
Case studies were gathered as part of the research for this report, and the full list can be found in section 5. Those submitting case studies were asked what the client's drivers were for implementing circular principles. Nine options were offered, and respondents could choose multiple drivers. Responses were provided for 16 of the case studies and the results are shown in Figure 3.

Whole life carbon or upfront embodied carbon reductions were named as a driver by nearly 40% of the projects, while nobody noted "certification requirements" as a driver. The most common 'other' driver was "educational interest", which refers to clients applying circularity on pilot projects to see how far they could reduce whole life carbon and what implications this would have on overall value. This supports the idea that circularity can potentially have multiple benefits, and decision-makers will have to apply the strategies that make the most sense for them.

There are numerous market and policy drivers emerging which are likely to increase the desire of building developers, owners, and occupiers to reduce WLC and implement circular economy principles. These include:

- Increases in the scarcity and prices of raw materials.
- Acceleration of corporate commitments to reducing and reporting carbon emissions as part of initiatives such as SBTi, Race to Zero, and the Taskforce for Climate-Related Financial Disclosures (TCFD).
- Growing of national and local regulations including WLC Assessments required by the GLA for referable applications, the spring 2022 Environmental Audit Committee report recommending regulating WLC, and the built environment industry itself advocating for embodied carbon regulation, such as through the Part Z initiative[11] and the Net Zero Whole Life Carbon Roadmap.

Figure 3: The Key drivers for using circularity on building projects



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Impacts of circularity on carbon and value

This section provides the key findings, examples, and inspiration from the collected case studies and task group discussions. There is a sub-section for each of the five circular economy principles.

EACH SUB-SECTION COVERS:

- **The aim of the principle**, as taken from the existing UKGBC circular economy guidance
- **How it can reduce carbon emissions**, with reference to case studies
- **How it can impact financial and non-financial value**, with reference to case studies
- **Perceived challenges** to implementing the principle and potential solutions

Principle 1

Maximise reuse

THE PRINCIPLES

A. Reuse the existing asset: Reusing an entire asset, or reusing a significant proportion of the existing asset, to accommodate similar or different needs and/or uses (e.g., from industrial use to mixed use) whilst exceeding current regulations and standards through restoration or significant changes.

B. Recover materials onsite or from another site: Incorporating reuse elements and materials that have been recovered from the existing site, or from another site, into the new development.

C. Share materials or products for onward reuse: Where materials and products cannot be reused on site, they will be sent for onward reuse via a broker or back to the material supplier for refurbishing, repurposing, or recycling (as a last resort).

CARBON IMPACT

Maximising reuse has a high potential to reduce upfront carbon emissions. All case studies reusing the existing asset and recovering materials on site reduced upfront carbon emissions, while sharing materials for onward reuse resulted in both embodied and operational carbon savings plus waste reduction.

Reuse the sub and super structure. These make up approximately 50% of the upfront embodied carbon of a project[12] and is often where the most significant upfront carbon reductions can be made

- The Entopia Building: Approximately 285kgCO_2e/m^2 saved from the reuse of the existing sub and super structure (about 53% of original carbon in the structure was retained). Estimated that the retention of this structure and upgrading to EnerPHit standard saved about 60% embodied carbon compared to demolishing and newbuild.
- Timber Square: Reusing 70% of the original structure, equating to 25% of the new development; saving 7,300tCO_2 in total compared to a completely new frame.
- The Bartlett School of Architecture: 440tCO_2e saved through reuse of the original structure.
- Cambridge Avenue: Reuse of the steel structure contributed to a 260tCO_2e saving (80kgCO_2/m^2).

Reuse elements of the building, such as the façade or flooring

- 1 Triton Square: 3,000m^2 of the panelised façade recovered, which resulted in 2,400tCO_2 savings compared to a new façade; 70tCO_2 was saved by refurbishing panels in a factory in Essex rather than in Germany; approximately 10% of the total upfront embodied carbon saving.
- The Entopia Building: Reusing existing raised access floor across most of the building; 32kgCO_2e/m^2 (or around 85tCO_2 total) saved compared to using new raised access floor panels.
- The Burrell Renaissance Project: 4.5km of aluminium glazing bars retained, saving over 8.5 tonnes of new aluminium, and preventing over 100tCO_2e associated with new aluminium production.
- Cambridge Avenue: Reuse of the Façade saved 30tCO_2e (9kgCO_2/m^2).

Reuse steel

- Cleveland Steel and Tubes and the UKGBC CE Forum have undertaken preliminary research that, while not a case study, indicates that reused or repurposed steel can result in a 95% carbon saving kilo for kilo.
- 55 Great Suffolk Street: the reuse of 9.5 tonnes of steel is estimated to save 25 tonnes of CO_2 (18kgCO_2/m^2).
- Roots In the Sky: the reuse of 30 tonnes of steel is estimated to save 74 tonnes of CO_2e.

Reuse furniture and other fit-out materials or pass them on for reuse

- JLL Office Fit-out: Task chairs refurbished from a major financial firm saving 61% CO_2e compared to new chairs. Also over 500 items donated from the former office clearance saving 45tCO_2e from emissions associated with downstream waste management.
- Cambridge Avenue: The reuse of the fit-out saved 10tCO_2 (3kgCO_2/m^2), and the reuse of the lift saved 25tCO_2 (8kgCO_2/m^2).
- Exchange House: By sharing on Globechain 3,832 tCO_2e saved by the fitting and furnishings not going to landfill.
- The Royal Bank of Scotland: Sharing carpet tiles through CollectEco saved 337.5 tCO_2e through reuse instead of recipient organisations buying new.

FINANCIAL VALUE IMPACT

Sub and super structure reuse

- 1 Triton Square: Overall project had 15-18.5% savings compared to new build, partly thanks to reuse of sub and super structure and materials.
- The Entopia Building: Estimated to be a 4-8% project cost uplift above a standard Part L retrofit, but this was an experimental trial project to bring carbon down as much as possible.
- Timber Square: By retaining the building there was a higher value floorplate compared to normal.

Façade reuse

- Triton Square: Savings of £2 million (10-20% cheaper than new façade) in part due to time savings.
- The Burrell Collection: £100-500k savings from retaining aluminium façade.
- 80 Charlotte Street: Reused existing brick façade; some additional testing and modelling costs compared to purchasing a new façade overall project remained on budget and on time.

Material and product reuse, e.g., glazing frames, brick, steel

- Preliminary work done by Cleveland Steel & Tubes and the UKGBC CE Forum indicates a profit opportunity of between 30 to 40% per tonne at current market prices of reused or recovered steel compared to new steel (32-44% savings), assuming the steel is in a building the client owns; buying reused stock from inventory is slightly more expensive, but still provides savings between 10-20%.
- JLL Office Fit-out: Savings of over £40,000 achieved by adopting a second life furniture package compared to equivalent new.

- Cambridge Avenue: Reuse of the lift saved £5000, and the reuse of materials enable a 25% cost saving in materials and products, however due to the complexity of the project it did not result in an overall cost saving compared with new build.

Shortened programme time

- The majority of studies leveraging asset reuse saw or are expecting to see a shortened programme time (note that in some cases this was disrupted by Covid). While safety and deconstruction may require a longer demolition process, once this process is complete, a significant portion of the existing building is on-site, and the overall programme is therefore shorter.

Market premium for net zero and circular buildings when selling or renting

- While not solely attributed to the use of circular principles, 80 Charlotte Street and 1 Triton Square both saw significantly faster let times, with 1 Triton Square -having the fastest pre-let in the London west end in over 20 years.

NON-FINANCIAL VALUE IMPACT

Circular principles contributed to numerous sustainability certifications and accreditations e.g., BREEAM and WELL

- The Entopia Building: On track for WELL Gold rating, BREEAM Outstanding, EnerPHit Classic (note that WELL Gold was decided to be more feasible for a major refurbishment than Platinum).
- 80 Charlotte Street: While circularity was not the sole contributor, development achieved BREEAM 2014 Excellent at design stage; LEED 2014 Gold.
- JLL Office Fit-out: The only office fitout to simultaneously achieve WELL platinum, BREEAM Excellent RFO, and SKA Gold.

