UNIVERSITY OF CAMBRIDGE
INSTITUTE FOR SUSTAINABILITY LEADERSHIP

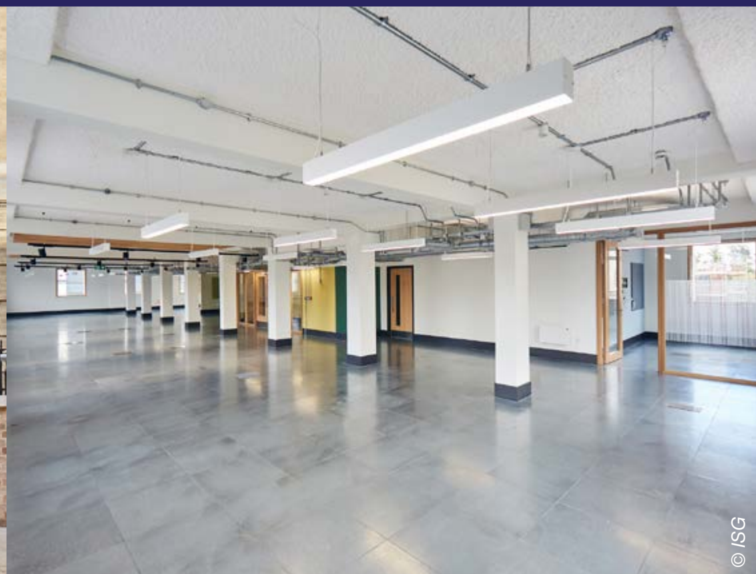
Building Entopia

The story behind the ultra-sustainable retrofit of CISL's new home in Cambridge

UNIVERSITY OF CAMBRIDGE
INSTITUTE FOR SUSTAINABILITY LEADERSHIP

"The path to a sustainable and resilient world will not be feasible without radical changes in the way we procure, design, construct and use our buildings. The central message of this paper is that those changes are both possible and affordable. Buildings like Entopia are attainable for all through sensible design strategy, careful analysis, collaboration and determined leadership against a clear, ambitious vision."

Clare Shine CEO CISL



Authors

This paper was prepared by CISL and authored principally by Mr Jeff Blaylock, Dame Polly Courtice, Dr Tim Forman, Prof John French, Dr Jake Reynolds and James Cole. The findings, interpretations and conclusions contained in the paper are those of the authors and do not represent or imply any official position, judgement or endorsement on behalf of CISL or any other party involved in the Entopia project. The opinions expressed here are those of the authors and do not represent an official position of CISL, the University of Cambridge, or any of the Entopia Building project team or clients.

Research approach

To create this study, we conducted one-to-one and small group interviews with stakeholders, a comprehensive review of project documentation, and observational research. We collected data over a 13-month period from February 2021, and drew on analysis of documentation from earlier project stages. We conducted 24 primary interviews from October 2021 to February 2022 with 15 individuals drawn from principle contracting organisations and project stakeholders in executive and senior operational positions. See p57 for more.

Funding

The Entopia Building project was made possible by a substantial donation from the global renewable energy and digital company, Envision Group, alongside grants from the European Structural and Investment Fund (ESIF) and the University of Cambridge's Carbon Reduction Fund.
This case study and its accompanying materials has been funded by CISL.

Find out more

If you would like to find out more about the University of Cambridge Institute for Sustainability Leadership, its Canopy startup incubator, or Entopia please contact info@cisl.cam.ac.uk

Acknowledgements

We gratefully acknowledge all members of the Entopia project team who helped turn our ambitions into reality. We are particularly grateful to those members who generously contributed their time to discuss in interviews their experiences of the project and the insights gained, from which the content of this paper was largely derived:

Samuel Maddin, 3PM
James Runciman, 3PM
Patrick Watson, 3PM
Wendy Bishop, Architype
Ben Humphries, Architype
James Hepburn, BDP
Lucy Townsend, BDP
Clare Shine, CISL
James Cole, CISL
Anna Nitch-Smith, CISL
Lei Zhang, Envision Group
Chris Read, Feilden+Mawson
Jack Lewis, Gardiner & Theobald
Katie Metcalfe, Gardiner & Theobald
Matthew Hallam, ISG
Peter Kelly, ISG
Nick Wood Moore, ISG
Michael Naylor, Jupiter Asset Management
Pria Lad, Max Fordham LLP
Roberta Ramaci, Max Fordham LLP
Gwilym Still, Max Fordham LLP
Alexander Reeve, University of Cambridge

A far larger group of people were responsible for making Entopia a success. In addition to many CISL staff, key individuals include:

Suzannah Howson, 3PM
Andrew Luff, ACL European Consultancy
Mary Sweeting, Architype
Michael Williams, BDP
Emma Cutting, CISL
Dr Kayla Friedman, CISL
Caroline Elvidge, CISL
Aidan Pittman, CISL
Andy Taylor, CISL
Ben Walbanke-Taylor, CISL
CISL's MSt Interdisciplinary Design for the Built Environment cohorts 26 & 27
John Osborne, ESIF
Eve Waldron, Eve Waldron Design
Ashlyn Vaikkath, ISG
Joel Gustafsson, JGC Engineering
Prof David Cardwell, University of Cambridge
Georgina Cannon, University of Cambridge
Prof John Dennis, University of Cambridge
David Hills, University of Cambridge
Prof Ian Leslie, University of Cambridge
Graham Matthews, University of Cambridge
Daniela Manca, University of Cambridge
Prof Andy Neely, University of Cambridge
Anthony Odgers, University of Cambridge
Prof Richard Prager, University of Cambridge
Chris Swaysland, University of Cambridge
Nick Tamkin, University of Cambridge
Prof Stephen Toope, University of Cambridge
Brian Williams, University of Cambridge
Report Project Manager: Catherine Foot, CISL
Report Design: Tom Yorke, CISL, with support from Adrenaline Creative
Photography by:
SOLK Photography Ltd
Jack Hobhouse

This project is part funded by the European Regional Development Scheme

European Union
European Regional Development Fund

HM Government

Envision
Net Zero Tech Partner

Foreword

The fact that the Entopia Building uses dramatically less energy than its predecessor is a success in its own right; that it has minimised the use of new materials through circular design and concurrently reaches three challenging building standards, is exceptional. Its true impact is still to come, however, through its role as a beacon project: an exemplar and teachable resource that creates positive ripples of change throughout the built environment community, influencing the course of other projects, policies and investments.

The lessons from this project extend far beyond the application of technology to sustainable design into new mindsets, collaboration models, and modes of leadership as this publication shows. These learnings challenge beliefs closely held by many in the industry, placing conventional processes and norms of design under the spotlight.

The communication of – and engagement with – the lessons from this project was a core ambition from the outset. Some projects use public relations to promote their project and brands, whilst others seek to protect the knowledge and insights gained by their innovation. We have chosen to do neither. By purposefully packaging the lessons from Entopia into this paper and using all our available avenues to reach industry colleagues, practitioners, town and country planners, and policymakers, we hope to maximise awareness of the lessons for all.

To support this ambition, a formal Communications Working Group was established within the Entopia Project Board, chaired by CISL and with representatives from the University, the supply chain partners and major donors. In line with the project charter, this was a collaborative process which pooled our collective insights and opportunities into a repository of communications assets that all partners can draw on. This publicly available case study is one of the key outputs of the working group, designed as a reference point for industry practitioners. In addition, a website [https://www.cisl.cam.ac.uk/about/entopia-building] is being maintained with articles, blogs and videos about the project, and a project data repository has been created to support future communications and research. Moreover, the project's lessons (as captured by the case study) are being taught on CISL's built environment leadership Master's and online courses, potentially reaching hundreds of senior practitioners each year. Tours and visits of the Entopia Building are being accommodated wherever possible. Project partners (including small suppliers) are being empowered to speak at industry conferences and webinars, and media channels have been engaged successfully throughout the process.

We hope you enjoy reading the case study and that it is helpful in your own journey towards transforming the sustainability of the built environment.

Entopia Communications Working Group

© UKGBC

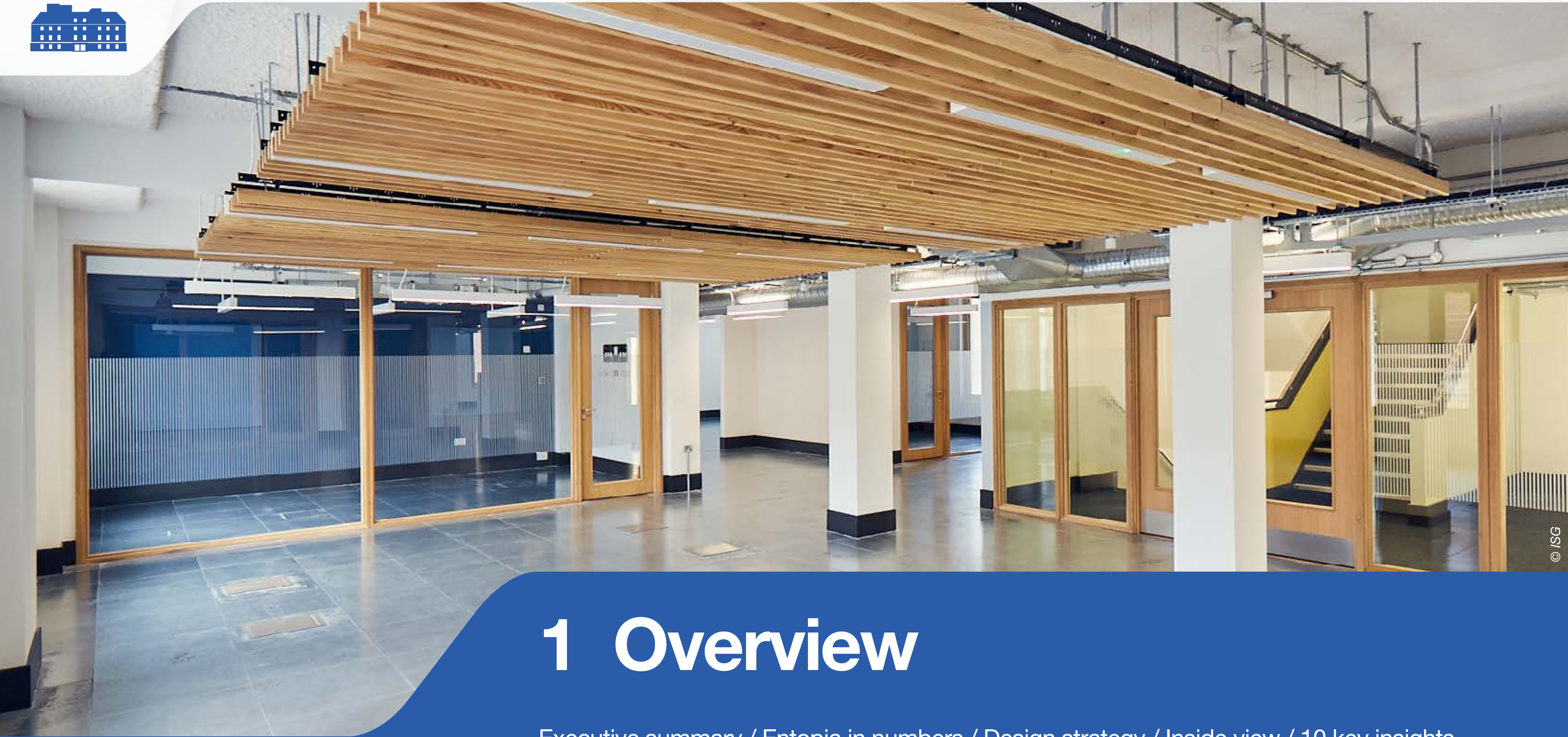
© UKGBC

© ISG

© Architype

This paper tells the story of the Entopia project from inception to handover, drawing out key points of learning, insight and innovation.

