BUSINESS IN THE COMMUNITY

The Prince's Responsible Business Network

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ADVANCING CIRCULAR CONSTRUCTION

Case studies from the building and infrastructure sectors

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Foreword

While the operational energy efficiency of new buildings in the UK has been improving, progress on embodied carbon, the lifecycle emissions of the materials and components within buildings, has been much slower. Last year's Completing The Picture report by the Ellen MacArthur Foundation shows that adopting circular economy approaches within just four key materials of cement, steel, plastic and aluminium could lead to a 40% reduction in emissions in 2050 compared to the business-as-usual scenario. The built environment currently uses almost half of all materials that are extracted from the earth each year so much of this potential reduction in emissions will depend on the sector doing things differently.

Doing things differently can be difficult, and with long implementation periods and often rigidly structured project planning the construction and property sectors have proved to be particularly slow to respond. But as we think about how to build back from the Covid-19 crisis, let's use the opportunity to do it better. The case studies which we present in this document offer a glimpse at what the future of construction and infrastructure could be. Unfortunately, such examples are still the exception in the UK. By highlighting the benefits and value these approaches bring we hope to accelerate the pace and scale with which the sector uptakes such techniques.

I am extremely proud of JLL's new Manchester office which we completed earlier this year and have used to prove the concept of a circular fit-out. We have seen first-hand, as well as hearing from clients, that having an environmentally friendly building is not purely an exercise in altruism but that there is real added value to be gained especially in attracting and retaining talent.

Having zero or positive impact on the planet is a demand by the younger generations which we simply must meet. We have got a long way to go but learning about innovative projects which meet this challenge is one of the highlights of my role. I hope that the examples which we feature here will inspire you as much as they have me, and I look forward to hearing how these ideas are adopted in other projects and what further ideas they spark.

Guy Grainger

Chair of Business in the Community's Circular Economy Taskforce and Chief Executive Europe, Middle East and Africa, JLL

Building a circular economy in construction and infrastructure

The construction, demolition and excavation sectors consume huge volumes of natural resources and create 60% of the UK's landfill waste, as well as contributing around 40% of the UK's total carbon footprint; we urgently need to rethink the design and construction of built assets to overcome these impacts.

The circular economy is a system designed to maximise the value of products and materials while in use, then to recover and repurpose them at the end of their lives, ultimately eliminating waste. This approach reduces demand for finite natural resources, lowering carbon and regenerating natural systems.

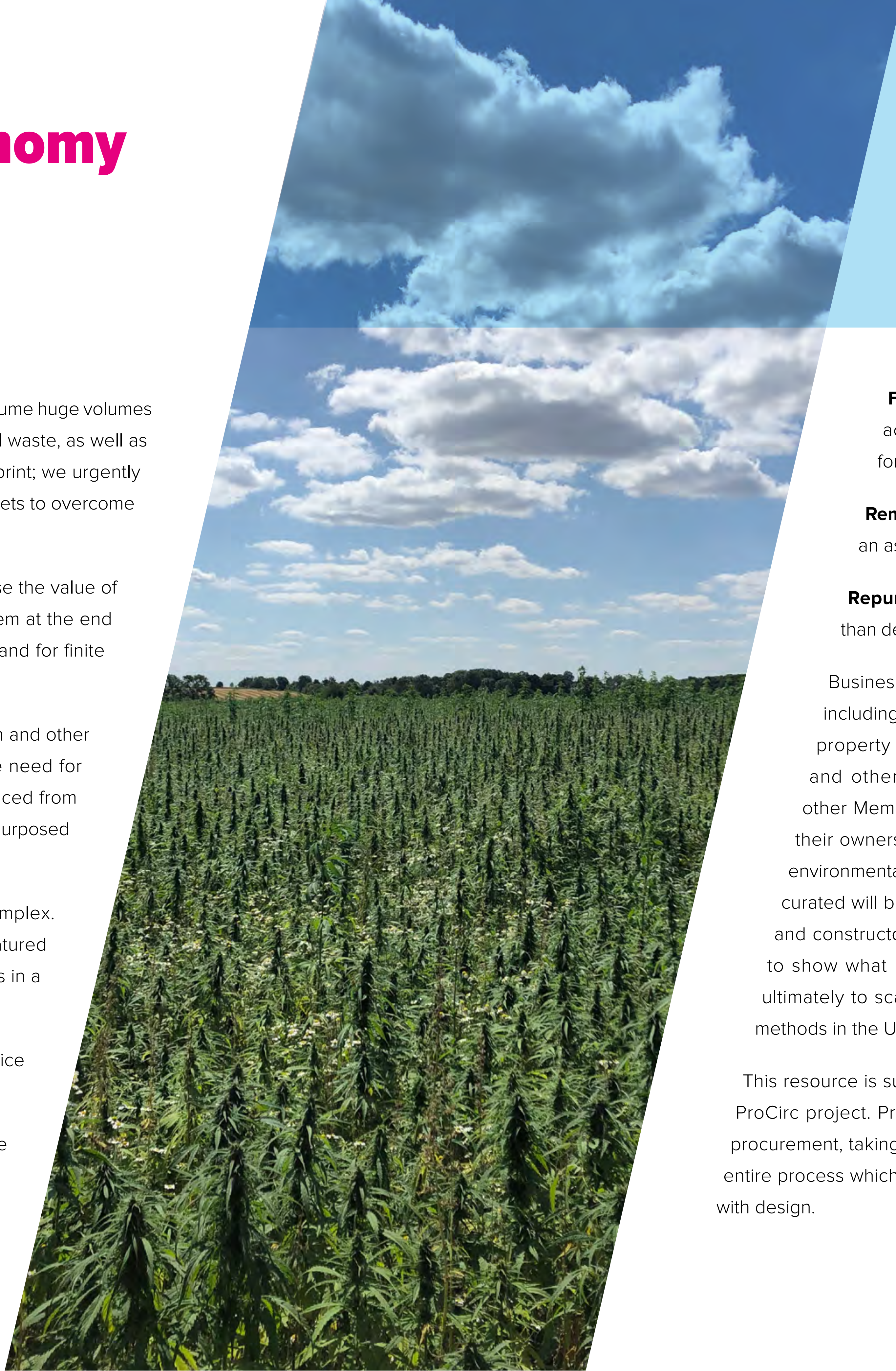
Applied to the built environment sector, this concept reduces the carbon and other lifecycle environmental impacts of building projects by eliminating the need for carbon intensive new building materials which would instead be produced from renewable sources, or else materials and components are reused and repurposed continuously.