Many of the case studies were undertaken as pilot projects to inform the clients' own sustainability strategies

- Holbein Garden, Cambridge Avenue, The Entopia Building, and 1 Triton Square were all projects which provided learnings about reuse to the project team and to share with industry.

Access to funding benefits that are only available for projects with explicit sustainable metrics and ambitions

- The Entopia Building and The Enterprise Centre both received European Regional Development funding for their reuse ambitions, alongside other circular strategies.

Value of maintaining the historical fabric and character of buildings

- The Burrell Renaissance Project: As a category A-listed museum it is of a great historical importance.
- 55 Great Suffolk Street: This will regenerate a grade II listed property.
- The Bartlett School of Architecture: Situated in the Bloomsbury conservation area local policies had to be followed to conform to local rules.
- 80 Charlotte Street retained elements of the façade for a cohesive look within the neighbourhood, while leveraging standardisation for other elements.

Job creation (e.g., pop-up factories for refurbishment and treatment of recovered materials), as measured by number of jobs created

- 1 Triton Square: Local jobs supported through the pop-up factory to refurbish the façade being based in Essex rather than Germany.

Reduced air pollution (PM 10, PM2.5) and local congestion, as measured by total mileage savings due to reduced transport emissions from less materials / transport needed

- 1 Triton Square: A pop-up factory in Essex rather than in Germany saved carbon and programme time.

Educational opportunities for staff or tenants

- JLL Office Fit-out: employees and clients engaged with circularity, including through the reuse of furniture and a table made of recycled yoghurt pots.

Social value through sharing materials onward to charities and schools

- The Entopia Building: Excess furniture worth £100,225 were donated to the community and local charities.
- JLL Office Fit-out: partnership with Business to Schools charity ensured unused furniture (£30,000) was donated to three schools.
- Exchange House: Through being shared on Globechain the fittings and furnishings worth £82,316 benefitted 7559 people through organisations the items were donated to.
- The Royal Bank of Scotland: Carpet tiles worth £308,250 were donated to 44 good causes across the UK through being shared via CollectEco.

CHALLENGES AND POTENTIAL SOLUTIONS

Challenges	Solutions
VAT on materials for refurbishment projects are higher than those for new build projects.	The cost differential can be reduced by reusing existing structural elements to reduce construction time and amount of materials. **The Bartlett School of Architecture** deep retrofit resulted in overall cost savings.
Local Authorities may have requirements for a building's heritage elements to be retained, which may hamper energy efficiency improvements.	Many Local Authorities have declared climate emergencies and/or have set stretching carbon reduction targets. These can be referenced alongside the potential carbon savings from replacing the building's heritage elements. **The Entopia Building** the Cambridge council conservation team wished to preserve the look of the Georgian style windows, which would limit natural light and the improvements in operational energy efficiency. Demonstrating how the carbon savings would align with the council's science-based reduction targets, alongside how the windows could be changed whilst still retaining the core heritage elements of the building, helped achieve a compromise.
Unknown building elements can add to programme time and costs.	Ensure time is allocated in the programme for assessing the state of materials before project commencement. Building material passports will make this easier in the future.
Deconstruction takes longer than demolition, and certain materials may not be immediately available. This is likely to both increase development costs and reduce rental income in the short term.	Develop a detailed programme and whole life cost analysis and engage contractors early in the process to minimise risks of delays. **The Entopia Building**, contractors were engaged from the end of RIBA Stage 3 under a pre-construction services agreement.
Visual appearance of reused materials perceived by agents and owners to reduce the letting potential of a building.	Find examples of reused assets or materials to show clients and agents, and ensure they know the marketing potential of low carbon properties. **The Entopia Building** the client was initially hesitant about the reused raised access floor as an exposed finish, but after seeing a similar example, they supported the installation of the flooring.
Difficult and costly to store and pass on used products for re-use.	Work with material exchange platforms, such as Globechain and Collecteco. Can also consider donating items for social value creation.
Costs associated with reprocessing or cleaning materials (e.g. reused bricks) and uncertainty that materials will achieve warranties and performance specifications.	When specifying reused materials, only procure reused items that are warranted. These costs and risks are expected to decrease as the industry becomes better equipped to support a circular construction industry (e.g., development of circular infrastructure, increasing familiarity with recovery processes, etc.).

Principle 2

Design for optimisation

THE PRINCIPLES

A. Design for longevity: Create a built asset with well-defined long-term needs this is, durable, resilient, and able to cope with societal and environmental change. It will require little modification/ no replacement of parts, due to its 'loose fit', generous proportions and readiness for alternative technologies.

B. Design for flexibility: Balance the needs of the present with how those needs will change in the future. Enable change through frequent reconfiguring including reconfiguration of non-structural parts - configurations are likely to be pre-agreed with planning and building control and will not involve 'wet trades' or any waste.

C. Design for adaptability: Meet the needs of the present, but with consideration of how those needs might change in the future, enabling change in the form of periodic remodelling. This should include alterations or replacement of non-structural parts, whilst modifications are likely to involve planning, building control and 'wet trades'.

D. Design for assembly, disassembly, and recoverability: Products and services are designed to be assembled, deconstructed, and reused or recycled on a part-by-part basis.

CARBON IMPACT

The carbon impact of applying optimisation principles can be particularly challenging to capture, as many of the benefits occur in the future. Also, such design choices may result in relatively higher levels of upfront embodied carbon. The case studies applying these principles did not demonstrate this, but some did identify significant future carbon savings.

Design for flexibility

- JLL Office Fit-out: 90% of the floorplate is reconfigurable with fixtures and furnishings reconfigurable or demountable. Minimising constructed cellular spaces created an active workplace design with no internal partitions. This resulted in, compared to a business-as-usual fit-out:
  - 17% upfront carbon savings from designing-out materials and products through adopting an open-plan office design approach therefore reducing the need of internal partitions.
  - 23% upfront carbon savings resulting from reused base-build MEP (mechanical, electrical and plumbing engineering) equipment where possible, and from designing-out MEP materials and products required through adopting an open-plan office design approach (by using 35 less Fan Coil Units than BAU, 6,528 kg of CO_2e were saved).

Design for assembly, disassembly, and recoverability

- Roots in the Sky: Bolted structural connections will be prioritised over welded connections where this is structurally and technically feasible. This will allow primary steel material to be re-used in future developments. Assuming 50% recovery rate, this measure has the potential to save around 3,500tonnes of CO_2e on future developments.
- Holbein Gardens: New bricks assembled with lime mortar; this can be cleaned off so the bricks can be disassembled at the end of life: With Lime Culture the CO_2 emissions are estimated to be around 20% lower than in cement manufacturing; lime mortar will also absorb CO_2 during the hydration process (carbonation) and over a period of time become carbon neutral.[13]

FINANCIAL VALUE IMPACT

Many of the projects applying the optimisation principles did not capture the impact on costs or programme, but the Task Group identified a number of ways through which design for optimisation is likely to create financial value for the building owners or occupiers, including the following opportunities.

Higher rental values as able to demonstrate to tenants the improved utility of the space

- 1 Triton Square: a significantly faster let time than expected for a property of its type, although this cannot be solely attributed to the use of circular principles.
- Canal Reach: The design means there is great flexibility with how many tenants can occupy the building due to the large floor plate. The building can be used as one, split into two buildings, or have up to 8 tenants per floor.

Flexibility can create mixed use buildings with greater value

- A building's value is based on the income it provides, which depends on the current use class: if a building can accommodate different uses, it should have higher value as a result.
- The Forge: The floor to ceiling height and reversible components mean future change of use is possible.
- 80 Charlotte Street: Basic steel structure and pre-cast planks enables possibility for future use change.
- The Bartlett School of Architecture: Communal spaces are designed to be flexible with some walls able to pivot or are lightweight so can simplify future layout configurations.

Income from onward sale of second-hand material (e.g., steel from a portal frame)

- Building as a material bank approach: material prices get higher, future owners will have value stored in the building components (value in the building itself, not just the land).[14]

Future repair / maintenance / replacement cycle costs reduced compared to business-as-usual

- This can save costs for the building developer / client if they intend to maintain ownership of the building, or the future owner / occupier if they have any direct control over the Use stage of a building.
- Adopting passive design strategies can provide resilience, as will sizing systems to cope with future climate scenarios.