It comprises six sections:



1 Overview

Executive summary / Entopia in numbers / Design strategy / Inside view / 10 key insights

"We wanted to transform a six-storey, 1930s telephone exchange into one of the world's most sustainable buildings. I believe we've achieved this goal and set new green standards in architecture and design."

Dame Polly Courtice Founder and Emeritus Director, CISL

Executive Summary

Setting new global standards in retrofit

Entopia is an internationally leading, fabric first, sustainable retrofit of a 1930s, five-storey concrete frame structure with basement, located in a local conservation area in the historic Cambridge city centre.

Entopia demonstrates that a ‘deep green’ retrofit can be delivered at a cost that is competitive to a conventional office refurbishment, with a total project cost of £12.69m (£4,250 per square metre, or £395 per square foot).

New HQ for CISL and its Canopy startup incubator

The Cambridge Institute for Sustainability Leadership (CISL) acquired permission from the University of Cambridge in October 2020 to refurbish and occupy 1 Regent Street, Cambridge, to serve as its new headquarters. This was the culmination of a four-year process to identify and acquire a single space to replace several offices across the University occupied by CISL after three decades of continued growth. The building would provide a ‘sustainability hub’ in central Cambridge for CISL’s staff, associates and Fellows, and University colleagues, as well as a new sustainable workspace for startups and small businesses aligned with CISL’s mission, working in CISL’s Canopy incubator.

Sustainability targets

The vision developed by the CISL leadership team articulated the following sustainability targets in the project brief:

Area	Target	Result
BREEAM Refurbishment and Fit-Out 2014	Outstanding (≥85%)	Interim estimate: 92.0% (target 93%)
EnerPHit standard	Classic	Achieved
WELL standard	Gold (≥60 points)	Current: 24 (target: 85)
Whole life embodied carbon (for 100-year life)	300 $kgCO_2e/m^2$ over 100-year building life	Construction stage (RIBA Stage 5): 409 kg kgCO2e/m², including in-use and end of life carbon, over 100 years (578 at RIBA Stage 2 assessment 434 at RIBA Stage 4 assessment)
Percentage of new materials bio-based, with responsible sourcing and traceability	70%	Current: ~35% by mass (~50% by volume)
Use of recycled and reclaimed materials, reflecting circular economy principles	Maximise where possible	Examples: I. Reused existing raised floor, saved 32 $kgCO_2e/m^2$ (approximately 85,000 $kgCO_2e$ total), compared with using new raised access floor panels. II. Steel structure for rooftop PV canopy built, using 3.79 tonnes of reused steel sections, saving at least 2,000 $kgCO_2e$ III. Carpet tiles retained, cleaned and reused for approximately 12% of building’s floor area, saving 2.4 $kgCO_2e/m^2$ (or around 7,000 $kgCO_2e$ total) compared to installing new carpet tiles. IV. A quarter of the paint used contained 35% recycled content, reduced embodied carbon by approximately 10%, compared to a similar product without recycled content) V. Electrical sub mains retained VI. Existing lift retained and refurbished VII. Existing generator retained and reused VIII. 5,139 items/43,409kg diverted from landfill

Project charter values:

1. Achieving the highest design quality
2. Recognise the potential of the project to be a global sustainable retrofit exemplar
3. Collaborative design process that both embodies CISL's values and exhibits their work
4. Work ethically, honestly and fairly, valuing the contributions of all
5. Be open to challenging the design and having the design challenged with freedom to innovate
6. Celebrate success and the input of the whole team
7. Lead by example, strive for consistency of behaviour in upholding the project values

Awarding the contract

An NEC Option A contract was awarded based on a two-stage tender with a PCSA period provided to allow for early engagement and feedback from the main contractor. The total cost of procuring the building and delivering the refurbishment as of March 2022 was £12.69m (£4,250/m^2, or £395/ft^2).

A fabric first refurbishment strategy

The refurbishment design strategy included the retrofit of the existing masonry walls with internal wall insulation and an airtightness layer using three bio-based products: wood fibre insulation, timber studwork, and lime and cork plaster.

We installed triple-glazed windows, inset into the new interior wall to provide a continuous internal thermal and airtightness line. The original transoms and mullions were omitted. With the inset frames, the glazed area was increased by 60 per cent relative to the original windows, and the associated heat demand was reduced by 35 per cent.

We embraced circularity principles throughout design and construction, leading to the re-use of 500l of paint, 350 lights from a CAT A fit-out in London, a high-end wooden reception desk, steel for the rooftop PV canopy, existing raised-access floor, lift, generator, cable trays, cables and electrical ducts, and the use of existing and procured second-hand furniture.

Costs

The total cost excluding unexpected items such as Covid-19-associated preliminaries (i.e. items or processes necessary for the completion of work), existing building issues, late changes introduced by the client, external works, and late changes to the interior design was £8.9m (£2,986/m^2, or £277/ft^2), which is representative of a more conventional refurbishment project. The project unfolded during a period of unprecedented supply chain disruption and price volatility due to the Covid-19 pandemic and Brexit-related events, which significantly impacted costs and delivery timeframes.

Final building

Entopia now provides approximately 3,000m^2 of renovated space for CISL's Cambridge-based staff, the newly created Canopy incubator, which supports small businesses and start-ups offering solutions to global sustainability challenges. It is a 'centre of sustainability thinking and practice' within the Cambridge region. Through enabling technology, it serves as a physical hub for CISL's network, local organisations, citizens and global partners.

Funding

The project was made possible by a substantial donation from the global renewable energy and digital company, Envision Group, alongside grants from the European Structural and Investment Fund (ESIF) and the University of Cambridge's Carbon Reduction Fund.

Entopia in numbers

£12.69m
Total project cost

48%
Bio-based materials incorporated by volume

21,000kg
of CO_2e saved through reclaimed materials such as the PV rooftop canopy, lighting and furniture, fixtures and equipment

£1m
enhancement of external building envelope

£0.5m
spent on triple-glazed windows to improve insulation and airtightness, control solar heat gain and maximise daylight

350
recycled LED lights

£4,250
Project cost per sqm (£395 per sq ft)

84%
carbon saved per m2 of GIA compared to a standard office fit out. (6,340kgCO2e/m2 GIA over 100 years)

2,986m²
renovated space for CISL staff

1
Reception desk recycled from Netflix

409kg CO_2e/m^2
Whole life embodied carbon of refurbished building, including in-use and end of life carbon, over 100-year building life (Stage 5 construction stage assessment)

62,332kg CO_2e
avoided in construction materials

Diverted from landfill	Donated to the community	
21,648kg	£100,225	furniture
19,380kg	£52,182	construction materials

Design Strategy

"Material-efficient 'deep green' retrofits are critical to meeting both sustainability and resilience goals. The remarkable achievements reflected in the Entopia building were made possible through the close collaboration and dedication of scores of individuals and organisations. CISL, its project partners, and the University of Cambridge as a whole, are proud of the outcomes achieved and are committed to sharing the knowledge, insights and innovations gained during the project's execution."

Prof John French CISL Associate and Senior Advisor to the project

Sustainability and cost-efficiency

Although we understood at the outset that it would be highly challenging to deliver a building project with both exemplary and sustainability credentials with minimal uplift in capital cost relative to conventional projects, this challenge was embraced by the project team[1]. This was ultimately achieved by making sustainability and cost-efficiency central goals in all considerations and, where possible, designing out risks that would influence price before contractors were engaged. Numerous obstacles were encountered, and while many were ultimately surmounted, not all were. The lessons gained in pursuing the project's considerable achievements – and in confronting obstacles and sometimes failing – are reported in the following chapters.

Whole life strategy

The design strategy was based on a 'whole life' perspective that considered sustainability impacts and benefits across the lifetime of the building to be fundamental parameters of design. The adoption of a 'fabric first approach' in design strategy prioritised reducing energy demand over obtaining energy from more sustainable sources and before designing the building services. This is essential to the Passivhaus concept and achievement of the Passivhaus standard, and the approach led to a substantial improvement in the energy performance of the building envelope (i.e. its structure and the components that enclose the internal spaces). Following the Passivhaus standard led to a major enhancement of the external building envelope (£1m) and a further £0.5m invested in high-performance triple-glazed windows to improve insulation and airtightness, control solar heat gain and maximise daylight. This reduced the sizing and quantity of mechanical, electrical and plumbing (MEP) systems, significantly reducing the building's carbon and material footprints and freeing up external space previously used. Consequently, the capital cost of the MEP systems was also lower than those in a conventional fit-out.

Circularity principles reduce embodied carbon

We introduced circularity principles as a core element of the brief at RIBA Stage 1, and consideration of this influenced appointment of the main contractor. Leveraging the contractor's supply chain to identify available materials for reuse in the building subsequently became an important procurement route in the project. A range of reclaimed and used materials, including donated materials, were procured and used in various applications such as the PV rooftop canopy, internal lighting and furniture, fixtures and equipment (FF&E). This enabled us to significantly reduce whole life embodied carbon (saving over 21,000 kg of CO_2e) and reducing the building's natural capital footprint. Moreover, large quantities of materials were reclaimed from the building prior to refurbishment and returned to the economy while being diverted from landfill. This included more than 21 tonnes of furniture and more than 19 tonnes of construction materials, which in turn contributed more than £150,000 in combined value to the community and avoided approximately 80,000kg CO_2e of emissions.