Conceptually the circular economy is simple, but its application is complex. There is no one way to 'do' circularity in the built environment. Our featured case studies show the benefits of applying a variety of circular principles in a range of project types.

Approaches taken in these case studies which we consider as best practice include:

Carbon positive materials from renewable sources, sequestering more carbon than they emit

Design for deconstruction allowing components to be segregated for reuse



Flexible spaces which are designed to accommodate changing user requirements for the building

Remanufacturing previously used products into an as-new items which come with a warranty

Repurposing existing building structures rather than demolishing and replacing with a new building

Business in the Community has over 750 members including construction and infrastructure companies, property management firms, housing associations, and others in the built environment sector. Many other Members have buildings commissioned, or else their ownership or use of buildings is a highly material environmental impact. The evidence base which we have curated will be used to engage new audiences of clients and constructors in the concept of the circular economy, to show what is possible, inspire new approaches, and ultimately to scale up the application of circular economy methods in the UK built environment.

This resource is supported by The Interreg North Sea Region ProCirc project. ProCirc aims upscale circular approaches to procurement, taking a holistic view of procurement as being an entire process which, in the context of built environment, begins with design.

JLL: LANDMARK OFFICE MANCHESTER

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Location: Manchester

Project type: Fit-out

Building type: Office

Circular principles being addressed: Reuse (including refurbishment and repurpose) / Design buildings for flexibility and optimisation / Servitisation and leasing / Design and construct responsibility

Key Impact: 62 tonnes of carbon saved through circular approaches in fit-out

CIRCULAR

Overview

JLL is a leading global professional services firm that specialises in real estate and investment management. With 94,000 employees, 280 corporate offices and operations in more than 1,000 locations in 80 countries, JLL helps shape the future of real estate for a better world by using the most advanced technology to create amazing spaces and sustainable real estate solutions.

In the UK, JLL's Manchester office is one of the largest outside London and needed to provide a market leading presence as a property advisory firm. Relocation from the previous office was recommended to greatly improve the workspace for our staff and to act as a sustainable showcase for our clients. After a market search in March 2019, JLL designed, fitted out and delivered a new workplace in just 12 months.

The objective was to deliver a sustainable, inclusive workplace that embedded wellbeing in its design. There was a further objective of embedding circular economy principles into the fit-out and incorporating energy efficiency in line with JLL UK's Net Zero Carbon and JLL's global science-based target commitments.

The opportunity

JLL wanted to create an exemplar for its clients to showcase how circularity and health and wellbeing can be brought to life in an office environment.

The market norm for office fit-outs is to design from a principle where visual impact and function are the sole measures of success for new products procured, and limited consideration is given to how to limit or remove virgin materials. This project created the opportunity for JLL to design and implement a fit-out that would deliver against its 2020 UK circular economy target and its 2030 UK Net Zero Commitment, while also incorporating active workplace design.

"The office was purposefully designed to showcase how circularity can be brought to life"

In addition to SKA Gold, which is required on all JLL UK fit-out projects, the new Manchester office is also targeting BREEAM Excellent for fit-out and WELL certification for fit-out.

What Was Done?

A flexible fit-out design has enabled JLL to reconfigure the floor plate to meet future needs. This was achieved through using low tack adhesives which allow meeting pods and kitchen island to be moved as required. Collaboration spaces adjacent to meeting rooms can easily be converted into meeting rooms via a single glass partition and door.

A key element of the strategy was to upskill JLL's own staff and wider project team in their understanding of the circular economy to enable the team to embed these principles into the design, procurement and the fit-out itself, as well as to advise their clients on best practice. This led to some design decisions being reconsidered. For example, the original proposal for a ceiling feature was replaced with an alternative with high recycled content and which meets the lifecycle requirements of the project.