Reduced future fit-out costs if the products and materials can be reorganised for a variety of multiple purposes

- Designing with flexibility in mind can ensure the materials and products can accommodate future uses or be used again by occupiers in other buildings.

NON-FINANCIAL VALUE IMPACT

As with the financial benefits, there is little evidence available to demonstrate the non-financial value created for owners or occupiers by design for optimisation, but the Task Group did identify some likely opportunities, including the following.

» WLC emission reductions for carbon/ CSR reporting, as well as lowered scope 3 emissions when occupying the building or selling the building onwards.

» Marketing benefits for developers who in the future will be looking to reuse buildings because of the carbon costs of building new.

» Contribution to numerous sustainability certifications schemes and accreditations e.g., BREEAM, WELL.

» Ability for domestic buildings to accommodate changing family sizes and structures due to reconfiguration.

» Longevity can mean a building is less likely to be demolished after 20 or 30 years due to changing tastes, which can increase social consent from the community.

CHALLENGES AND POTENTIAL SOLUTIONS

Challenges	Solutions
When developments are being constructed for sale, rather than ownership by the client, optimisation for future scenarios is not usually undertaken.	Client teams and designers should be incentivised to think about the future use of assets and one way of doing so may be to include yearly carbon reporting alongside WLC assessments. Leverage the marketing opportunities of future benefits, including from buildings as material banks, such as the BAMB2020 project.
Market tastes are likely to change, and many buildings are not used for their full design life.	Longevity should be not used as a standalone solution, but instead combined with deconstruction, flexibility, and adaptability. Better community engagement is needed to first prioritise existing buildings and how they can be leveraged for a different use, and where possible, involve the end user in decisions to better design for future possibilities.
Frequent replacement cycles can lead to quicker redundancy of long-lasting materials.	Standardising fit outs to apply flexibility, adaptability, and disassembly might result in lower carbon than fit outs designed for longevity. This is because fit-out styles frequently change, and elements are likely to have shorter design lives. Incorporating clauses for appropriate maintenance is necessary for reduced carbon no matter which design approach is applied.

Principle 3

Use standardisation

THE PRINCIPLE

Designing and constructing buildings that apply standardised elements or modular designs for materials and products that enable a reduction in construction waste and easier reuse in next life.

CARBON IMPACT

Standardisation when twinned with off-site methods that reduce waste can reduce upfront carbon. But standardisation across a design could actually increase carbon if not carefully and strategically applied. Standardisation also has close ties to Designing for Deconstruction if the system is designed for easier reuse.

There are also links to Flexibility and Adaptability if the standardised components are designed to be modular and interchangeable, whether it be for internal furnishing or structural components. Some examples of upfront carbon reductions were identified through the case studies.

Standardised products are specified to limit upfront carbon

- The Forge: The use of a Platform Design for Manufacture and Assembly (P-DfMA) means the project is on track to have an upfront embodied carbon reduction of 25% against a typical new build baseline.

Standardised products increase productivity on site while reducing construction time, this leads to a reduction in construction site emissions

- 80 Charlotte Street: Prefabrication of the façade with pre-cast modular installation and other structural elements (pipework risers and soffits) led to reduced waste, construction impacts, and labour onsite. This also saved construction time.
- JLL Office Fit-out: Standard size materials implemented to minimise construction waste; along with designing out waste, there was a 14% upfront carbon saving compared to baseline due to transportation of less materials, products, and waste, as well as reduced energy required on-site due to less materials and products installed.
- Blackrock Street: The use of timber and pre-insulated external wall panels and floor cassettes in a 'flat pack' MMC (Modern Methods of Construction) approach meant they went up in days and there was a reduced carbon impact from the use of timber. This was also cheaper than traditional manufacture.

FINANCIAL VALUE IMPACT

The case studies and Task Group discussions indicate that financial value can be generated through:

- A reduced construction programme and more efficient site construction.
- Cost savings from standardised components, rather than bespoke materials, and overall reduction in material usage as well as easier replacement in the future.
- Higher rental charges for flexible space.
- Financial value add if the standardised components can be reused in the future.
- Cost savings and potential income from reusing standardised materials from previous fit-out.
- Receive government funding for using innovative approaches such as PDfMA, as on The Forge.

NON-FINANCIAL VALUE IMPACT

Increased onsite safety due to pre-fabricated components allowing easier assembly

- 80 Charlotte Street: industry leading safety rate due to pre-fabrication of concrete façade offsite.
- The Forge: Pre-fabricated components designed with safety in mind e.g. soffit fixing were pre-drilled into the slabs, rather than workers having to drill them in after, so there was reduced working at height and no dust fell on construction workers.

Standardisation of fit-outs can enable higher spatial flexibility with interchangeable partitions and pods creating more uses of the space

- JLL Office Fit-out: used standardised materials with a large number being reconfigurable or demountable.

CHALLENGES AND POTENTIAL SOLUTIONS

Challenges	Solutions
The upfront enabling costs for the 'tooling' of on-site production facilities if clients use their own standardised systems.	This should ultimately lower upfront costs as a client's economies of scale develop. Off-site production facilities, if clients can ensure carbon savings from the standardised methods, will outweigh transportation carbon. On-site facilities can also speed up construction time, increase local job creation and reduce transportation / construction intensity over time.

Principle 4

Products as a service

THE PRINCIPLE

Establish and promote a payment structure through which customers have unlimited access to resources but only pay for what is actually used, or for the result linked to their use. This represents a transition from selling products to selling services.

CARBON IMPACT

Products as a Service (PaaS) has the potential to reduce carbon through efficient maintenance and refurbishment cycles, as well as takeback schemes that focus on preventing waste and recovering or adapting products for future use. The WLC of PaaS should be considered before installation as there is currently limited evidence that products as a service lead to reduced whole life carbon and no case studies have been provided which included PaaS. The case studies in this section have been sourced from the websites of various PaaS companies, not all of which operate in the UK.

Lighting as a service can result in reductions in operational and embodied carbon due to improved performance of the products

- eLight: Lighting as a Service (LaaS), eLight run the maintenance of the lighting fixtures whilst also installing an energy metering system to improve energy usage efficiencies. In one school they saved 62 tCO_2e per year with predicted annual savings of eLight use[15]. At end of life, the original light fittings are taken back by eLight and recycled and repurposed through Recycling Lives.[16]
- Signify: Through Lighting as a service they offer a 50% longer lifespan, which suggests product carbon savings.[17]

Category B fit-out items, like furniture, that is offered as a PaaS model can offer reduced upfront carbon in comparison with purchasing new products - but the evidence is less clear cut

- Ahrend, Gispen and Martela all offer furniture as a service - they all suggest reduction in material usage and carbon, as furniture is maintained and refurbished after takeback for use in other projects. For Ahrend this was tested in Ellen Macarthur offices.[18]

Air conditioning as a service can result in more efficient operation and thus reduce carbon

- Kaer: offers air-conditioning (cooling) as a service (CaaS). Kaer takes responsibility for both the design and installation of the air-conditioning system, thereby avoiding over-specification. They also managed the operation to ensure the system runs more effectively. Through this model, a building owner can purchase air-conditioning at a fixed fee in the form of air-conditioning as a service. One data centre example showed that "The energy efficiency of the cooling system is 15% better than current Green Mark Platinum benchmarks."[19]

FINANCIAL VALUE IMPACTS

Technology-based products can result in smaller upfront costs for owners to pass onto renters, or financial savings with reduced bills and reduced operational energy usage

- eLight: Cost savings for consumers through reduced operational energy costs: £19,841 for one school based on comparison to bills before new technology installation.[20]

Reduction in upfront costs for developers

- If PaaS is considered at this early stage in a built to sell project, then it is integrated efficiently which is more effective than reactively installing new kit and contracts after the building has been sold.

Free repairs and maintenance for high quality Interior furnishing products

- Ahrend: Free repairs, for a €45,000 working environment investment, with estimated savings of around €6,000 .[21]

NON-FINANCIAL VALUE

High potential to reuse products if there is advance planning for replacement including when using PaaS. The original products may be passed to a charitable project, creating social value

- eLight use a charity that supports people who may find it hard to get work to sort and recycle old kit removed from projects.[22]

CHALLENGES AND POTENTIAL SOLUTIONS

Challenges	Solutions
Concerns over additional programme time and resources needed due to the additional planning required, for things such as developing the lease, working with PaaS providers, and spending more time with the tenant so that they understand the lease requirements.	Calculate the cost savings arising from the avoidance of replacement purchases under a PaaS model.
Tenants not taking care of products, which leads to higher maintenance and repair costs for the owner.	Include requirement under green leases for protection/maintenance of items to ensure they are not replaced too frequently and are handled with care.