1 The combined leadership team, design team and delivery team.

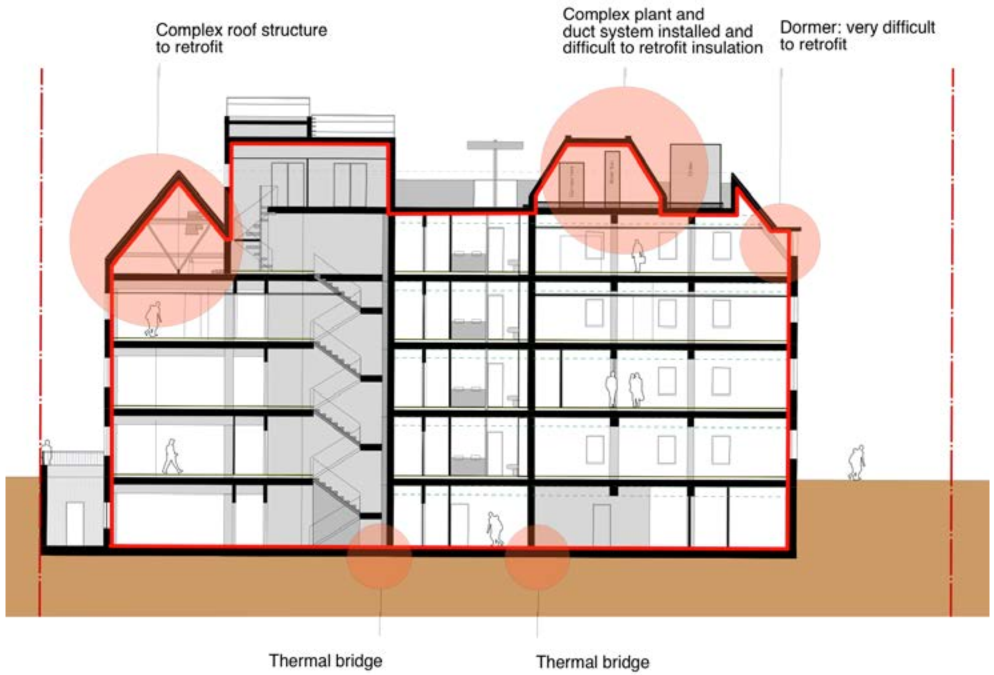
Design Strategy

Energy and carbon savings
The refurbished building is expected to require approximately 15 per cent of the energy consumed by the building pre-refurbishment.[2] Pre-construction it was estimated that this would save £1.1m over the first 15 years, not including the expected savings in maintenance and lifecycle repairs (relative to conventional buildings) associated with reduced requirements for the quantity and size of mechanical, electrical and plumbing equipment. A subsequent review of energy price inflation in the light of the invasion of Ukraine means this saving is now thought likely to be significantly higher at over £1.5m over the first 15 years.

The total whole life embodied carbon of the refurbished building was 409kg CO_2e/m^2, including in-use and end of life carbon, over a 100-year building life (based on a Stage 5 [construction stage] assessment), which compares very favourably to new construction.[3] It must be noted, however, that this is assessed over a 100-year period, so certainty in the value is limited. Omitting in-use and future phases and considering only the carbon embodied in the building at handover stage (life stages A1-A5), the project compares favourably, with an assessed 130kg CO_2e/m^2.

Moreover, 35 per cent of all new materials used in the project by total mass are ‘bio-based’. This proportion is almost 50 per cent when calculated by volume. They are derived from biological sources rather than synthetic or mineral origin.

Sustainability certifications
The approach resulted in an exceptionally lean project that made the minimum possible interventions to the existing building to enable the highest possible lifecycle sustainability performance. The project has been designed to achieve three highly challenging sustainability certifications: BREEAM Outstanding, WELL Gold and (has achieved) EnerPHit Classic, as well as minimising whole life embodied carbon and demonstrating ‘circularity principles’ in design and the specification of materials.



2 Pre-refurbishment energy demand averaged 140kWh/m² (gas) and 223kWh/m² (electricity). Predicted post-refurbishment energy demand is 57.5kWh/m² (electricity only, excluding generation from on-site solar PV panels).

3 The London Energy Transformation Initiative (LETI) suggests a baseline value of 1000 kg CO_2e/m^2 for new construction commercial office buildings (life cycle stages A1-A5, including substructure, superstructure, MEP, façade and internal finishes) (LETI, 2020).

Inside View

Existing building:
Six-storey concrete frame (five storeys above ground, with one basement storey). Originally constructed in 1939, with extensive internal refurbishment and extension carried out in 1998.

Building purpose: Provision of office space, start-up incubator and collaborative activities.

Gross internal area (post-refurbishment): 2,939m^2.

Retrofit strategy:
Fabric first approach.

Planning restrictions:
Non-listed building, located in conservation area.

© Feilden + Mawson (cutaway render) © ISG (building pop-ups)

10 Key Insights

1 **Competitive cost** A low carbon, energy-efficient refurbishment of an existing building can be delivered at a competitive cost relative to a traditional fit-out when operating costs are considered. The capital cost of Entopia is estimated to be eight per cent higher than a traditional fit-out, but this is expected to be recovered within five to eight years through lower requirements for operational energy.

2 **Sustainability targets improve performance** The application of three sustainability standards (BREEAM, WELL and EnerPHit) helped to define a broad range of sustainability targets, leading to a high-quality refurbishment with outstanding sustainability design performance and resilience.

3 **Close collaboration and a project charter** The delivery of an ambitious client brief required close involvement of client-side stakeholders, consensus-building, strong leadership and effective governance throughout the project. Using the brief to derive a 'project charter' at a workshop for the delivery team at an early stage (late 2019) was an effective way of creating early awareness and aligning team members with the project's aspirations.

4 **Protecting green ambitions against cost pressures** Value engineering was applied to meet agreed budgets. The pressure to dilute sustainability objectives was strong, and a high level of collaborative working across all of the project stages was required to maintain course.

5 **Fabric first approach reduces cost and risk** Existing buildings are idiosyncratic and complex, and early adoption of a 'fabric first' approach is necessary to optimise building assessment, and design and construction strategy. It becomes harder, more costly and riskier to address fabric improvements at a later stage.

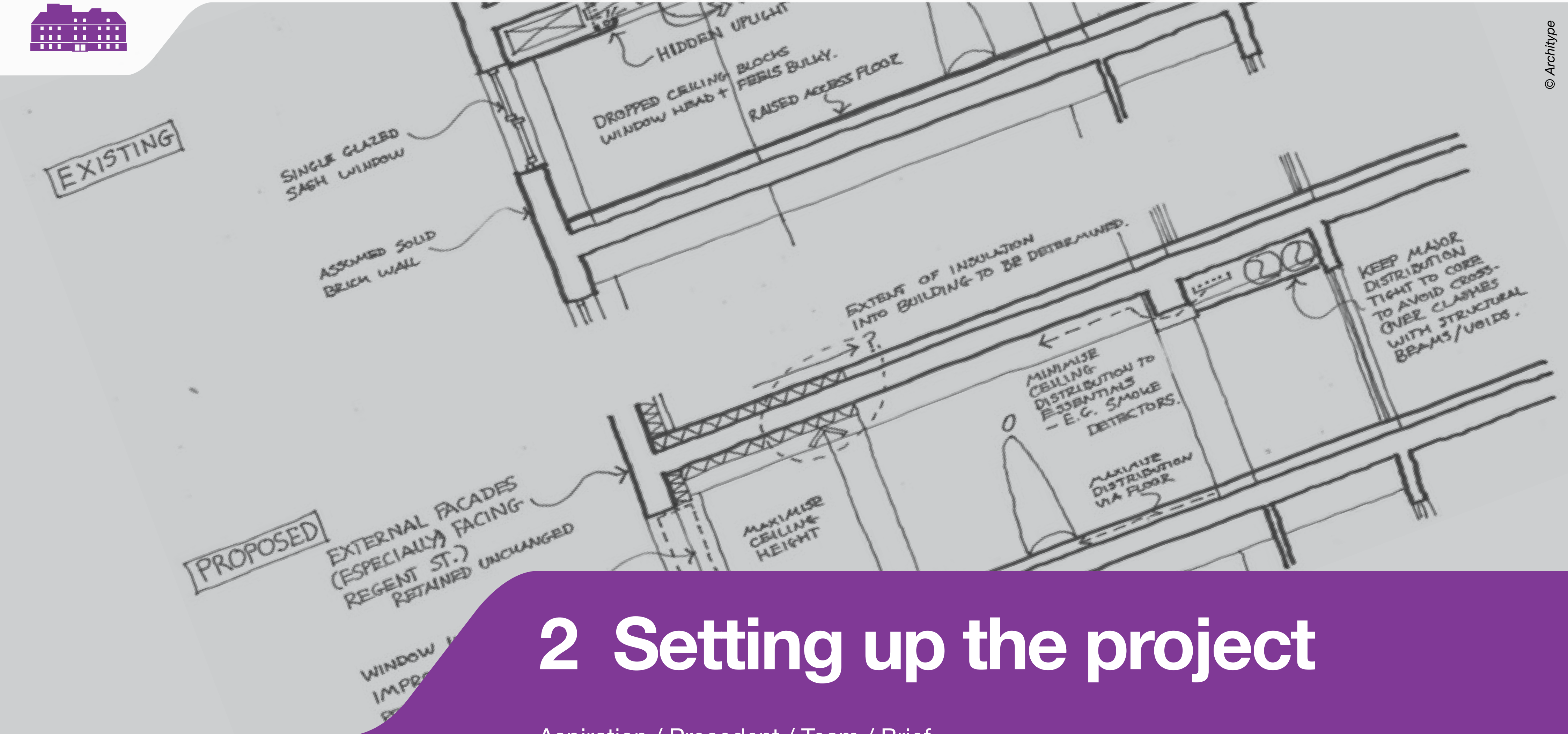
6 **Real and virtual collaboration** The use of collaborative workshops and virtual working enabled a faster and more productive workflow. This was predominately achieved through client-side leadership.

7 **Local authority support for balancing heritage and energy efficiency concerns** To achieve the project's ambitious energy performance targets, some original design elements needed to be changed in the window replacements. Because meeting these targets was essential to the local authority's own stated sustainability commitments, an argument for an exception to some heritage restrictions was made. This enabled critical design elements – which by convention would not have been allowed due to heritage and other concerns – to be included, establishing a new precedent in the local planning process that may allow wider prioritisation and acceptance of energy efficiency strategies in future. In the UK context, standards such as EnerPHit and whole life embodied carbon targets could be used as a condition of planning consent (similar to the present use of the BREEAM standard) or regulatory approva if balanced with heritage, social value and natural capital concerns.