Where new products had to be installed, they were required to either have longevity and end-of-life management embedded in their design or, alternatively, to use upcycled materials. For example, Cradle to Cradle Interface flooring was procured which, when needing to be replaced, will be recycled by the manufacturer to produce new flooring. JLL also purchased recycled plastic boards from

Smile, which are made from recycled yoghurt pots and plastic packaging, to use as desktops in reception, the kitchen, and meeting rooms.

“The project maximised financial and social value from items and materials in previous office”

Over 190 reused and remanufactured furniture items were supplied by Rype Office. These products are indistinguishable from new and delivered a carbon reduction of 9.3 tonnes compared to newly manufactured products. JLL also reused Audio Visual (AV) equipment and table frames from its previous office and repurposed glass table-tops, which were laser cut and now serve as signage in the new office.

Any new AV equipment was procured through a leasing model. This has retained capital on the balance sheet, outsourced the obsolescence risks and increased JLL’s flexibility to respond to future technology demands without additional capital costs. The provider will maximise the value of the AV asset at the end of the lease, selling to the secondary market, supported by a refurbishment service and warranty for future owners.

JLL also sought to maximise the value and social benefits of items cleared from the previous office which are no longer required. In total, over 500 items including furniture and IT equipment were delivered and donated from the JLL site through Crown Workspace, a workplace solutions provider, and Business2Schools, a community partner, achieving 45 tonnes of CO_{2e} savings and diverting c15 tonnes of products back into reuse. This contributed to achieving reuse on over 90% of the products from the previous office.

Lessons learnt

It was found that embedding circular economy principles while simultaneously achieving the requirements of the WELL certification was challenging where specific ratings or products are required under the standard. Through consultation and detailed discussion this was largely addressed but it was very time consuming.

Additional lessons from the project which would be beneficial for future projects include:

- Sourcing a building at an earlier stage to influence the tenant's fit-out specification (Cat A) and avoid retrofitting
- Exploring additional 'product as a service' models eg lighting and flooring which lend themselves well to secondary markets
- Prioritising a circular brief over a design-led brief for deciding what items of furniture are required as some products could not be sourced from a circular supplier
- Ongoing education of internal teams is required to embed circularity into project cycles at an early stage

Impact measurement

JLL UK's Net Zero commitment stated that it will seek to halve the embodied carbon of fit-outs. JLL has sought to quantify the CO_{2e} savings based on verified data attributed to reusing products, both in the new office and in external projects.

Impact	Data
Materials recycled	15.3 tonnes: fit-out materials 15 tonnes: steel storage from existing office clearance materials
Materials reused	2.5 tonnes: products resold from previous office clearance 15 tonnes: 500 furniture products reused via Business to Schools 1.93 tonnes: 107 products purchased through Rype Office
Materials remanufactured	1.3 tonnes: 88 chairs remanufactured through Rype Office
Carbon footprint savings	8.05 tonnes CO_{2e}: products resold from previous office clearance 45 tonnes CO_{2e}: Business to Schools furniture donations 5.7 tonnes CO_{2e}: purchasing previously used products through Rype Office 3.5 tonnes CO_{2e}: remanufacturing chairs through Rype Office Total: 62.25 tonnes CO_{2e}
Social impacts	Furniture worth £30,000 donated to schools through Business2Schools
Cost savings	£47,300 vs buying new

MARGENT FARM: FLAT HOUSE

MARGENT FARM: FLAT HOUSE

Location: Cambridgeshire

Project type: New build

Building type: House

Circular principles being addressed: Standardisation or modularisation / Design and construct responsibility