Principle 5

Minimise impact and waste

THE PRINCIPLES

A. Use low impact new materials: Any new materials specified in the development are low impact materials with little or no adverse effect on either the environment or human health throughout its lifecycle.

B. Use recycled content or secondary materials: Recognise and encourage the use of recycled content and secondary aggregates, thereby reducing the demand for virgin material and optimising material efficiency in construction.

C. Design out waste: To design out waste over the whole life cycle of the building, so there is minimal waste during the design, construction, deconstruction, and next life of the built asset. Whilst designing out waste is key, it should be noted that when designing for future adaptability and flexibility, it could require over specifying the structure to support additional loadings in the future.

D. Reduce construction impacts: Ensure construction sites reduce on-site waste, including packaging.

CARBON IMPACT

Low-impact materials identified in the case studies did not lead to higher upfront carbon emissions. However, the full WLC of low-impact materials must be considered to ensure there are no unintended carbon impacts required from any frequent replacement or refurbishment cycles.

Using low impact materials can lead to buildings having lower WLC than refurbishing the existing building

- The Enterprise Centre: local natural materials (Norfolk flint), hemp fabric, Sonaspray, Warmcell, clayboard, locally sourced timber frame and straw thatch cladding, solvent free paints, linoleum, linseed and hessian matting on recycled glass screed: overall the project embodied carbon is 65% less than a conventional higher education building (at the time).
- Blackrock street: The use of timber as the primary construction material saved 102kgCO_2e/m^2 (if counting sequestration).

Using recycled content in the cement can result in lower upfront carbon

- The Enterprise Centre: 70% GGBS (Ground-granulated Blast-furnace Slag) in the concrete gave a 62% embodied carbon reduction compared to typical cement concrete.
- 1 Triton Square: An average of 65% cement replaced with GGBS provided upfront embodied carbon savings 665TCO_2e compared to the 30% PFA (Pulverised Fuel Ash).
- The Forge: GGBS 50% in substructure and 40% in superstructure provided a 40% carbon reduction in the substructure and 22% carbon reduction in the superstructure compared to typical cement concrete.
- Cambridge Avenue: Recycled concrete specification saved 200tCO_2e (63kgCO_2e/m^2).

Using recycled paint can result in lower upfront carbon

- The Entopia Building: 165 litres of paint (25% of the paint used) contained 35% recycled paint content, saving around 10% embodied carbon compared to a similar product.

Using recycled flooring can result in lower upfront carbon

- Timber Square: Reclaimed raised access flooring has approximately 20% the upfront carbon compared to new.
- 80 Charlotte Street Fit-out: Recycled content in carpet saved 67kgCO_2e/m^2 of carpeted area (22tCO_2e) than a less environmentally friendly option from the same manufacturer.

Using recycled glass can result in lower upfront carbon

- The Burrell Collection: Using a closed loop glass recycling approach, 16+ tonnes (over 16%) of glass was processed into cullet to produce new architectural glass; saving 5 tCO_2e.

Using recycled plastic can result in lower upfront carbon

- Blackrock street: 100% recycled plastic drainage, formwork and separating joints reduced the need for concrete providing a 17 tCO_2 saving.

Designing out waste is an easy win for carbon reductions, though it can be challenging to quantify. Designing out waste is closely linked to designing for Flexibility and Adaptability and can often aid in disassembly and recoverability, particularly for components or materials prone to changing tastes (e.g., Cat A or B fit-outs where the tenant will make significant changes to suit their style)

- The Entopia Building: Avoided finishes on raised access flooring to reduce embodied carbon; galvanised steel surface floor cleaned up and left exposed in some areas to reduce embodied carbon; (this is linked with reusing the original floor - Reusing existing raised access floor saved 32kgCO_2e/m^2 (or around 85,000kgCO_2 total) compared to using new raised access floor panels).
- 80 Charlotte Street Fit-out: Entire design minimises finishes where possible, using exposed ceilings with acoustic panels and aluminium clad exposed services - saved 346tCO_2e compared to a suspended ceiling.
- JLL office Fit-out: Material obviation, exposed services design avoided use of suspended ceiling, which combined with an acoustic soffit spray delivered acoustic comfort. This achieved a 66% carbon savings compared to fit-out base case resulting from low-carbon flooring finishing products, exposed ceilings, and the reduced amount of internal partitions saving on need for extra finishes.

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Shortened construction programmes have the potential to reduce site impacts which can potentially be achieved through standardisation:

» Timber Square: Dry construction techniques, minimising wet trades on-site e.g., Raised-access flooring with minimal screeds. Minimisation of internal materials such as omission of a full suspended ceiling. A pre-demolition survey has been undertaken by Erith to investigate how recycling of any demolition and excavation material can be maximised: construction impacts reduced about 50% compared to typical office.

» The Forge: offsite manufacturing reduces material waste on site.

FINANCIAL VALUE IMPACT

Where an external or internal carbon price is being used, cost savings can be recognised through minimising impact and waste

» Magnitude 314: reduced offsetting costs to meet the UKGBC Framework for Net Zero in Construction.

» Holbein Gardens: The inclusion of circular principles is expected to lower the cost of carbon offsetting once complete.

Designing out waste has close links with designing for optimisation, as minimalist designs lend themselves to greater flexibility and adaptability in the future. This reduces upfront construction costs while also representing a marketing opportunity for greater space utilisation

» Canal Reach: designed out waste by having an exposed structure which reduced the need for short life finishes in tenanted areas; this had minimal / no impact on costs.

NON-FINANCIAL VALUE IMPACT

Job creation (e.g., using locally sourced and grown low impact materials)

» The Enterprise Centre: 300 jobs created or safeguarded through the use of circular approaches and by procuring low impact materials.

» Blackrock street: 75% labour and 50% of subcontractors from within 10 miles of the site.

Supporting local suppliers

» The Enterprise Centre: sourced materials almost exclusively from local suppliers with lots of materials from local sources (Norfolk Flint, Suffolk and Norfolk straw and reed, Thetford Forest Timber).

» Blackrock street: 75% of materials were locally sourced.

Increased health and safety of the manufacturing and demolition process and better community relationships

» The Entopia Building used the Considerate Contractors Scheme to mitigate any negative impacts on their workers and the community during construction.

Low impact materials can contribute towards green rating schemes and increase health and wellbeing

» 80 Charlotte Street Fit-out: Targeting WELL Gold and BREEAM Excellent for refurbishment and fit-out.

Pleasant spaces for occupants designed with wellbeing in mind

» 80 Charlotte Street: Arup Ground floor to lower ground central staircase made of CLT rather than steel, saving 3.8-4.2tCO_2e and acting as a key social hub that is enjoyed by employees.

The use of low impact materials can lead to benefits from better health & wellness

» Magnitude 314: Used low VOC paints to contribute to a WELL rating.

Educational opportunities

» JLL Fit-out: kitchen tabletops made with recycled yogurt containers are a talking point.

» The Enterprise Centre: Won numerous awards for its design and the building is now a demonstration of what can be done with natural and reused materials.

Health and well-being benefits in flexible spaces that encourage movement, which can be a part of fit-out strategies when designing out waste

» JLL office Fit-out: active workspace design with reduced desk ratios to encourage movement. Technology is helping to measure the success of the design via 80 occupancy and 14 environmental sensors measuring the office space in real time. Utilisation of dashboards which showcase environmental conditions are located throughout the office enabling their employees to find the best space for their needs.