8 **Circular approach embraced by all** Pursuing circular economy principles added complexity in design, procurement and construction. Success relied on objectives and targets being embraced fully across the project team. Building contractors were particularly instrumental in realising circularity aims due to their extensive networks in construction value chains that allowed them to identify opportunities and source cost-competitive secondary materials.

9 **Intrusive surveys prove vital** Refurbishment projects benefit from intrusive surveys to identify and reduce risks prior to commencing construction work; this is especially true when retrofitting building fabric to reduce heat losses.

10 **Decisions shaped by total lifecycle costs** It is crucial that lifecycle cost, not just upfront capital cost, informs decision making. A focus on energy efficiency reduces future liability for energy costs or deferred improvements to heating, cooling and ventilation systems.



2 Setting up the project

Aspiration / Precedent / Team / Brief

“The procurement of buildings with ‘deep green’ sustainability and resilience performance is critical to the global effort to address climate change and environmental, social and economic sustainability. We wanted to demonstrate how this can be done.”

Dr Jake Reynolds Executive Director, CISL

Aspiration: create a sustainability exemplar

Promote collaboration

The Entopia building was created to provide a new UK headquarters for the University of Cambridge Institute for Sustainability Leadership (CISL). After more than 30 years of growth, the organisation found its UK operation spread across five offices in Cambridge, limiting collaboration and external engagement with the University and its principal partners in business, government and finance.

The decision to refurbish an existing building at **1 Regent Street in Cambridge** was taken in October 2020, four years after a new headquarters was mooted, with site works commencing in early 2021. (see timeline on p25).

Demonstrate leadership in sustainability

From the outset, Entopia was conceived as an opportunity to demonstrate and highlight how global trends and challenges can be addressed meaningfully at the scale of a single building – hence knowledge creation and knowledge exchange have been central throughout. The innovations, best practices and new insights that emerged from the project have been documented in this paper to be shared with the design and construction value chain and with wider stakeholders.

From the inception of the Entopia project, CISL sought to embody its mission to develop leadership and solutions for a sustainable economy. The aspiration to be a sustainability exemplar was shared across CISL's staff and, importantly, by its major donor, Envision Group.

Improve energy performance across the built environment

The building sector – including the construction and operation of buildings – accounts for nearly one-third of total global final energy consumption and almost 15 per cent of direct CO_2 emissions, which exceeds the footprint of any other economic sector based on common calculation boundaries (IEA, 2021). Yet as much as 75 per cent of the total building stock in Europe is considered 'old and inefficient' (European Commission, 2018). Improving the energy performance of these buildings to align with Europe's net zero ambition is an enormous and urgent challenge. In addition, buildings and construction have significant impacts on the environment and are responsible for nearly one-half of global primary energy demand and annual natural resource extraction (Dixit, 2017), around 30 per cent of waste flows and at least 15 per cent of global freshwater use (Pomponi & Moncaster, 2016).

Build resilience and skills

In keeping with universal frameworks such as the United Nations Sustainable Development Goals (SDG), the project brief for Entopia reflected the importance of social, economic and resilience concerns alongside environmental goals. The expansion of social value, local economic stimulus and capacity building, knowledge creation, upskilling, and valuing cultural heritage, among other 'holistic sustainability' concerns, were important design aims.

Challenge orthodoxy

Entopia sought to demonstrate that from a sustainability perspective, a deep green refurbishment is a better alternative to a new building; that it can operate in a highly efficient fashion; and that when considered over lifecycle terms (including capital and operational costs), this can be achieved without a significant financial premium relative to conventional refurbishments or new construction. Moreover, the project sought to demonstrate this through a pragmatic and replicable approach. The project has challenged the norms and orthodoxies of the built environment industry. In doing so, it provides a model for the University of Cambridge, which has committed to reaching net zero emissions by 2048[4], and for millions of clients like it who wish to achieve radical improvements in sustainability over a short space of time (University of Cambridge, 2020).

"Sustainable buildings should not be any more expensive. As a principle, it's about design development, it's about the team thinking collaboratively and getting value for money."

4 The University has expressed an aspiration to be ten years ahead of its Science Based Target decarbonisation pathway at all times and to reach zero carbon by 2038, with a 75% decrease in GHG emissions by 2030.

Precedent and building history

Passivhaus exemplar
We found no fully analogous office refurbishment or fit-out projects in the UK to act as precedents for Entopia, illustrating its value as a beacon project. However, the goals and design approach of Entopia were influenced by the experience of the team behind the Enterprise Centre at the University of East Anglia (UEA), many of whom were appointed to work on Entopia. This two-storey 3,400 m^2 new build, completed in Norwich, UK in 2015, achieved a 93 per cent BREEAM Outstanding rating. It was constructed using a timber frame with thatched cladding, with 70 per cent bio-based materials in its construction (by mass), many of which were sourced locally.

The Enterprise Centre building has an exceptionally high level of airtightness, which is essential to energy performance, with tests indicating 0.21 air changes per hour occur at 50 Pa; this is among the lowest air permeabilities tested in a non-domestic building.[5] The building has almost 500m^2 of roof-mounted photovoltaic panels that generate approximately 44 MWh a year, exceeding the planning requirement that ten per cent of electricity be provided from renewable sources. The building's whole-life embodied carbon has been calculated to be one quarter of a typical conventional building. The Enterprise Centre won the UK Passivhaus Award in 2018, as well as the BREEAM Award in 2016. It was delivered for £11.6m (£3,400/m^2, or £317/ft^2).

> **"The age and poor energy performance of the pre-refurbishment building is, unfortunately, representative of the majority of buildings in the UK and of hundreds of millions of buildings across Europe and worldwide."**

European Commission, 2022; United Nations Environment Programme, 2021

The original building
One Regent Street was originally built to house the Cambridge telephone exchange in 1939 and now sits within a conservation area. It was converted into offices in 1998 for Cambridge Assessment, which was the last tenant before CISL was allocated the property by the University. The original five-storey concrete-encased steel frame structure (with one basement storey) contained cast in-situ concrete floor slabs and downstand beams, and this was retained almost entirely in the refurbishment. An extension added in 1998 (the last bay on the Park Terrace elevation) was steel frame construction with precast concrete floor slabs and block and brick cavity walls.

Minimal maintenance and superficial fit-outs were conducted over the building's life prior to the refurbishment, as well as some limited structural repair near the main entrance. The building remained highly energy inefficient and poor in daylight, with interior spaces described as 'dark and gloomy' by modern office standards. Building comfort was maintained through a gas boiler feeding wet radiators, chillers feeding chilled water to four-pipe fan cooling units (FCUs) and air handling unit (AHU) cooling coils, as well as some reversible direct expansion (DX) fan coil units (see glossary for definitions of these terms).

© Architype

5 Unit of pressure and stress in the metre-kilogram-second system (the International System of Units [SI]).

Team

“We needed to meet challenging targets, so sought a team of pioneering architects, designers, sustainability experts and cost consultants, supported and guided by the University’s Estates Division and CISL staff.”

Prof John French CISL Associate and Senior Project Advisor

CISL drives the project
As the future user of the building, fundraiser for its refurbishment, and overseer of the execution of the project, CISL was a core member of the leadership team alongside the University’s Estates Division, to whom the cost managers, Gardiner & Theobald, and project managers, 3PM reported.

The director of CISL at the time, Dame Polly Courtice, and her senior team had been conceptualising the project as early as 2014 and played a critical role in maintaining ambition within the leadership team. CISL was advised by Prof John French from the University of East Anglia (UEA), who had previously led the development of its Enterprise Centre in Norwich. Prof French joined CISL specifically for this purpose and remained with the project as a senior advisor until its completion.

Design and delivery teams appointed via frameworks
The design stage team was appointed to the project at RIBA Stage 1 (preparation and briefing) to develop the project, it was retained client-side from RIBA Stage 4 (technical design stage) in an ongoing advisory role. The team was procured via established frameworks and supplemented by key parties with the expertise required for challenging targets, such as Passivhaus certification. The delivery team joined the project team at RIBA Stage 4 when ISG was formally appointed as the main contractor and brought its contractor-side design team that remained engaged through the design development process.

Project Partners		Funding		
Building Owner	Planning	Co-Funder	Co-Funder	Donor
University of Cambridge	Cambridge Council & Local Planning Authority	European Regional Development Fund	University of Cambridge Institute for Sustainability Leadership (CISL)	Envision Group

Project Team

Leadership Group

Client	Project Manager	Cost Manager
CISL & University of Cambridge	3PM	Gardiner & Theobald

RIBA	Role	Organisation	Stages
Client Side Design Team	Sustainability Consultant	BDP	Stage 1 – Stage 5
	Architect	Archiptype	Stage 1 – Stage 5
	Building Services Consultant	BDP	Stage 1 – Stage 5
	Structural Engineer	BDP	Stage 1 – Stage 5
	Acoustic Consultant	BDP	Stage 1 – Stage 5
	Passivhaus Certifier	MEAD Consulting	Stage 4 – Stage 5
	Interior Design	Eve Waldron Design	Stage 4 – Stage 5
Contractor Side Design Team	Structural Engineer	CAR Ltd	Stage 4 – Stage 5
	Acoustic Consultant	Max Fordham	Stage 4 – Stage 5
	Consultant	Max Fordham	Stage 4 – Stage 5
	Passivhaus Engineer	Max Fordham	Stage 4 – Stage 5
	Architect	Feilden+Mawson	Stage 4 – Stage 5
Delivery Team	Main Contractor	ISG	Stage 4 – Stage 5

The major stakeholders in the Entopia project, spanning the project team, project partners and funders. The term ‘project team’ refers collectively to the combined Entopia leadership, design, and delivery teams.

Collaboration with the University's Estates Division occurred throughout the project, with a project board overseeing the capital budget. Ultimately the Estates Division was supportive of the project's ambitions and embraced its potential to generate useful knowledge, while seeking to ensure that internal guidance and processes that would typically apply to a refurbishment project were followed. Given the innovative nature of the project, some deviations from the standard procurement approach were accommodated to keep the project on track through derogations at RIBA Stage 3.

"To meet the goals of the project, a multi-skilled team was required with appropriate experience and willingness to take on unprecedented challenges."

We undertook the design-stage contract-tender process using the initial sustainability aspirations that would ultimately form the basis of the project brief. Several members of the team that delivered the UEA Enterprise Centre project tendered to contract for Entopia and were identified as having the requisite skills and experience.