Key Impact: 2.32 tonnes of carbon removed from the atmosphere annually

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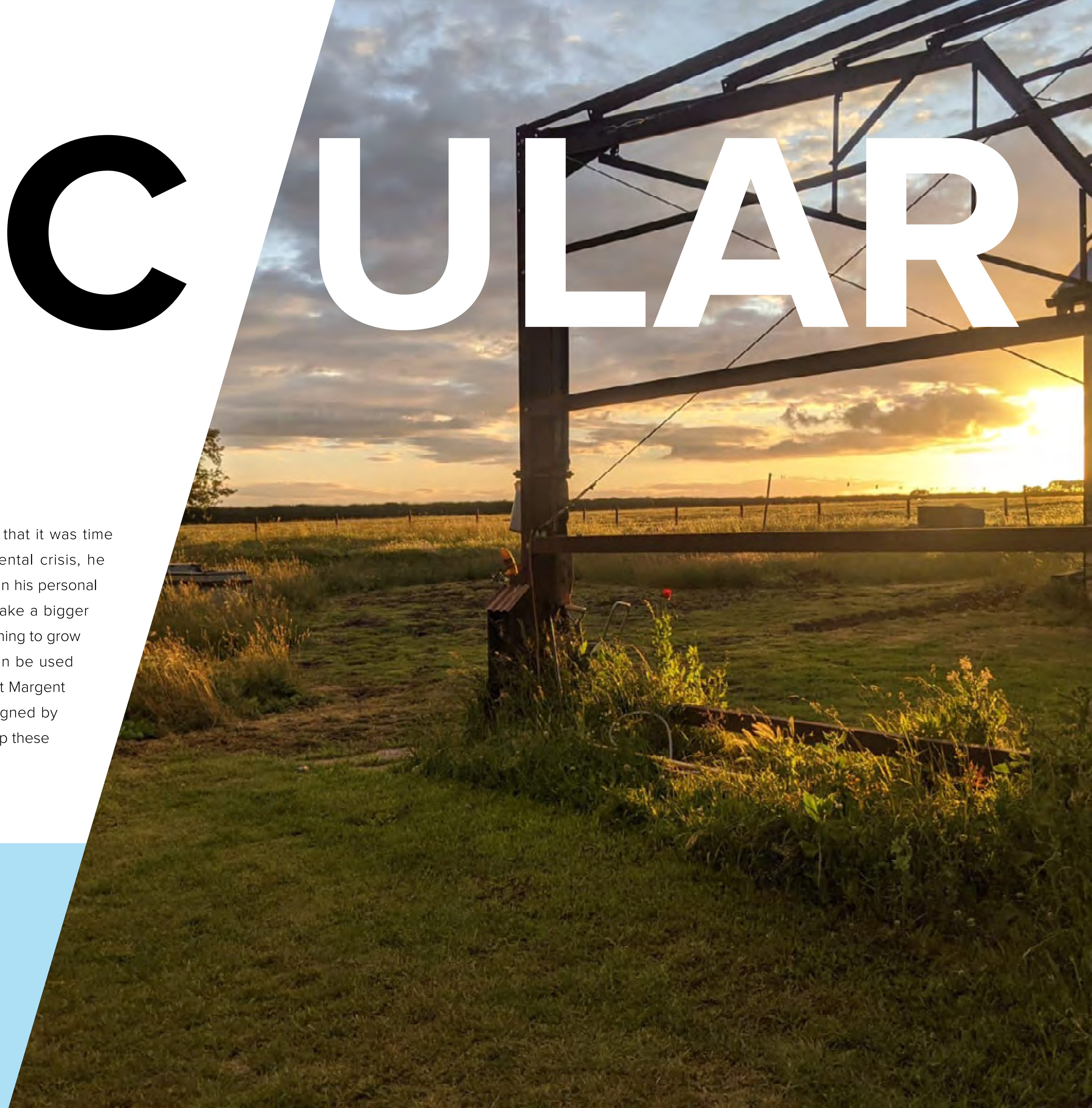
Overview

When film director Steve Barron realised that it was time for action to respond to the environmental crisis, he wanted to go beyond taking small steps in his personal life to try to do something that would make a bigger difference. This was the catalyst for beginning to grow hemp - a carbon-positive crop which can be used for a variety of industrial material applications - on his arable land at Margent Farm. The Flat House is a prefabricated construction system designed by Practice Architecture that demonstrates the possibilities for scaling up these sustainable construction techniques.



The opportunity

Housing in the UK is typically constructed from brick or block walls set on a concrete foundation with a tiled roof. While this has become a trusted method of creating a safe and secure building, this style of construction has environmental disadvantages. Many of the core materials used are carbon intensive and while estimates vary, several studies have put the amount of embodied carbon in new build houses at 50 – 80 tonnes. [1 2 3]

Another disadvantage of the common approach to housebuilding is that it has little regard for what will happen to the building at its end-of-life, resulting in a demolition process which destroys much of the building components and therefore, eliminates reuse opportunities. The Flat House seeks to prove that the innovative use of hemp-based materials can be a safe and reliable method of overcoming these challenges.

“The house makes innovative use of renewable hemp-based materials”

Margent Farm is currently looking to expand its production of hemp to create building materials for use in larger scale homebuilding projects.

What Was Done?

This is a unique project as it was approached from the perspective of using the raw material that was grown on the farm and demonstrating how hemp-based products can be used as more sustainable building materials. Architecture firm, Practice Architecture was approached by Steve Barron to design a house which would realise this ambition.

Hemp is a material source that has a low environmental impact. It can be grown effectively in the UK and because it sequesters carbon better than commercial forestry, it can be carbon negative (i.e. it sequesters and stores more carbon than is produced in turning it into a commercial product) if, as in this case, there is a low transport-related environmental footprint. The hemp plant’s long tap roots can also help

to regenerate the soil by channelling water deeper and holding the soil structure in place.

The main body of the house is constructed out of 'hempcrete' – a mixture of hemp shiv (the woody core of the plant) and lime. It was decided at an early stage that this project should not only demonstrate the environmental and structural benefits of using hemp as a material, but that it should also do so in a way which is scalable. For this reason, the building is constructed from prefabricated hempcrete panels, based on timber I-joists with a hempcrete infill. These panels can be easily disassembled at the end of their life and either re-used or mulched and composted back into the soil.

"Growing hemp sequesters carbon better than commercial forestry"

Practice Architecture developed the structural panel system with input from hempcrete specialist Will Stanwix and carpenter Oscar Cooper, and they were produced at HG Matthews's Brickworks in South Buckinghamshire. In the Flat House, the internal facing side of the hemp panels have been left unplastered and covered in only a thin layer of clay paint. This results in warm, textured surfaces and a sense of connection with the story of the building.

The external cladding of the building is a unique corrugated composite material made from the hemp fibre grown on site that is thermally compressed with a sugar-based resin made entirely from agricultural waste. While this innovative material appears similar to the familiar corrugated cladding seen on agricultural buildings around the Cambridgeshire countryside, its production requires 2.6 times less energy than bitumen plastic and

1.5 times less energy than galvanised steel cladding.