CHALLENGES AND POTENTIAL SOLUTIONS

Challenges	Solutions
As minimising impact and waste may be a diversion from the norm, there could be fewer options and availability for low carbon materials which can have a cost uplift (especially if combined with design for disassembly) and longer programme implications.	Liaising with manufacturers and contractors earlier will make it easier to understand availability and opportunities for low impact materials that don't add to cost and programme; alternative options are also often not explored as procurement is discussed too late. Early engagement was key to the success of **The Forge** and **The Entopia Building** projects. **The Enterprise Centre** was an experimental project to test low impact materials, but the final price of £2700 cost per m^2 GIA did not differ significantly from BAU.
Potential for extended programme time through use of materials that minimise impacts. e.g., concrete with high levels of GGBS can have a longer curing time than regular cement.	Explore opportunities for other circular design strategies to make up for any extended programme requirements. In **The Forge**, the PDfMA propping system meant that the building could be move upwards whilst the GGBS was curing, while in **The Enterprise Centre**, the timber frame sped up delivery.
Reducing the amount of plastic packaging can constrain supply and choice. This can potentially have knock on effects if products are damaged due to improper packing which could create more waste.	Specify manufacturers with take back services for packaging.
Lower impact materials are thought to be pricier.	This will be product specific, and higher upfront costs may be outweighed by other benefits (e.g., health / lower VOC).
Tenants and letting agents still wish to have fitted-out interiors to view during marketing, despite these fit outs often resulting in unnecessary costs and carbon.	Some methods to save costs and avoid fit-out waste can include avoiding carpets that may be changed in future and designing one floor as a marketing floor while leaving the others empty. Virtual reality headsets can also be used to avoid any physical fit-out for marketing.

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Conclusions

The Net Zero WLC Roadmap shows that the UK built environment can be net zero carbon by 2050 and that in order to do this both embodied and operational carbon must be reduced to almost zero, and circular economy principles are an important part of the solution.

The case studies in this report demonstrate that many new and existing building projects have already used circular economy principles and are able to evidence associated reductions in carbon. This impact was most clearly seen through the reuse principle, and a range of impacts on financial and non-financial value were also identified across all the principles. This demonstrates that circularity benefits not just carbon reduction, but a much broader set of organisational, social, environmental, and financial aspects.

However, the case studies and task group also identified that measuring the impact created by the application of circularity is infrequent, inconsistent, and difficult. One solution identified was to have a commonly accepted and applied set of metrics and methods to measure both the WLC and circularity of projects. Important to both of these, and the aim of increasing circularity and reducing WLC, is Module D, which covers the potential benefit of recovery, reuse or recycling of components and materials after the end of their use on a building. The specific issue is how best to calculate and attribute the carbon savings between the donor and new building.

Many individuals and groups are working to improve clarity and consistency on these issues. This includes an updated version of the RICS Whole Life Carbon Assessment for the Built Environment that is due to be published in 2023, the UKGBC Circular Economy Forum working to identify a set of circular economy metrics, and significant discussions within this project's task group and beyond on Module D.

5

Case studies

- A - 1 Triton Square
- B - 55 Great Suffolk Street
- C - 80 Charlotte Street
- D - The Bartlett School of Architecture
- E - Blackrock street
- F - The Burrell Renaissance project
- G - Cambridge Avenue
- H - Canal Reach
- I - The Enterprise Centre
- J - The Entopia Building
- K - Exchange House
- L - The Forge
- M - Holbein Gardens
- N - JLL Manchester Office Fit-out
- O - Magnitude 314
- P - Roots in the Sky
- Q - The Royal Bank of Scotland
- R - Timber Square

Case studies

There are 18 case studies referenced within this report and available in full on the UKGBC Solutions Library. Five of the case studies are provided here in more detail. They were chosen based on the availability of data for the projects and to provide a mix of building type, location, and circular economy principles used.

Name	Year complete	Sector	Size	Type	Location
1 Triton Square	2021	Office	47,170m^2	Deep Retrofit	London
55 Great Suffolk Street	TBC 2023	Office	1,412m^2	Deep Retrofit	Southwark, London
80 Charlotte Street	2020	Mixed use (Office, Residential, Retail)	35,300m^2	Refurbishment	Fitzrovia, London
The Bartlett School of Architecture	2016	Higher Education	9000m^2	Deep Retrofit	Bloomsbury, London
Blackrock street	2021	Residential (Social Housing)	22 Dwellings	New build	Manchester
The Burrell Renaissance project	2022	Museum	12,374m^2	Deep Retrofit	Glasgow
Cambridge Avenue	2014	Warehouse and Office	3,284m^2	Re-Build	Slough
Canal Reach	2021	Office	54,000m^2	New Build	Kings Cross, London
The Enterprise Centre	2015	Higher Education	3,400m^2	New Build	Norwich
The Entopia Building	TBC 2022	Higher Education	2,939m^2	Deep Retrofit	Cambridge
Exchange House	2021	Office	6000m^2	Sharing materials onward for reuse	Broadgate, London
The Forge	TBC 2022	Office	42,367.2m^2	New Build	Southwark, London
Holbein Gardens	TBC 2022	Office	2,323m^2	Refurbishment	Belgravia, London
JLL Manchester Office Fit-out	2020	Office	1,291m^2	Fit-out	Manchester
Magnitude 314	2020	Warehouse and Office	27,577m^2 Warehouse and 1,539m^2 Office	New Build	Milton Keynes
Roots in the Sky	TBC 2025	Office	38,550m^2	New Build with part-retention	Southwark, London
The Royal Bank of Scotland	2020-2021	Office	N/A	Sharing materials onward for reuse	Edinburgh
Timber Square	TBC 2024	Office and Retail	33,430m^2	Deep Retrofit with part New Build	Southwark, London

Case studies

1 Triton Square

Year: 2021

Sector: Office

Scale: 47,170m² / 507,735ft² (GIA/IPMS 2)

Type: Deep retrofit

Project Team: British Land (Client), ARUP (architecture, façade, and engineering), M3 Consulting (Project manager), Lendlease (Main-Contractor), AECOM (Cost Consulting, Employers Agent), Gartner (Façade Contractor)

The original 1998 structure required updating as it was no longer fit for purpose. By retaining the original structure, a significant upfront embodied carbon saving could be made which led to the exploration of how circularity could enable larger carbon savings through marginal gains.

CIRCULAR ECONOMY DRIVERS:

» Whole life carbon reduction: Initially driven through cost savings and programme time, the design team realised once the design of the refurbishment has commenced that the frame had the capacity to take on additional floors and would not need to be demolished; an extension could be added on. After that, reducing embodied carbon and whole life carbon became a major driver.

CIRCULAR PRINCIPLES WHOLE LIFE CARBON IMPACT:

Total embodied carbon savings of 25,000tCO_2e, a 54% saving compared to British Land benchmark. Whole life carbon (Modules A-C) carbon intensity is 448kgCO_2/m², calculated via eTool

1a) Reuse the existing asset: A substantial amount of the existing structure was retained, including 88% of the substructure; by removing the thermal cores of the building to exclude the staircases on each corner, operational energy efficiency has also increased.

» Carbon fibre concrete wraps were used to strengthen existing columns rather than adding additional columns.

» 3300m² limestone, 35,000 tonnes of concrete, 1877 tonnes of steel retained in the original structure amounting to 45% of the total carbon saving.

1b) Recover materials and products on site or from another site: 3000m² of the panelised façade reused

» Reusing the façade led to 2400tCO_2 (A1-A3) saved compared to a new façade; 70tCO_2 (A4) saved through transport emissions by refurbishing panels in a factory in Essex rather than in Germany.

» 2800m² of paving and other roof covering were reused from other demolished buildings leading to 10tCO_2e saved compared to baseline.

2d/3) Design for assembly, disassembly and recoverability, and Use standardisation; the new extension includes a demountable M&E kit and standardised products enable disassembly and recoverability.

» This had a negligible impact on carbon.

5b) Use recycled content or secondary materials: An average of 65% cement replaced with GGBS

» This provided upfront embodied carbon savings of 665tCO_2e compared to the 30% PFA which was assumed at design stage 3. This gave 45% carbon saving compared to the original 30% cement replacement.

FINANCIAL IMPACT:

Overall project: 15-18.5% cost savings compared to new build

1a) Achieved savings of around £3,000,000 to £5,000,000 from reusing the existing sub and super structure. A new build programme would have added on at least 6 months to a year of additional works (30% extended programme).

1b) Overall façade saving achieved for the retained elements was around £2,000,000 (10-20% cheaper than new façade) this is in part due to time savings.

2d/3) Negligible cost impact.

5b) Some cost savings for using GGBS instead of regular cement.