The original procurement strategy was a single-stage design-build contract, which is typical of most fit-out projects. However, the project managers subsequently advised CISL and the University to procure through a two-stage New Engineering Contract 4 (NEC4) Option A contract (see Box 1 for further context) to de-risk the project, by bringing the contractor into the project earlier under a Pre-Construction Services Agreement (PCSA).

Some members of the leadership team noted that this added an unnecessary step that potentially extended the project's overall timeline by as much as nine months, due to redesign activity spurred by the involvement of the contractor-side design team. An opinion was also voiced that had CISL been involved in decision-making, the team would have had fewer difficulties addressing the brief. Nevertheless, it was reasoned by others that the PCSA procurement approach enabled the project to access stronger technical insights and to mitigate risks more closely, relative to a single-stage process. It was recognised that it may have been difficult to attract interest in a single-stage contract from potential bidders.

Contract type: NEC4
A two-stage NEC4 Option A is a priced contract with an activity schedule that allows for early-stage engagement with the contractor as it joins the team under a Pre-Construction Services Agreement (PCSA) before being appointed through a tender process.

A PCSA period allowed the main contractor to conduct more detailed surveys and investigative works. This earlier engagement with the market ensured that feedback was gained on feasibility from the main contractors and their supply chains. This improved cost certainty before the technical design stage.

© Architype

Planning the project brief and charter

"The implementation of an aspirational project brief requires client-side ambition and good governance. CISL ensured it was approved at the first project board meeting so that the ambitions were firmly established."

Shaped by education practice
The approach to Entopia was partly inspired by education practice, which is core to CISL's mission: if a new course is planned to teach students, a clear set of learning outcomes states what is to be taught and the criteria against which will assess students' learning attainment. These objectives need to be described in unambiguous language to inform and shape the required teaching to achieve the targeted outcomes. Similarly, the design brief for Entopia served to articulate and codify its objectives, and ensure their alignment with the project's goals. It also defined the targets and criteria against which success would be measured so that the project's vision would not be lost over time.

An initial draft of the project brief was developed through a brainstorm by members of the CISL leadership team in consultation with its staff and the design stage team to describe the project ideals and sustainability goals. We recognised sustainability standards as valuable frameworks by which the project goals could be translated into objectives and targets, and appropriate benchmarks could be identified.

Keeping sustainability goals front and centre
The aim of writing the brief was to agree on a demanding set of objectives and targets that would be 'indelible', framing subsequent action in the project. The brief ensured sustainability goals were not deprioritised in subsequent project stages in response to cost or time pressures. This was achieved in two steps:

1. Project vision and objectives
We wrote these in a clear and compelling style that people could understand and internalise to ensure that they understood the common vision and motivation, while also understanding the detail of what needed to be achieved.

2. Good governance
The project exhibited clear lines of authority and accountability to a project board which oversaw the capital budget and maintained clear oversight of project discipline, reporting to the University's Planning and Resources Committee (PRC). The draft project brief gained approval at the first project board meeting and was subsequently revised, with sustainability goals and targets added.

One participant described the value of the brief as helping to hold the project team true to its sustainability vision when proposals emerged that might adversely affect their achievement. They went on to say that it allowed team members to say, "what are you doing meddling with that. That is not something you can meddle with. This is gospel, and we will not dilute our ambition."

"The projects that really work are the ones where there is a clear sustainability brief, and that everyone in the design team, and the client team, are buying into that brief because if that doesn't happen at the start, you're kind of fighting a losing battle."

© ISG

Project charter

"The brief was summarised in the form of a project charter, or one-page mission statement that was signed by all members of the delivery team. This contained references to targets and standards that were to be achieved. A project charters should be a living document and the client, designers and contractors must remain responsive to it, with mutual accountability."

At the conclusion of RIBA Stage 3, the project managers were asked to review the original project brief that was created in RIBA Stage 1 and draft a 'project charter' to articulate and codify its objectives and collaborative ethos and vision in the form of a one-page mission statement signed by all of the key members of the leadership and delivery team before the commencement of RIBA Stage 4. This ensured that the delivery team understood and accepted the brief, and the leadership team understood what they were expecting to be delivered. The project charter was critical to ensuring that existing and incoming team members knew and accepted the project vision and objectives. Team members subsequently used it as a reference against which they could assess performance, and it was revisited at every collaborative workshop.

Click here to read The Entopia Building Project Charter

1. PURPOSE
2. VISION
3. PROJECT CHALLENGES
4. SUCCESS CRITERIA
5. PROJECT VALUES

UNIVERSITY OF CAMBRIDGE
INSTITUTE FOR SUSTAINABILITY LEADERSHIP

The Entopia Building Project Charter

1. PURPOSE

It was agreed between project partners that a project charter would be collectively agreed and entered into, setting out core behavioural values though the life of the project.

2. VISION

To stimulate the delivery of a low carbon retrofit for 1 Regent Street that is both practical and pragmatic in approach, representing good value for money whilst challenging conventional norms around building refurbishment. The project will in itself be an 'educator' and enable leadership and dissemination to others. The built environment represents a major contributor to GHG emissions in both construction and operation; the historic stock of energy inefficient buildings in the UK is a significant challenge. In developing this project specification the challenge is to deliver locally in terms of functionality and performance, but to also provide much needed strategic leadership at national and international level.

1. PURPOSE
2. VISION
3. PROJECT CHALLENGES
4. SUCCESS CRITERIA
5. PROJECT VALUES

The following are the agreed design challenges for the Entopia Building:

- A new building which will play a key role in facilitating culture change within CISL to enable the projection of its core values
- Enhance the reputation of the University of Cambridge
- Provide an inspirational environment
- The project should look at considered innovative solutions to provide habitats to support biodiversity including use of the roof terrace
- Seek to enhance and adopt new working practices to promote effective delivery of low carbon retrofits
- Deliver a scheme within the normal cost profile and range predicted for a project of this type & scale

4. SUCCESS CRITERIA

The project's success will be monitored against the following success criteria:

- Low Carbon Retrofit
- Circular Office Case Study – suitable for recognition by BCO, RIBA, Civic Trust
- Curate and demonstrate what has been achieved throughout the project
- EnerPHit +
- BREEAM Outstanding
- WELL Gold (look to exceed)
- Embodied Carbon <300kg C02 /m2 as a benchmark
- Technology Innovations
- High % of bio-based materials and traceability register
- Soft Landings with Post Occupancy Evaluation (to run over 3 years)

5. PROJECT VALUES

A successful project requires collaboration from the entire project team including the contractor, subcontractors, designers, end users, Estates functions, Envision (funder) and CISL.

The following project values will be adopted by the team and will be key to the successful delivery of this project:

1. Achieving the highest design quality
2. Recognise the potential of the project to be a global sustainable retrofit exemplar
3. Collaborative design process that both embodies CISL's values and exhibits their work
4. Work ethically, honestly and fairly, valuing the contributions of all
5. Be open to challenging the design and having the design challenged with freedom to innovate
6. Celebrate success and welcome the input of the whole team
7. Lead by example, strive for consistency of behaviour in upholding the project values

Project targets as outlined in the brief

"A low carbon retrofit for 1 Regent Street that is both pragmatic and practical in approach, represents good value for money whilst challenging conventional norms around building refurbishment. A key indicator will be building performance and user satisfaction."

The Entopia Building project brief

Educate and lead the building industry

- Minimise carbon and negative environmental impact
- Inspire staff and visitors and encourage collaboration
- Achieve the highest possible level of efficiency
- Adopt recycled and bio-based materials
- Deliver value for money

50-75% carbon saved compared to building anew

70% bio-based materials

1 new HQ from 5 disparate offices

< 300 kg C02/m_2 over 100-year life

Promoting sustainable solutions
From its inception, the Entopia project was highly ambitious in vision and scope. CISL's goals for its new headquarters in Cambridge were directly informed by its mission to promote and develop leadership and solutions for a sustainable economy.

Sited in a local conservation area in the centre of Cambridge, the project needed to balance heritage and conservation concerns with a specific focus on energy, carbon and materials. The project goals were to achieve a 'deep green' retrofit that maximised operational utility, value and energy efficiency and minimised adverse embodied (e.g. upstream carbon) impacts, while pursuing opportunities for holistic sustainability and resilience.

Specific objectives included:
- Radical improvements in the building's energy efficiency.
- Minimisation of whole-life embodied carbon.
- Prioritisation of circular design principles.
- Maximisation of bio-based materials and nature-positive design solutions.
- Adherence to responsible procurement practices.
- Careful attention to indoor environmental quality, health and safety concerns, social and community value, and heritage conservation.
- Attention to economic concerns, including opportunities for employment and decent jobs, training, knowledge creation, and knowledge exchange.

Unlock collaboration
CISL previously occupied five separate office spaces across the University's historic estate. Fragmentation across them – and even within the offices due to the traditional cellular layouts of the buildings – hindered communication and cooperation among staff and partners. Entopia was envisaged as a space that would also instead be conducive to collaboration and discussion, while still allowing some quieter spaces for desk-based working. It was important that the project would unlock collaboration, both within CISL and with its external partners and extensive network, and that it provide a friendly and welcoming presence for the University on a popular street in Cambridge.

Minimise embodied carbon
Recognising the existential threat of climate change, the Entopia project set out to minimise whole life embodied carbon. This spans carbon associated with the extraction and transportation of resources used in the production of materials and equipment, their manufacture and transportation, to site and installation.

Projects that focus purely on operational carbon (i.e. carbon released by a building in use) neglect a crucial dimension of building impact – the carbon used during initial construction and refurbishment. The building was designed based on an expected 100-year service life, which is significantly longer than is typically targeted in conventional construction practice.

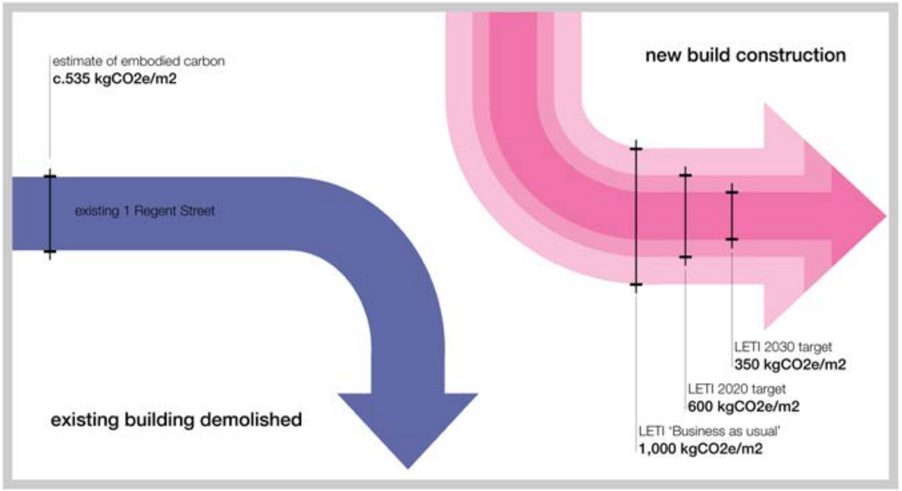
Click here to read the project brief

Compare retrofit versus build anew

Desk-based Sankey[6] analysis compared the impact of refurbishing 1 Regent Street versus the creation of a notional new building. This suggested that a newly constructed building, including demolition of the existing structure, would likely generate between 970-1,620 $kgCO_2e/m^2$. In contrast, it was estimated that a deep retrofit would generate 400 $kgCO_2e/m^2$, hence this option was preferred[7].