The simple design of these walls facilitates breathability, allowing air and moisture to pass through freely. The nature of the thermally massive materials removes the need for many discreet layers and petrol-based membranes, while maintaining a comfortable temperature in the building.

Additionally, the building was constructed upon the existing steel frame from barn that was previously on the site, adding an element of reuse and further material savings to the project.

Lessons learnt

A barrier to replicating the approach taken by the Flat House is that while hemp is already grown at scale in the UK, it is mainly used for horse bedding and the availability of hemp-based construction products is still low. Practice Architecture has subsequently set up a not-for-profit organisation, Material Cultures, which is working with ARUP, UAL, UCL and others to research and upscale the approach of off-site construction using natural materials for a broader market. It is in the process of developing more systems and models for different applications and is looking at how this integrates with regional manufacturing.

Despite removing the need for finishing work, building with an exposed structure comes with its own challenges and the need for precision. The panels had very little tolerance and required an amount of 'persuasion' to get tightly into place. Despite this, all of the panels were lifted into place by crane in two days, with the rest of the work being carried out from a scaffolding.

Impact measurement

The annual CO_2 emissions of the property were calculated as part of the SAP (Standard Assessment Procedure) calculations, a requirement of all new-build homes in the UK. This is based on the construction of the home, its heating system, internal lighting and renewable technologies which were installed.

Impact	Data
Annual CO_2 emissions	-2.32 t/year
Dwelling CO_2 Emission Rate	-21.52 kg / m^2
Construction cost	£250,000
Construction cost per m^2	£1,600 (including hot house), £2,200 (main house only)

Endnotes

1 Embodied and operational energy for new-build housing: A case study of construction methods in the UK, Energy and Buildings, 2013

2 New Tricks Old Bricks: How reusing old buildings can cut carbon emissions, The Empty Homes Agency, 2008

3 What's the Carbon Footprint of.... Building a House, Berners-Lee, M., The Guardian, 2010

TIDEWAY: THAMES TUNNEL

TIDEWAY: THAMES TUNNEL

Location: London

Project type: Interception tunnel

Building type: Sewerage system extension

Circular principles being addressed: Designing out carbon

Key Impact: 1379 tonnes of carbon avoided through circular design changes

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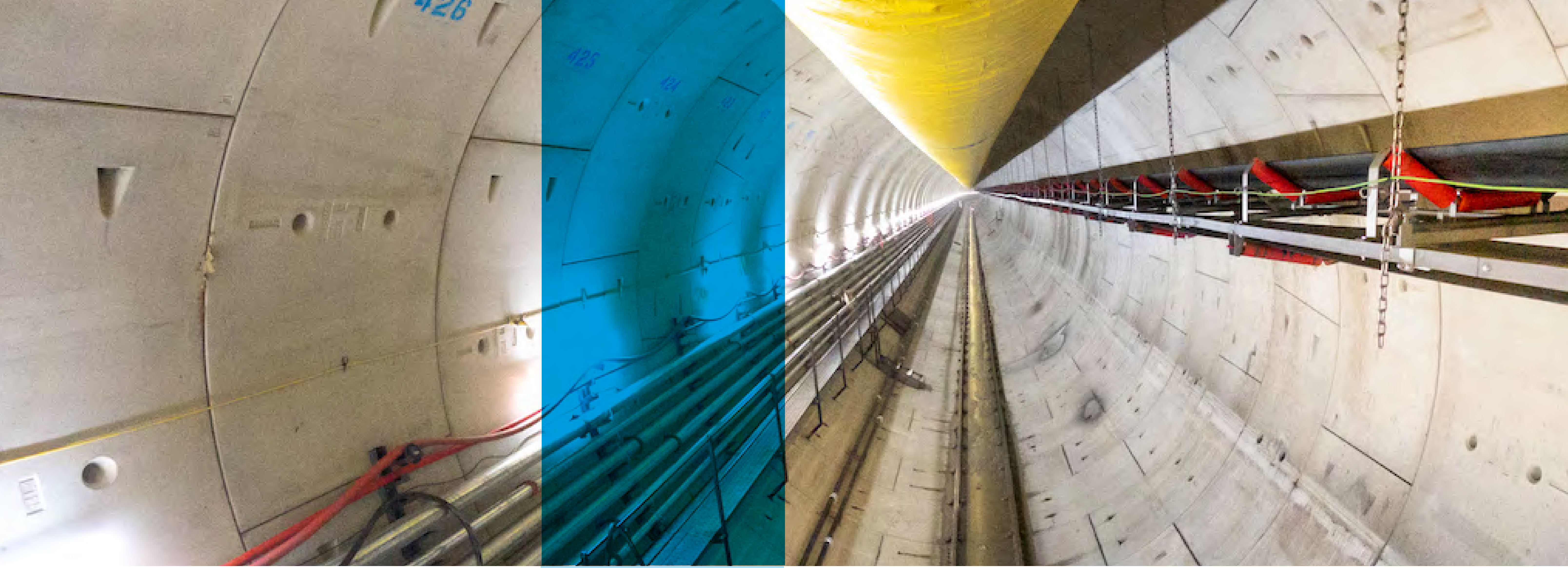
Overview

The Thames Tideway Tunnel, which is currently under construction, is a 25km tunnel running under the tidal section of the River Thames through central London. The tunnel will capture and store raw sewage and rainwater discharges that currently overflow into the river. Through innovative design, using waste materials in construction, and positive collaboration between contractors, significant cost and embodied carbon savings have been achieved.