VALUE:

Overall project value, to which circular principles contributed to:

» Biggest pre-let in the London west end in over 20 years.

» BREEAM Outstanding.

» 9 local apprentices placed with subcontractors at Triton.

» In total 63 local students/residents were offered work experience opportunities. Through Covid-19 we adapted our offering to develop a week-long virtual work experience in partnership with Argent/ BAM and Regents Place.

» 9,386 sq. ft landscaped public realm.

» 7 Kickstart opportunities advertised; over 50 have been secured over the year.

Case studies

1 Triton Square

- 13 site visits were offered to local schools and community partners – 81 people took part.
- The team volunteered 840 hours across the project.
- £32,000 raised and donated to charities by the Construction team.
- Over 780 students engaged with in the borough through our school engagement programmes.

KEY LEARNINGS:

- **Challenge assumptions:** Assumptions in the carbon calculation tool used are unable to include mechanical and electrical replacement cycles in module B. The tool also was not well adapted to cope with elements of circularity, such as reusing substantial components of the building and the use of cement replacement at different levels (as it has set percentages for cement replacement which did not match those used on project); these assumptions had to be adapted for the tool to provide accurate calculations.
- **Be flexible:** The client switched contractors to one willing to collect data that would enable verification of the carbon savings that needed to be achieved on this project.
- **Collaborate:** The design team collaborated with the client to reduce the extent of the structural works to an absolute minimum by undertaking in-depth design studies which allowed for the re-use of most of the existing structural frame.

Case studies

The Entopia Building

Year: TBC 2022

Sector: Higher Education building

Scale: 2,939 GIA m^2

Type: Deep retrofit

Project Team: Cambridge Institute for Sustainability Leadership (Client). Architype (Architect Stages 1-3, Passivhaus designer Stages 1-3), Feilden + Mawson (Architect Stage 4 onwards), ISG (Contractor), 3PM (Project manager), MEAD (PH certifier), Gardiner and Theobald (Cost Consultants), Max Fordham (M&E Engineering Stage 4 onwards, Passivhaus designer Stage 4 onwards, Acoustics Stage 4 onwards), BDP (M&E Engineering Stages 1-3, Acoustics Stages 1-3, Structural Engineering Stages 1-3 and BREEAM and WELL consultant all Stages), CAR [Cambridge Architectural Design] (Structural Engineering Stage 4 onwards)

This 1930's telephone exchange aims to be an exemplar demonstrator building for sustainability principles. The original structural frame has been retained for a fabric first deep retrofit approach along with extensive reuse of materials from the site and other sources to lower embodied carbon.

CIRCULAR ECONOMY DRIVER:

- Whole life carbon reduction: Exploring how to maximise whole life carbon reduction on a deep retrofit with the same cost and time as a new build and create a demonstratable case study of a sustainable building.

CIRCULAR PRINCIPLES AND THEIR WHOLE LIFE CARBON IMPACT:

- Overall, an 80% saving in whole life carbon emissions (over 10,000 kg CO_2e/m^2) is expected across the building's assumed 100-year lifespan, compared to a standard office refurbishment.
- The overall project embodied carbon is 408 $kgCO_2e/m^2$ (Modules A1-5, B1-5, C1-4) for all the newly added materials, including the ongoing maintenance and replacement and end-of-life of existing retained fabric (although excluding the A1-A5 emissions as well as any B1 carbon absorption associated with the existing retained fabric) across the building's assumed 100-year lifespan.
  - Note that this excludes fit-out emissions (calculations in progress).
- 130$kgCO_2e/m^2$ upfront embodied carbon, achieving the LETI target of <300$kgCO_2e/m^2$.

1a) Reuse the existing asset: Original building sub and super structure / envelope retained

- Estimated that the retention of the existing building structure, and upgrading it to EnerPHit standard saved around 60% of the embodied carbon compared with demolishing the existing building and building a new building of the same size to the LETI 2030 target of 350$kgCO_2e/m^2$ (285/535 = 53% of original carbon in structure retained).
- Estimated that the existing building would have had an upfront carbon (Modules A1-5 excluding sequestration) of around 535$kgCO_2e/m^2$ already invested in it, and if it was demolished, this 'carbon investment' would be lost, along with generating considerable end-of-life carbon, plus upfront carbon for a new build. Instead, some limited elements (single glazed windows, finishes, MEP services) were removed, and 130$kgCO_2e/m^2$ upfront carbon (Modules A1-5 excluding sequestration) added to the building through the refurbishment works.
- Repaired brickwork and roof tiles from original stock (this includes structure, repaired brickwork and roof tiles from original stock).

1b) Recover materials onsite or from another site:

- 350 light fittings recovered from another site to be retested and re-warrantied with few alterations.
- Reusing existing raised access floor across most of the building; 32$kgCO_2e/m^2$ (or around 85,000kgCO2 total) saved compared to using new raised access floor panels.
- Steel structure for the PV canopy was built using 3.79 tonnes of reused steel sections, saving at least 2,000 $kgCO_2e$ of embodied carbon.
- Original oak reception desk and Cabling were reused.
- Carpet tiles were retained, cleaned, and reused for approximately 12% of the building's floor area; compared with replacing with new carpet tiles, this saved 2.4$kgCO_2$ /m^2 (or around 7,000 $kgCO_2e$ total) of embodied carbon.

1c) Share materials onwards:

- Excess furniture shared onward through CollectEco - 21,648kg furniture shared onwards from the site (donated). Thus avoiding 21,648$kgCO_2e$ (equivalent CO_2 to buying new), and a £100,225 value donation to the community.

2d) Design for assembly, disassembly, and recoverability:

- 3D printed lights which can be sent back at end of life to be re-printed as new fittings (used in reception area, some track lights, pendants in main areas and toilet core areas).

5a) Low impact materials:

- 35% by mass biobased specification – including Sonaspray K-13 acoustic cellulose insulation, Gutex woodfibre insulation, Diathonite plaster with cork granules, hemp fibre insulation, Warmcel cellulose insulation and linoleum.

5b) Use recycled content or secondary materials:

- 165 litres of paint; 25% of the paint used contained 35% recycled content (saving around 10% embodied carbon compared to a similar product).

5c) Design out waste:

- No new floor finishes in exposed areas to reduce waste; galvanised steel surface floor has been cleaned up and left exposed in most open plan areas to reduce embodied carbon (linked with 1b and reusing raised access floor).

5d) Reduce construction impacts:

- Minimum of 85% of construction waste from landfill, finding alternative options for the following wastes:
  - Wood off-cuts are sent to panel board manufactures or to biomass burners for waste to energy.
  - Ferrous and non-ferrous metals are bulked up and sent to European Metal Recycling Ltd.
  - Cardboard and paper are separated, baled, and sent to Cycle Link International.
  - Mixed rigid plastics are separated, baled, and sent Monoworld Recycling Ltd.

FINANCIAL IMPACT:

- Overall project: estimated 4-8% uplift compared to standard Part L retrofit, but is still subject to cost benchmarking, RIBA Stage 4 October 2020 – June 2022 (approx. 20-22 months, similar to new build).
- Marketing for the University of Cambridge, CISL, and the companies involved in the retrofit.
- ~70% of extra costs attributed to limited understanding of the building's condition, until contractors appointed.

ADDITIONAL VALUE:

Overall project:

- On track for WELL Gold rating, BREEAM Outstanding, EnerPHit Classic.
- Establishing new confidence in the university to deliver net zero carbon buildings.
- Considerate construction scheme.
- Sharing materials onwards has a positive socioeconomic impact.
- Learning vehicle for students.
- Some funding came from a guarantee that this would be an exemplary home for green and sustainable businesses (European Regional Development Fund).
- Set planning precedent for sustainability changes to buildings in conservation areas.