Improve operational efficiency

We sought a radical improvement in operational energy efficiency and carbon intensity through the project, which would also provide improved thermal comfort and benefits for occupant wellbeing and productivity. To achieve this, the building fabric and building services would require a significant upgrade. The highly demanding EnerPHit standard (from the Passivhaus Institute) was selected to provide a clear target for the building's operational energy performance. An alternative scheme, the Royal Institution of Chartered Surveyors' (RICS) SKA rating scheme, which is an environmental assessment method for non-domestic fit-outs, was felt not to complement BREEAM as well in this particular project



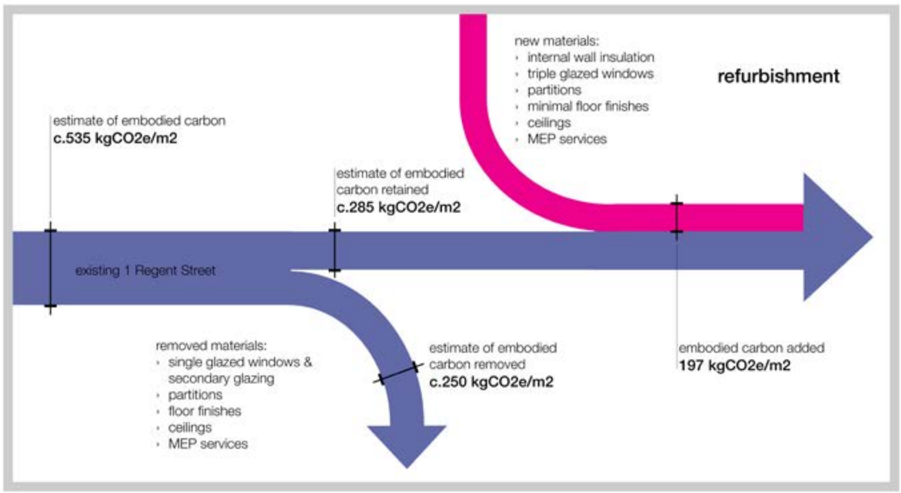


Figure 3: Sankey diagram showing preliminary assessment of whole life embodied carbon preliminary options

6 Data visualisation software mapping material, cost and energy flows.

7 Carbon intensity (i.e. greenhouse gas intensity) is measured in kilograms of carbon dioxide equivalent (kg CO_2e) per square meter (m^2), and in this project it is determined based on Entopia's gross internal area (2985 m^2). This unit is commonly used in industry.

Maximise sustainability

"BREEAM Outstanding became a non-negotiable component of the brief."

The BREEAM standard is based on comprehensive sustainability and resilience indicators representing environmental, social and economic concerns. The certification (or 'rating system') provides a framework for maximising sustainability and resilience benefits and minimising or mitigating adverse impacts stemming from specification and construction. The top BREEAM level – BREEAM Outstanding – is achieved by less than one per cent of UK non-domestic refurbishments or fit-out projects and is considered suitable for 'innovators' targeting the above best practice.

The BREEAM UK Non-Domestic Refurbishment and Fit Out Scheme, and the EnerPHit standard (see box) were felt to provide a suitable structure for the project, reinforced by team members' positive experiences with these schemes elsewhere (Building Research Establishment, 2022; Passivhaus Trust, 2022).

Conservation and restoration of natural capital ('nature positivity') – both on and off the building site – were crucial goals in the project. Although BREEAM addresses relevant aspects of this in construction, the team felt that Entopia could be more ambitious. A target was set to source 70 per cent of materials by mass from bio-based origins, with an ambition to document the sourcing and traceability of all materials, goods and services in the project.

Health and well-being for users

The WELL standard (see box) was subsequently added to the brief to complement the environmental focus of BREEAM and EnerPHit (International WELL Building Institute, 2022). WELL concentrates on the health and wellbeing of building users. WELL Gold – the third highest of four levels of certification – was targeted for the project. This sets a range of requirements for policy, design and operation that affect health and wellbeing, such as internal air quality, drinking water quality, acoustics, light, physical comfort, wellness and safety.

Standards applied in Entopia

The BREEAM, EnerPHit and WELL standards complement each other to form a rigorous and wide-ranging sustainability framework for building projects.

The **BREEAM (Building Research Establishment's Environmental Assessment Method) standard** is an international certification scheme that provides an independent third-party certification for the assessment of the sustainability performance of individual buildings, communities and infrastructure projects. The highest rating in the certification process is 'Outstanding'.

The **EnerPHit (Quality-Approved Energy Retrofit with Passive House Components) standard** is a certification from used for assessing the retrofit of existing buildings. Similar to the Passivhaus standard, it is developed by the Passivhaus Institute and administered by the Passivhaus Trust. There are three categories of EnerPHit: Classic, Plus and Premium. Each of these typically has not the same base requirements, but each differs in the amount of additional renewable energy that is generated on-site to offset usage. The Entopia Building has been awarded the EnerPHit Classic standard.

The **WELL standard** addresses health and wellbeing criteria in the design and construction of buildings. Run by the International WELL Building Institute (WBI), these performance standards target design interventions, operational protocols and company-wide practices that enable healthy environmental conditions for the future users of the building throughout the design and construction stages. The highest rating in the standard is WELL Platinum.

Reclaim and reuse materials

While the ambition to follow circular design principles through procurement was strong, no practical standard or certification scheme was identified to guide implementation. We, therefore, set objectives to maximise the use of secondary materials (reclaimed and reused materials), design out waste, allow for maintaining of products and materials in use and, when feasible, use bio-based materials.

Bio-based materials are derived from living organisms such as plants or algae, which, when sourced responsibly, can be considered renewable and sustainable. Their ability to biodegrade and re-enter biological systems at the end of service life means that, in principle, they are better positioned for circularity. Specifying bio-based materials in buildings reduces the need for non-renewable natural resources in building materials which may require carbon-intensive industrial manufacturing (European Commission, 2022).

Meet multiple targets

> **“While some of the targets may be considered routine for leading sustainable buildings, others were more difficult, and the combination of multiple objectives and targets was extremely challenging given the lack of precedents in the industry. This challenge was embraced by project team members as a key opportunity for creating learning and innovation in the project.”**

CISL decided to pursue multiple certifications in consultation with the design stage team and with support of the project partners. We agreed that no single rating system existed that was sufficiently comprehensive in its objectives or targets.

The project brief was always intended to be challenging, not just in its targeting of BREEAM Outstanding, EnerPHit Classic and WELL Gold certifications, but also in placing circularity and low whole life embodied carbon as central goals in the project. The final brief is shown here, and the project charter is shown here. The final brief included BREEAM Outstanding, EnerPHit Classic and WELL Gold certifications, with bespoke targets added for circularity, bio-based material content and embodied carbon performance.