The project is being delivered by three joint ventures: BMB JV (BAM Nuttall, Morgan Sindall and Balfour Beatty) for the West contract; FLO JV (Ferrovial Agroman UK, Laing O'Rourke Construction) for the Central contract; CVB JV (Costain, Vinci Construction Grands Projects and Bachy Soletanche) for the East contract.



The opportunity

The scale of Tideway and the quantity of carbon-intensive materials being used throughout the project presented significant opportunities to improve environmental performance and challenge industry standards by reducing the amount of carbon embodied in materials. To meet the project ambition of reducing Tideway's whole life carbon footprint, the team continually seeks innovative solutions to design out carbon through prioritisation of low-carbon materials and redesign of assets.

"The Tideway project is a 25km sewage tunnel running under the river thames"

What Was Done?

In the East section of the tunnel, CVB identified numerous carbon saving opportunities within the design of the shaft secondary lining and base slabs. The shaft base slabs sit at the bottom of the giant shafts that will connect the old Victorian sewers to the new tunnels. First, at Chambers Wharf, the main drive site for the tunnel boring machine in the East section, the redesign from a flat structure to a dome-shaped base used 1,500m^3 of concrete in comparison to 3,500m^3 for the flat structure used at comparable sites across the project, resulting in savings of 750t CO_{2e}.

The FLO secondary lining team then reviewed the existing design of the central section of the main tunnel, identifying an opportunity to reduce the lining thickness there too. It was a significant decision but led to a 16% saving on the volume of concrete used across the 12.6km central section of the tunnel, achieving a 5% saving in the tunnel's embodied carbon

footprint, and £2.7m in material costs.

In addition, project designers maximised the volume of cement replacement using waste products from industrial processes: Pulverised Fuel Ash (PFA) and Ground-granulated Blastfurnace Slag (GGBS). For example, increased cement replacement (PFA) of 75% has been achieved in the base plug pour at Chambers Wharf. Tideway's whole-life approach to managing and reducing carbon on the project was included as a case study within the first annual report of i3P and was showcased at its conference in City Hall at the beginning of November 2019.

"Design changes resulted in a 16% saving on the volume of concrete used across the central section"

Embedding new thinking in ways of working

The design changes were driven by the team's ambition to challenge specifications and reduce materials and waste. Including environmental team members early in the design process allowed for the material selection and quantification of carbon benefits to be realised, captured and shared. As a result, CVB's new low impact designs have been implemented on all other sites on the Eastern section for the base slab and shaft linings.

Each stage of the design was reviewed by the Project Manager and Client teams and included a carbon assessment. These reviews have resulted in several significant reductions in material use whilst maintaining the assets' integrity. At the time of writing, the proposal for the design of tunnel reinforcements is projected to save 2,000t of material, equivalent to 31% of the original design, and also substantial labour cost savings through improved productivity due to a reduced congestion. The Carbon Infrastructure Transformation Tool was used to calculate that the carbon savings of 1,379.4t CO_{2e} made through the reduction in reinforcement at two Tideway sites, Chambers Wharf and Greenwich Pumping Station shafts. This demonstrates how sustainable innovation can add both environmental and financial value in an infrastructure project.