KEY LEARNINGS:

Challenges:

- **Trade-offs with operational energy reduction:** Some tensions between making the building as energy efficient as possible and the aesthetics as it is situated in a conservation area, but the savings in operational energy from the fabric first approach are vast and the build is currently on track to cost marginally more than a standard fit-out.
- **WLC calculation:** Lack of data around the carbon contained in some products (especially when looking at MEP services), the calculation methodology itself, and understanding which assumptions to use within the calculations lead to a peer review process to ensure that everything had been accounted for correctly. Some ambiguity in the calculation of module A5; Entopia took the approach of calculating material wastage for each material/assembly based on WRAP data, as well as adding an overall site activities allowance, based on project value (RICS 1400kgCO_2e/£100k).
- **Programme time:** The lack of full surveys and opening up meant that elements of the construction, such as the extent of the precast planks, were only discovered once on site. The concrete columns were in worse condition than anticipated, and some steel ones were encased in concrete. Time added to programme due to redesign from not having the original plans, which could have been shorter if the building had been opened up earlier. This is difficult to do as the client does not want to open the building if they do not know if they can afford the refurbishment.
- **Harmful materials:** Asbestos, delamination, leaching of products through the sonaspray, waterproofing issue, exposed rebar which had to be covered due to fire safe columns, beams were in poor condition –embodied carbon added to get these aspects up to standard.
- **Limited materials available** – niche suppliers, risk to ISG (contractors). Some tended to be smaller manufacturers which meant it could be difficult to get the quantities needed for this job.

STRATEGIES:

- **Referencing Science Based Targets that local authorities have signed up for:** This can help with conservation issues that might otherwise prevent achievement of sustainability targets. The Cambridge council conservation team wanted to preserve the look of the Georgian style windows, limiting natural light and operational energy efficiency; ongoing discussions to ensure the windows could be changed which was achieved in the end as Cambridge had signed up to science-based targets.
- **Finding examples to show clients:** There were hesitations around reusing the raised access flooring and exposing it as a finish, which could save a lot of carbon. The client was shown a similar example and they approved the flooring. Frequently, elements of fit-outs are removed for style purposes which needs a culture change in industry.
- **Communication was key:** Understanding where price increases might come from and explaining to the client why prices might be higher so they can prepare can help prevent unexpected price increases; this prevented needless risk price increasing and the very detailed programme also allowed them to understand where costs come from.
- **Early engagement:** The contractors were engaged from RIBA Stage 3 under a pre-construction services agreement. Difficulties, longer programmes, etc. were more easily managed.
- **At RIBA Stage 1, obtain a second opinion on the cost estimations:** The quantity surveyors estimated it would be a 25% premium, but the team agreed at stage 3 that this was unlikely to be the case. The overall cost uplift is estimated at about 4-8%. These misunderstandings come from limited benchmarks as there are not enough projects being done to inform comparison, particularly for Stage 1 (highly hypothetical data at Stage 1).

80 Charlotte Street

(including Arup Fit-out)

Year: 2020

Sector: Mixed use (office, retail, residential)

Type: Deep refurbishment

Scale: 35,300m^2

Project Team: Derwent (Client); Make (Architects); Multiplex Construction Europe Limited (Contractor); ARUP (Engineering)

80 Charlotte Street is an all-electric building in central London which reuses some of the original 1960's building.

CIRCULAR ECONOMY DRIVER:

- Upfront carbon reduction: Overall project driver was primarily to reduce operational carbon, but CE principles applied where possible to reduce upfront embodied carbon.

CIRCULAR PRINCIPLES AND THEIR WHOLE LIFE CARBON IMPACT:

Overall project:

- » Embodied carbon at practical completion: 506 $kgCO_2e/m^2$ (19,790 tCO_2e).
- » Embodied carbon at practical completion (including tenant fit-out but excluding furniture, fittings, and equipment data): 665 $kgCO_2e/m^2$ (26,719 tCO_2e).
- » Embodied carbon over the life cycle (Modules A-C): 1,025 $kgCO_2e/m^2$ (941,155 tCO_2e).
- » Whole life carbon (A-C): 1,650 $kgCO_2e/m^2$.
- » Measured with OneClick LCA and Arup PECC tool.

1a) Reuse of the existing asset: 30% of the original structure retained.

1b) Recover materials onsite or from another site: Reused elements of the Façade.

2a / 2c) Design for longevity and adaptability: Basic steel structure with concrete pre-cast planks enables resiliency against climate change and future uses. A 500-600mm leaner floor sandwich meant they could add in another floor.

3) Use standardisation: Prefabrication of the façade with pre-cast modular installation led to reduced waste and construction impacts–structural elements such as pipework risers and soffits.

5b) Use recycled content or secondary materials: Low embodied carbon for concrete with fly ash replacement (40%); low embodied carbon product selection for finishes: gypsum plasterboard, paint, ceramic tiles; low embodied carbon blockwork; prioritisation of timber framing against steel for internal walls.

FIT-OUT - ARUP

- » 38% lower embodied carbon than the benchmark (circa 1000$kgCO_2e/m^2$) for an office building[23].

1b) Recover materials onsite or from another site: Reused furniture from old site saving 31tCO_2e in the fit-out compared to new.

2d) Design for disassembly: Short life components (expected life up to 25 years) such as finishes and building services to be designed with reusability and recoverability in mind.

5a) Use low impact new materials: Balustrade and stairs on the Ground floor to Lower ground floor are made with Cross Laminate Timber from France. This created 3.8-4.2tCO_2e savings compared to steel stairs.

5b) Use of recycled content or secondary materials: Recycled content in carpet saved 67$kgCO_2e/m^2$ of carpeted area (22tCO_2e) than a less environmentally friendly option from the same manufacturer.

5c) Design out waste: entire design minimises finishes where possible, using exposed ceilings with acoustic panels and aluminium clad exposed services. This saved 78$kgCO_2e/m^2$ of ceiling (346tCO_2e) compared to a suspended ceiling.

FINANCIAL IMPACT:

- » Overall project: use of circular principles comparable to BAU.

1b) Panels refurbished at pop up factory less than 30 miles away; some additional façade testing costs.

3) Pre-fabrication off-site led to saving in construction time.

VALUE:

3) Use standardisation: Pre-fabrication offsite led to reducing on-site labour and an industry leading safety rate.

OVERALL PROJECT:

- » £1.76 of socio-economic impact for every £1 spent.
- » 5381 people engaged, including local CSCS 100 students.
- » £12,292,632 in local procurement.
- » BREEAM 2014 Excellent at design stage; LEED 2014 Gold, Targeting WELL Gold for the fit-out.
- » Targeting Energy Performance Certificate B rating.

KEY LEARNINGS:

- » Early engagement between the client, architect, consultant team, principal contractor and sub-contractor was critical to ensuring that the stretching sustainability goals could be achieved. This early engagement then allowed for an ongoing open collaboration between all parties throughout the build to ensure any challenges could be solved early in the process.

Case studies

The Forge

Year: TBC 2022

Sector: Office

Scale:139,000sq ft

Type: New build

Project Team: Landsec (Client), Bryden Wood (Architects), Piercy & Company, Gerald Eve, Gardiner & Theobald, Mace, Sir Robert McAlpine (Contractor) // Key Trade Contractors & Suppliers: J Coffey Construction, DAM Structures, N G Bailey, Hotchkiss, Hall & Kay, Aluprof, NACWL, Kone, Tata Steel, Schneider Electric.

The Forge uses Platform Design for Manufacture and Assembly (P-DfMA) to reduce embodied carbon, costs, and shorten the construction programme.The project is on track to reduce upfront embodied carbon (A1-5) by 24% per m^2 compared to the baseline. It also aspires to be the first commercial building to be both constructed and operated in line with the UK Green Building Council's (UKGBC) net zero carbon buildings framework, helped by a 44% reduction in regulated CO_2 against the Part-L baseline.

CIRCULAR ECONOMY DRIVERS:

- The client wanted to test the productivity improvements and apply learnings from manufacturing and construction of applying the platforms approach.
- Landsec want a 15% reduction from stage 3. This is mainly on the contractor to look for lower carbon materials and closer materials– this reduction is post the P-DfMA approach.

CIRCULAR PRINCIPLES AND THEIR WHOLE LIFE CARBON IMPACT:

2b) Design for Flexibility: Other internal furnishings such as suspended ceilings and partitions have also been removed to provide a flexible open-plan space

2c) Designed for Adaptability: future change of use possible with the floor to ceiling height and reversible components

2d) Assembly, disassembly, and recoverability: The use of standard parts with reversible joints means the building can be deconstructed in pieces, extending the life of components for potential reuse.

3) Use Standardisation: The P-DfMA approach uses standardised parts

5b) Use recycled content or secondary materials: GGBS 50% in substructure and 40% in superstructure and specifications of high recycled content in steel and façade:

- The GGBS provides a 40% carbon reduction in the substructure and 22% carbon reduction in the superstructure.