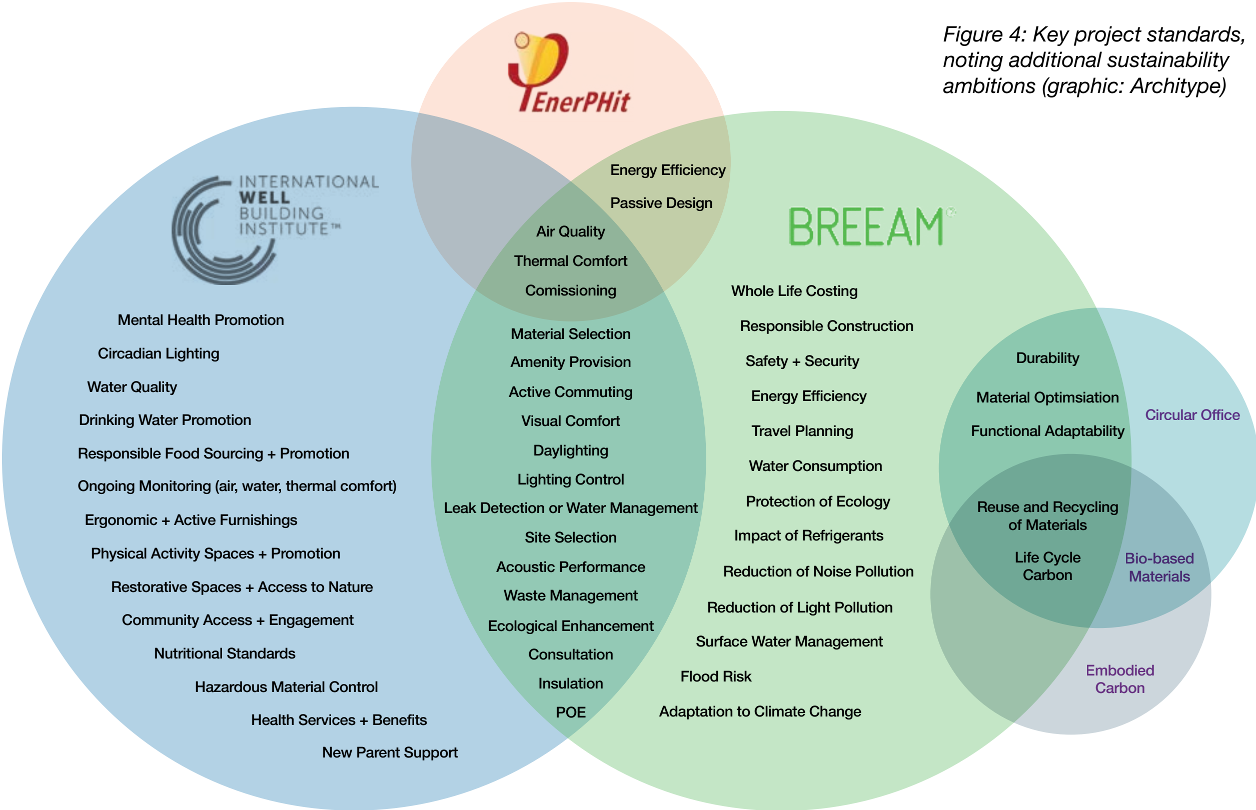
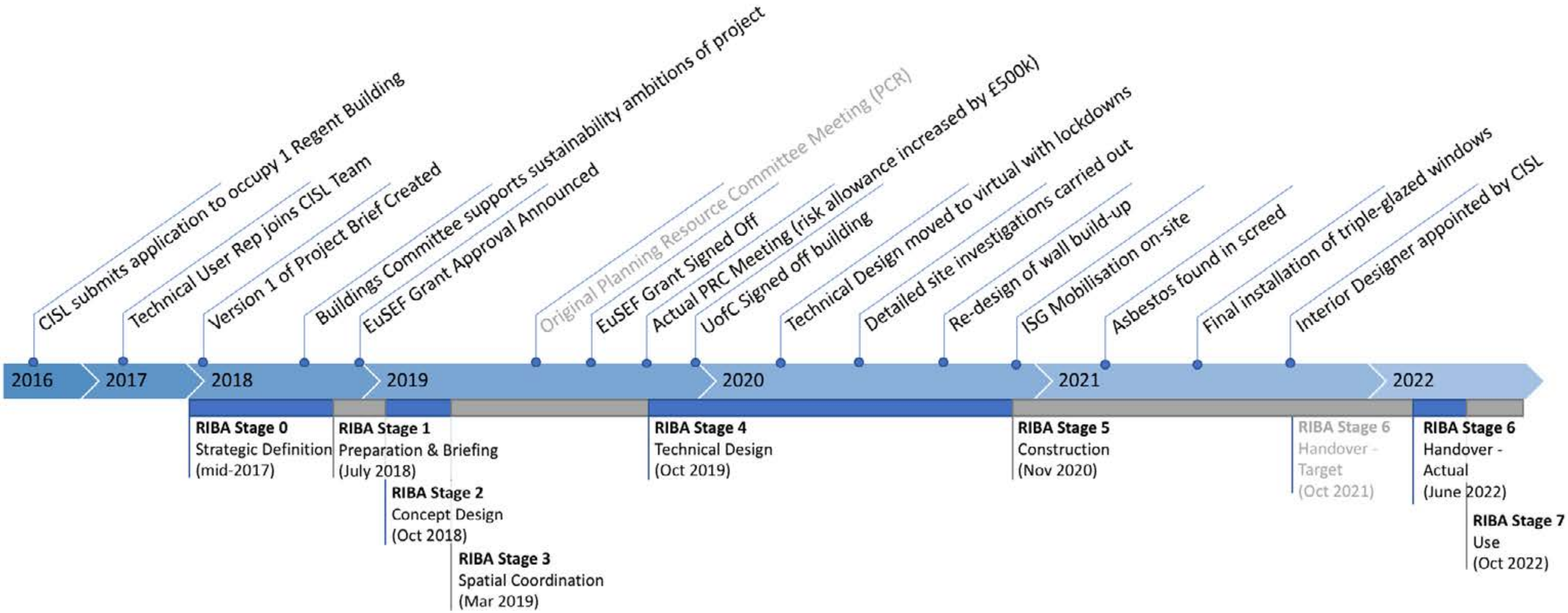


Figure 4: Key project standards, noting additional sustainability ambitions (graphic: Architype)

In summary, the following targets were included in the final brief:

- BREEAM Outstanding.
- EnerPHit Classic.
- WELL Gold.
- Low embodied carbon (target < 300kg CO_2/m^2 for 100-year life).
- Targeting 70% of bio-based materials, with responsible sourcing and traceability.
- Use of recycled and reclaimed materials, emphasising Circular Economy principles.

Project timeline, highlighting RIBA stages



© SOLK Photography Ltd / ISG

3 Activities and outcomes

Fabric first / Building services / Budgets / Conservation / Standards / Materials

“The design strategy was based on a ‘whole life’ perspective that considered sustainability impacts and benefits across the lifetime of the building as fundamental design parameters.”

A fabric first approach

Fabric first improves energy performance
The adoption of a 'fabric first approach', in which reducing energy demand is prioritised above obtaining energy from more sustainable sources and is considered in design before the building services, led to a remarkable improvement in the predicted energy performance of the building envelope (i.e. its structure and the components that enclose the internal spaces). This enabled a corresponding reduction in equipment capacities required in the building's mechanical, electrical and plumbing (MEP) systems.[8]

Smaller carbon footprint
Ultimately, by reducing the requirements for the building's services, we could achieve a substantial corresponding reduction in the building's carbon and material footprint. Additionally, the ability to specify smaller MEP equipment reduced the associated capital costs of the MEP systems relative to a conventional fit-out. This common-sense approach to design, combined with a strategy of minimising interventions to the existing building, enabled Entopia's exceptionally lean and sustainable outcomes.


© Architype

Improved collaboration
The layout of the office spaces supports collaboration through purpose-designed team-working spaces, open plan seating, and meeting rooms. Opportunities for collaboration are further enhanced by the presence of start-ups in the building located within the Canopy incubator area. Quieter areas for desk-based work, meeting rooms and sound-attenuating surfaces accommodate a range of user preferences.

Fabric first interventions
The fabric first approach focuses on thermally insulating the building envelope and making the building as airtight as possible to enable more efficient control of internal conditions. This holds the heating or cooling in the building for longer as there is little opportunity for the air to escape, and the walls are well insulated with limited thermal bridging. This strategy, coupled with a highly energy efficient MVHR ventilation system, provides thermal comfort with less reliance on heating and cooling systems. This reduces energy (and therefore carbon emissions) required to maintain thermal comfort and allows smaller MEP equipment – and less of it overall – which reduces the building's whole life embodied carbon. The fabric first approach is challenging to implement in existing buildings as it requires a deep understanding of the existing structure and a different approach to design.

Meeting the EnerPHit standard
A fabric first approach is required to achieve the airtightness levels specified within the EnerPHit standard. This requires the construction of an internal insulation line for buildings in conservation areas or otherwise needed to maintain the appearance of the external façade.

Installing a new internal build-up of the external wall can be achieved using a bio-based airtightness layer, but additional design and construction challenges are involved in achieving this. In Entopia, this entailed the construction of an internal timber stud wall, which allowed the windows to be inset to maintain a contiguous thermal and airtightness line.

Procuring triple-glazed windows that met the sustainability requirements was a notable challenge encountered in the project, particularly as the UK does not have a large market for these types of windows. The windows were supplied from Austria in partnership with a UK installer. The supply of high-performance building components in the UK will need to improve if the building regulations are to require increased levels of building energy efficiency.

8 Equipment capacity refers to the maximum output of equipment, which generally corresponds to the quantity of material required in its manufacture and the equipment's demand for energy while in use.

Maintaining façade while creating an airtight envelope

The fabric upgrade included installing a new continuous internal wall insulation line throughout the building, which maintained the appearance of the original external façade. This was important given the building's location within a local conservation area[9]. We installed this new 'internal, external' wall to maximise the benefit of an airtight envelope, a process described on-site as constructing a 'building within a building'. This is evident in the cross-section shown in Figure 5, which shows the additional build-up applied to the inside of the existing wall (reducing the net internal area of the building slightly).

The new internal wall build-up employed wood fibre insulation to reduce thermal conductivity and a lightweight lime and cork plaster to increase airtightness and provided additional insulative value, which also reduces the moisture risk of internal wall insulation. Gutex, a 40mm wood fibre insulation product, and Diathonite, a lime and cork plaster applied to existing walls in two 20mm layers, were installed. We believe this is the first time Diathonite has been used on a commercial building of this size. It was noted in interviews that its specification introduced challenges as it requiring an additional wet trade to be introduced into the project programme. This was accompanied by the installation of a timber-framed stud wall and new windows inset to the new position of the wall to provide a contiguous thermal and airtightness line.

© SOLK Photography Ltd / ISG

9 Building projects within local conservation areas are commonly subjected to additional scrutiny and debate with regard to heritage and conservation concerns in the planning permission process.

Tackling rising damp
A notable challenge was the need for remedial basement damp proofing when rising damp was discovered on deep inspection. While this could be addressed relatively easily in a conventional project, the brief required an evaluation to determine whether the required materials could be bio-based. We found a solution by using a conventional 'non-vapour breathable' (i.e. low vapour permeable) high-density polyethylene (HDPE) 'eggcrate' tanking member to form a drained cavity. The bio-based timber studwork and insulation used elsewhere could then also be used within this watertight lining. This bespoke solution required additional time to be allocated into the delivery programme.

Striving for airtightness
We presumed the existing concrete floor slabs to have good airtightness, and we considered it important to place an integral screed over the exposed slab areas and no plans were made to install new screed. We subsequently discovered that the existing screed had a bitumen coating containing asbestos, and so the top layer had to be removed, which required disturbing the intact layer. Using an air test bay, we tested an experimental low-permeability layer for localised use in this area. Although it did not provide complete airtightness, we determined it to be sufficient for this application. This solution also helped to mitigate undesirable permeability levels associated with an old heating trench that was found with pipes penetrating the external wall where the new internal wall line was planned. Due to the requirements for high fabric efficiency, this could not be remedied as easily as in a more conventional project where higher permeability values could be tolerated.

It is also worth noting that during opening up works, it was discovered that part of the building was a later extension, with a different primary structure. This required an alternative airtightness strategy.

The services trench around the perimeter of the building was discovered during opening up works, and also required airtightness treatment.

Sourcing energy-efficient glazing
The existing single-glazed windows in the building – supplemented by some secondary glazing installed in 1998 – provided poor energy and daylighting performance and so were replaced with new high-performance triple-glazed units. We found it challenging to identify a supplier capable of providing windows of the required size, energy performance, Passivhaus certification, acoustic performance, secure by design requirements and aesthetic specification.[10] We sought a supplier who also had confidence in the necessary fixing detail and would sign standard contract terms. We eventually identified a single suitable supplier, Internorm, based in Austria. Window supports were treated using airtightness membranes (Proclima Intello and Blowerproof) and an insulating and sealing system (Winframer). As the allowable thickness of insulation was limited on dormer window cheeks, aerogel insulation (Spacetherm) was applied due to its high thermal performance per unit thickness. Among other design factors, this permitted the installation of manually openable windows.

© ISG

10 A police-backed drive to encourage the construction industry to incorporate crime prevention measures in order to improve building security.

Provision of building services

"Following the fabric upgrade, the second part of the design strategy concentrated on building services. The aim was to maximise the efficiency of equipment and systems to allow heating and cooling of the building without gas supply as the mains gas supply was to be disconnected."