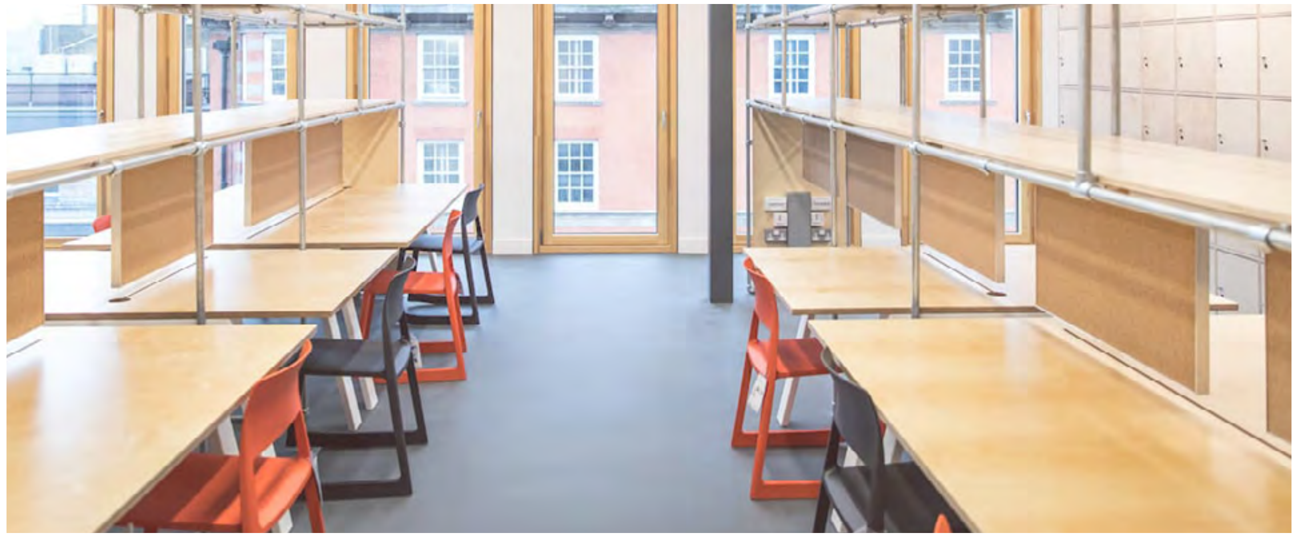
Impact measurement

The Carbon infrastructure Transformation Tool demonstrated the embodied carbon and cost impact of each material element within an infrastructure asset. Tideway's contractors found the tool's automated embodied carbon calculations easy to use. The grid below shows impacts from design changes which reduced the need for reinforced bars.

Site	**Greenwich Pumping Station**		**Chambers Wharf**	
Component	**Base slab**	**Shaft secondary lining**	**Base slab**	**Shaft secondary lining**
Impact			**Data**	
Material saving	23.44 tonnes 24% of original design	132 tonnes 17% of original design	100 tonnes 32% of original design	700 tonnes 40% of original design
Material cost savings	£61,000	£145,000	£50,000	£350,000
Carbon savings			1379 tonnes CO_{2e}	

GILBERT ASH: UCL SCHOOL OF ARCHITECTURE

GILBERT ASH: UCL SCHOOL OF ARCHITECTURE



Location: 22 Gordon Street, London

Project type: Complete retro-fit and extension

Building type: Academic centre

Circular principles being addressed: Reuse (including refurbishment and repurpose) / Design buildings for flexibility and optimisation / Design and construct responsibility

Key Impact: 400 tonnes of carbon saved by retaining original concrete frame

CIRCULAR

Overview

In the £20 million refurbishment of its world-renowned Bartlett School of Architecture, University College London wanted to double the amount of research and teaching space within the existing 1970s concrete frame. The architect, Hawkins/Brown, had an ambition that the design would be open, interconnected and collaborative to encourage an interactive learning and social experience for students.

The project is part of UCL's wider programme to modernise its Bloomsbury Campus and the contractor, Gilbert-Ash, saw this project an important opportunity to demonstrate how the retrofit of 1970's building stock is possible, whilst retaining the embodied energy and CO_2 emissions held in the concrete frame. The project achieved an overall rating of BREEAM Excellent representing best practice in sustainable design and construction taking the building well beyond minimum standards.

The project was completed in November 2016 after a construction period lasting 78 weeks.

The opportunity

The former president of the American Institute of Architects, Carl Elefante, once said: "The greenest building is the one which already exists." While old buildings may not always operate efficiently or meet modern standards, the environmental impacts of new build construction are significant. One of the key concepts of the circular economy is the reuse and repurposing of existing assets to meet evolving requirements. For buildings this includes retrofitting, rather than replacing, old structures. The usual approach to a project such as the Bartlett School of Architecture would be to demolish the original building, then to design and construct a new building in its place. However, the team instead embraced circular economy thinking by reusing the existing building structure as a central design principle for the project.

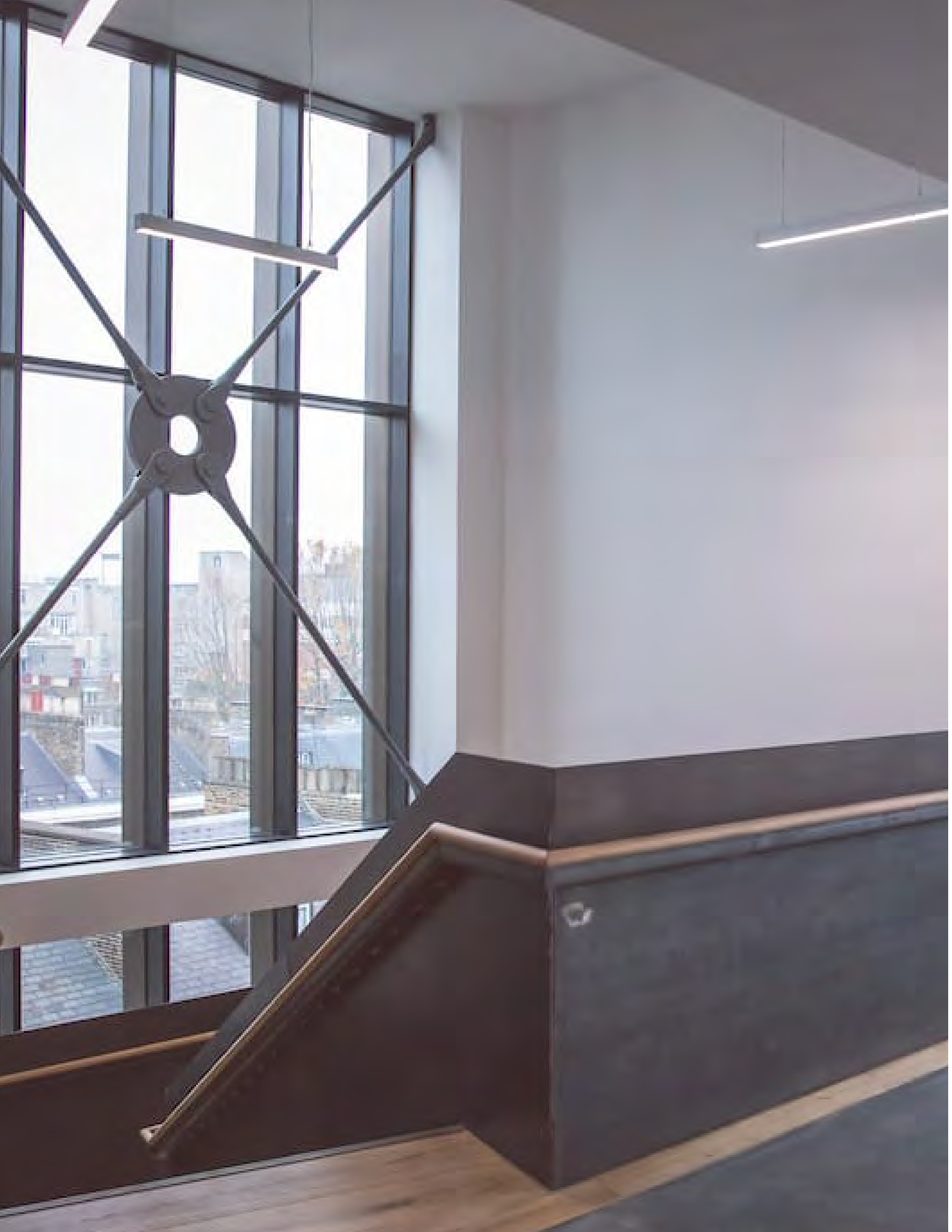
"The project reuses the existing structure as a central design principle"