5d) Reduce construction impacts: the offsite manufacturing helped reduce material waste on site.

FINANCIAL IMPACT

Programme implications:

5b) PDfMA propping system enabled ongoing construction whilst the GGBS was curing, shortening delays that may have otherwise occurred with GGBS use.

5d) PDfMA enabled a faster build time and safer work environment as there was reduced working heights.

VALUE:

- Social: Sharing materials onward to local community if they are now not needed in the building, wanted to ensure everything not used goes somewhere useful.
- Recipient of government funding for its innovative approach to building.

KEY LEARNINGS:

- Learning process as new way of building, no-one built like that before.
- Everything designed with health and safety in mind. Soffit fixing was pre-drilled into the slabs, rather than workers having to drill them in after, so there was reduced working at height and no dust fell on construction workers.
- The first few floors took longer but after everything was quicker as the process was repeatable.
- The focus was on finding solutions, and they now know the value of this method.
- Went to look at principal contractors to see who had the most drive to achieve what they wanted and so ended up with two principle contractors.

Case studies

JLL

Manchester office fit out

Year: 2020

Sector: Office

Scale: 1,291 m^2

Type: Fit-out

Project Team: JLL

JLL's Manchester fit-out provided them with the opportunity to implement circular principles and work towards their net-zero targets.

CIRCULAR ECONOMY DRIVER

JLL's internal Net-zero target for 2030: the fit-out provided JLL with the opportunity to implement the embodied carbon reduction advice they are giving, inform their future work and clients, and support their circular advocacy.

CIRCULAR PRINCIPLES AND THEIR WHOLE LIFE CARBON IMPACT

Overall project: 38% upfront embodied carbon saving compared to a standard office fit-out approach; 116KG CO_2e/m^2 achieved compared to baseline of 185kgCO_2/m^2 saving 89,615kgCO^2e.

1b) Recover materials and products on site or from another site: Task chairs refurbished from a major financial firm saving 61% CO_2 and 75% water compared to new chairs. Further, over 500 items were delivered from former office clearance saving 45tCO_2e from emissions associated with waste management.

1c) Share materials onwards: Over 90% of the previous fit-out's furnishings donated or shared onwards, partly though the Business2Schools scheme.

2b) Design for flexibility: 90% of fixtures and furnishings reconfigurable or demountable; A 23% upfront carbon saving came from reusing base-build MEP equipment where possible and from designing out MEP materials and products through adopting an open-plan office design approach (35 less Fan Coil units needed than BAU saving 6,528 kg CO_2e).

3) Use standardisation: Standard size materials implemented to minimise construction waste.

5b) Use recycled content or secondary materials: recycled tabletops and kitchen counters; carpets are made from recycled plastic and unused yarn and ceiling features are made of 70% recycled PET plastic; reused base build MEP equipment.

5c) Design out waste: Material obviation such as the use of an acoustic soffit spray which reduced need for a suspended ceiling by using corrugated steel with concrete on top:

» 66% carbon savings resulting from low-carbon flooring finishing products, exposed ceilings, and the reduced number of internal partitions saving on need for extra finishes.

» 17% carbon savings resulting from designing-out materials and products through adopting an open-plan office design approach, therefore reducing the need of internal partitions.

» 21% carbon savings resulting from active workspace design with reduced desk ratios (1 desk per 1.8 person over traditional 1 desk per person plan) and procurement of reused and remanufactured materials.

» Additional savings due to transportation of less materials, products and waste as well as reduced energy required on-site due to less materials and products installed.

FINANCIAL IMPACT:

» £40,000 cost saving from using second hand furniture packages compared to new products.

» Speed of delivery: Designed, fitted out and delivered in 12 months.

» Cost savings not compared to BAU normally as this was a pilot.

ADDITIONAL VALUE:

» Donation of 90% of previous fit-out materials shared onwards; partly through partnership with Business to Schools charity ensured unused furniture (£30,000) was donated to three schools.

» Overall project: the workspace also incorporates active workplace design via its flexible layout; designed with wellbeing in mind.

KEY LEARNINGS:

» All fit-outs products have an end-of-life plan to enable easier reuse in the future; this is necessary for long term sustainability and to avoid premature waste.

» One of the challenges encountered on this project was the initial team knowledge. To combat this JLL ran training sessions across the whole project team to empower them to find solutions.

» Another area of complication was the lack of embodied carbon data on MEP. Industry must begin capturing this data on a wider level for more accurate WLC assessments, particularly for fit-outs.

» The immaturity of the second-hand market in the UK meant that the traceability of materials could be challenging to track and conflict with the requirements from WELL.

Glossary

BS EN 15978 - *Sustainability of construction works - assessment of environmental performance of buildings - calculation method.* This is the standard which covers the lifecycle stages of a project from raw materials extraction to end of life and disposal or future use. This includes the operation, maintenance, and repair of the materials in the project. In this standard, they have been broken down into different modular components; cradle to gate, cradle to practical completion, cradle to grave, and cradle to grave including benefits and loads beyond the system boundary.[24]

Carbon: 'Carbon' is used in this report to refer to all GHG emissions, set out in BS EN 15978 as Global Warming Potential (kg CO_2 equivalent).

Circular Economy - A circular economy is an alternative to a traditional linear economy (make, use, dispose) in which we keep resources in use for as long as possible, extract the maximum value from them while in use, then recover and regenerate products and materials at the end of each service life.[25]

Circular economy design principles - As defined in the UKGBC Circular Economy guidance for construction clients, these are five key principles which can be applied at RIBA stages 1 and 2 to aid circularity throughout a building's lifecycle.[26]

Embodied carbon - is the total GHG emissions and removals associated with materials and construction processes throughout the whole life cycle of an asset (Modules A1-A5, B1-B5, C1-C4).[27]

Life Cycle Assessment (LCA) - A method for analysing the environmental impact of materials/products/systems/buildings. The environmental impact is expressed by environmental parameters, each of which shows the magnitude of predicted atmospheric pollution, water pollution, soil pollution, natural resources depletion and so on.

Net Zero Whole Life Carbon Roadmap – This sets out a common vision and agreed actions across industry to achieve net zero in the construction, operation, and demolition of buildings and infrastructure in the UK.[28]

Operational carbon - GHG emissions arising from all energy consumed by assets in-use (Lifecycle Assessment Module B6), but with data estimated on an annual basis for each sector (using annual average carbon factors per fuel type).[29]

Refurbishment - as distinct from replacement, is defined as a planned alteration or improvement to the physical characteristics of the building in order for it to cater for the desired future function identified and quantified at the outset. This would typically involve a predetermined change of use at a point during the service life of the project, as well as a sizeable amount of works to several parts of the building.[30]

Retrofit - upgrades or replacements to a building to improve the buildings fabric - this can often be associated with improving the operational efficiency of a building. This report makes a distinction between deep retrofit and light retrofit:

> **Deep retrofit** - Significant works of size or scale that result in a fundamental change to the building structure and/or services. This can be represented as a collection of light retrofit enhancements or individually disruptive measures, such as major plant replacement.
>
> **Light retrofit** - focus on performance optimisation, basic remodelling, replacement, or adaptation of existing building elements which tend to focus on a single aspect or feature (lighting upgrades, optimisation of building controls and operation, etc).[31]

Scope 3 - Greenhouse gas emissions that occur directly due to a company's activities or indirectly from its use of energy are known as scope 1 and scope 2 emissions, respectively. All other greenhouse gas emissions that occur due to its activities, but which it has no direct ownership or control over, are known as scope 3 emissions.[32]

Upfront embodied carbon / upfront carbon emissions - the carbon emissions associated with the materials used and construction processes in the build stage (Module A1-A5) of the building's lifecycle. Upfront carbon excludes the biogenic carbon sequestered in the installed products at practical completion.[33]

Whole life carbon (WLC) – The sum total of all asset-related GHG emissions and removals, both operational and embodied over the life cycle of an asset including its disposal (Modules: A1-A5; B1-B7 (plus B8 and B9 for Infrastructure only); C1-C4). Overall WLC asset performance includes separately reporting the potential benefit from future energy recovery, reuse, and recycling (Module D).[34]

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