What Was Done?

The Bartlett refurbishment included demolishing one floor of the building and adding another two, to give eight storeys in total. The floor-plate of the existing building was increased to almost double the size - 8,500 m^2 in total. The building façade was stripped back and a full new façade created using hand-cut bricks.

Central to the design philosophy was opening up the façade of the building to reveal the activity within. This was achieved by placing formal and informal exhibition spaces at ground floor level, inserting a new staircase to open up the building's circulation, re-orientating the entrance and expressing key spaces to give inspiring views of London.

There is nothing frivolous or wasteful in the final building, balancing architectural elegance with optimising value. Raw, hardwearing finishes tell the tale of the building's 1970s concrete origins. They will also survive intense use by notoriously hands-on maker students, a suitable backdrop to pinning up



work, storing 3D models and staging exhibitions.

The building achieved BREEAM Excellent, exceeding UCL's campus-wide energy efficiency targets and transforming the life-cycle cost and comfort of using the building. Retaining the original concrete frame not only saved money and build time, it saved 400 tonnes of carbon.

"Indoor spaces are deliberately versatile to maximise their utility"

Communal spaces are deliberately versatile. Gilbert-Ash developed bespoke furniture using a Kee Klamp steel system with birch plywood. This system not only acts as furniture which can be used on a daily basis but also can be taken down and rebuilt in different sequences which frees up the space in the building in the future and avoids the need to procure further materials. Walls either pivot open or are lightweight, simplifying future layout reconfigurations as teaching and learning needs develop over time.

Keeping the original concrete frame reduced waste, reduced the need for virgin material, retained the embodied carbon and reduced building time. It also reduced transport, noise, dust and vibration levels that are often associated with a demolition negatively impacting the local community.

The project demonstrated the financial and environmental potential for retrofitting 1970s building stock.

Lessons learnt

The building's structural raft foundation was designed to carry the existing building with limited capacity for additional loading. The building was extended by adding an additional floor and floor space to each level, which had to be carefully considered to ensure the existing foundation was not overloaded. Lightweight steel, floor finishes, and a slender brick facade where chosen as part of the design process to overcome this challenge, further reducing overall material volumes.

One of the inherent challenges of retrofitting this structure was that the existing floor-to-ceiling heights were significantly lower across the majority of the floors than what would be found in a new building; this was problematic when installing the required mechanical and electrical services into the project. Gilbert Ash utilised point cloud survey information of the structure and used 3D modelling to design out any pinch points. It is recommended that other retrofitting projects take this approach.

Impact measurement

Gilbert-Ash uses project trackers to monitor, measure and report on sustainability performance across all projects including benchmarking based on waste (m^3 of waste /$100m^2$ of building footprint) and energy (kg CO_2/$100m^2$ of building footprint) in accordance with BREEAM.

Impact	Data
Waste generated	7.4 m^3 of waste per $100m^2$ (Construction Stage)
Materials (m^3) recycled	98% of waste diverted from landfill
Carbon footprint	137,690 kg CO_2 / $100m^2$ (Electricity & Transport Emissions)
Carbon footprint savings (t CO_{2e})	400 tonnes carbon saved by retaining original concrete frame
Social impacts	38/50 Considerate Constructors Scheme Section 106 – 2 apprenticeship positions initially employed as part of this project are now full-time members of the Gilbert-Ash team (engineer and document controller)

Find out more about the UCL project in this video

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Contact :

Pete Belk, Circular Economy Director

peter.belk@bitc.org.uk

Business in the Community

137 Shepherdess Walk

London N1 7RQ

www.bitc.org.uk