84%
cut in energy usage compared to pre-refurbishment

350
recycled LED lights

5.4 KWh
KWh/m2 GIA a year from solar PV

Air source heating
An air source heat pump provides heat in the air handling unit (AHU) that circulates warm air through the ventilation system to the whole building. This is supplemented by local electric radiators with simple controls and by fan coil units in high occupant density spaces such as meeting rooms. The fan coil units use a separate heat pump system to provide energy-efficient space heating and cooling. Peak cooling thresholds are set so that up to 4°C is removed from incoming air when the external air temperature is above 28°C. During summer nights, the AHU brings in cooler outside air to remove the building's thermal mass from the heat built up during the day, helping to pre-cool.

Solar PV for the roof
The roof terrace cover contains photovoltaic (PV) panels to provide an estimated 5.4 KWh of renewable electricity per metre squared GIA per year (KWh/m² GIA per annum). This post refurbished building is predicted to use 57.5 KWh/m2 of electricity generation across the building anually, representing an 84 per cent reduction against the building's pre[1]refurbishment baseline for total energy usage (see Table 1). The roof terrace cover contains photovoltaic (PV) panels to provide an estimated 5.4 KWh of renewable electricity per metre squared GIA per year (KWh/m2 GIA per annum).

Table 1: Annual energy usage before and after refurbishment project

Energy	Gas (KWh/m² GIA per annum)	Electricity (KWh/m² GIA per annum)
Pre-refurbishment*	223.0	140.0
Post-refurbishment (prediction)	n/a	57.5**

* *based on 2017 and 2018 utility bills*
** *from design stage BREEAM ENE02 Metering Strategy, does not include electricity generated on site from PVs, which, if included, would reduce this figure*


© ISG

Minimal active heating and cooling
We considered MEP provision carefully to maximise efficiency and performance. The fabric first approach allowed electrical capacity requirements to remain at pre-refurbishment levels, despite the switch to all electric heating. This avoided the high-cost risk associated with requiring more power capacity from the regional electrical distribution network operator. This was also valuable as it avoided the requirement for a new electrical transformer, for which little space was available on the site. The high performance of the building fabric allows thermal comfort to be maintained with MVHR ventilation and minimal active heating or cooling, including fewer local radiators and fan coil units relative to conventional buildings. Coupled with energy efficient Heating, Ventilation and Air Conditioning (HVAC) specifications, this reduces the amount of energy (and therefore carbon emissions) required to maintain thermal comfort and allows smaller MEP equipment – and less equipment overall (for instance, fewer local radiators and fan coil units) – to be used, this, in turn, reduces the building's whole life embodied carbon.

We designed ventilation ducting to maximise the floor-to-ceiling height in office areas and allow larger ceiling heights than the building afforded prior to refurbishment.

Services design included point-of-use tankless water heaters to reduce heat loss from distributing water from a central plant, plus the provision of zip taps to replace kettles at tea points, which were researched to be more efficient based on consideration of likely occupant behaviour.

© SOLK Photography Ltd / Architype

© SOLK Photography Ltd / Architype

LED lighting
A total of 350 LED lights were reused from a fit-out project in London. The original supplier of the lights agreed to retest and re-warrant the lights, and new endplates for the fittings were 3D printed so they could be installed on the exposed ceiling. Interviewees reported that this process was reliant on insurance approval and the client's willingness to engage in the reuse process.

MEP design strategy
Energy consumption post-refurbishment is expected to be less than 16 per cent of the pre-refurbishment level.

Exceptional gains in energy efficiency and optimisation of equipment capacity were enabled by the fabric first approach which had knock-on benefits throughout the building as less kit and smaller equipment avoided many potential design constraints.

The energy performance of the building will be monitored via a three-year post-occupancy evaluation (POE) programme to allow actual consumption data to be compared with predicted performance.

Controlling budgets

"Although the project was ambitious in vision, the leadership team wanted to challenge – and hopefully disprove – the notion that an exceptional building of this kind should necessarily cost more than a typical refurbishment."

£11.5m
initial budget

£12.7m
total project cost (subject to final adjustments)

£2.1m
estimated savings over 15 years

Setting budgets
An initial budget of £11.5m was allocated to the project. The funding requirement was met by various organisations, most notably from a generous £6m donation from Envision Group, a £3m grant from the European Regional Development Fund (ERDF) (with a further £1m to support the establishment of the startup and small business Accelerator activities programme), and £0.5m from the University of Cambridge's Carbon Reduction Fund. The remaining balance was expected to be drawn from CISL's financial reserves and from a partial VAT recovery.

It was critical that the project stayed within budget since any additional costs would be drawn directly from CISL's reserves, reducing its financial security and compromising its ability to invest in its mission to develop leadership and solutions for a sustainable economy.

Benchmarking challenge
The projected cost was difficult to benchmark as there were no fully analogous office refurbishment or fit-out projects in the UK to act as precedents. Interventions in any existing building present intrinsic uncertainties, and the structural risks and associated cost implications represented by the existing (pre-refurbishment) building were deemed significant in early-stage assessment. The original cost consultant allocated a 25 per cent cost uplift to accommodate the sustainability premium. This projection was considered high and jeopardised the future of the project[11].

When the leadership team challenged the basis of the estimate, the cost consultant could not justify the assumed uplift value. Subsequently, the cost consultant was not successful in retaining the role when a new consultant team was appointed at the beginning of Stage 2. The new cost consultant agreed "not to use a standard process, but instead take careful consideration to develop an estimate with appropriate confidence".

Establishing a budget to meet the brief
Cost consultants should be open to using non-standard approaches informed by conversations around contingencies at early stages of the process. Careful rechecking and evaluation of costs in Entopia avoided initial cost estimates that were 15-20 per cent higher than those reached in practice, which might have otherwise pushed the cost beyond the client's budget. Early contractor engagement with a knowledgeable sub-contractor enabled a more accurate tender and improved the contractor's awareness during the tender phase and their confidence in cost estimation.

11 The initial estimated total project cost was £11.5 million, and the total project cost before final adjustments is £12.7 million, which represents a 10.4 per cent overspend relative to the initial estimate.

Contingency funds tackle risk
Roughly £1m in contingency funds were retained in the budget in response to the risks identified. The most significant of these stemmed from the fact that the existing building had not been stripped back to its structure at a sufficiently early stage. In alignment with the NEC contract, the budget contingency contained three allocations: a project reserve, a construction contingency, and client-held scope items. The contingency and reserve elements were merged to allow money to be moved sensibly and efficiently. The contingency at early RIBA Stage 4 was approximately ten per cent of the total budget, and this was reduced to approximately four per cent after enabling works were completed.

Lifecycle cost savings
We also estimated the lifecycle cost during the budgeting stage, factoring in operational energy use over 15 years. As shown in Figure 6, it is predicted that the refurbishment (proposed scheme) could save £1.1m over the first 15 years of life compared to the pre-refurbishment building. Moreover, the proposed design could save £0.6m in expenditure on operational energy relative to a conventional office fit-out.

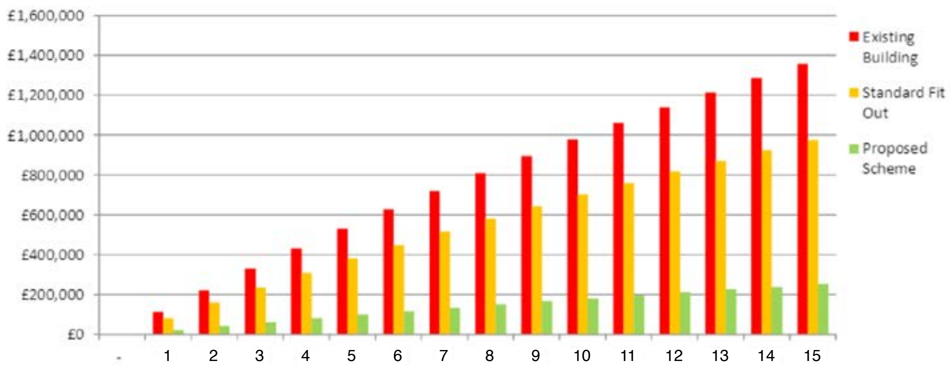


Figure 6: Estimated cumulative operational energy cost over a 15-year period

Whilst inflation at two per cent per annum was included in the cost assessment, no other allowance was made to reflect the generally accepted view that real energy costs were already increasing significantly in response to geopolitical instability and supply constraints. A review of energy price inflation in the light of the invasion of Ukraine means an additional savings of £0.4m over the first 15 years are now thought likely. In this way, Entopia illustrates a strategy for resilience against increases in the cost of energy, which significantly reduces financial risk for its owner-occupant.

"I think the biggest thing in terms of cost management was the fact that the client took on the existing building risk, as that kicked out quite a lot of discoverables for the project."

The impact of Covid-19 and other factors
The total forecasted cost as of March 2022 was £12.69m (£4,250/m^2, or £395/ft^2). However, it is estimated that the building could have been delivered for £8.9m (£2,986/m^2, or £264/ft^2) if the unexpected items specific to the project were excluded (see Table 2). These include prelims associated with the Covid-19 pandemic, existing building issues, and changes requested by the user, as well as uplifts associated with external works and interior design. Despite changes and alterations due to discoveries on site, the project was completed within the allocated contingency.

Risk analysis key to cost control
The quantitative risk analysis conducted every three months throughout construction proved essential to cost control. Achieving three challenging sustainability standards in parallel did not directly affect the cost of the project as the associated fees were budgeted from the outset. Conversely, meeting the standards did protract the duration of the project as items that might ordinarily have been reviewed relatively quickly sometimes required additional time given the complexity of criteria that needed to be considered.

Table 2: Total project cost with reduced project-specific items

	Total (£)	£/ft²
Total Final Account	10,540,524	317
Less Client Change and External Maintenance Works	10,106,795	304
Less Costs of Extended Programme for Existing Building Risks	9,878,965	298
Less PSCA and Stage 4 Design Fees	9,368.645	282
Lesss Covid-19 Costs for Site Operating Procedures	8,934,050	269

Cost increases caused by knowledge gaps not sustainability goals
It was reported that most of the changes and additional costs stemmed from a lack of knowledge of the existing structure rather than measures required to meet sustainability targets. This highlights the difference in approach that is required in a sustainable refurbishment as compared to a more conventional project, which can also be seen in the total cost breakdown (Figure 7). Relative to business-as-usual projects, it is estimated that 15 per cent more expenditure was spent on fabric enhancements and nine per cent more on contractors' costs. This additional cost was projected to be offset by a 15 per cent savings from the reduced MEP requirements and nine per cent from any additional shell and core work.

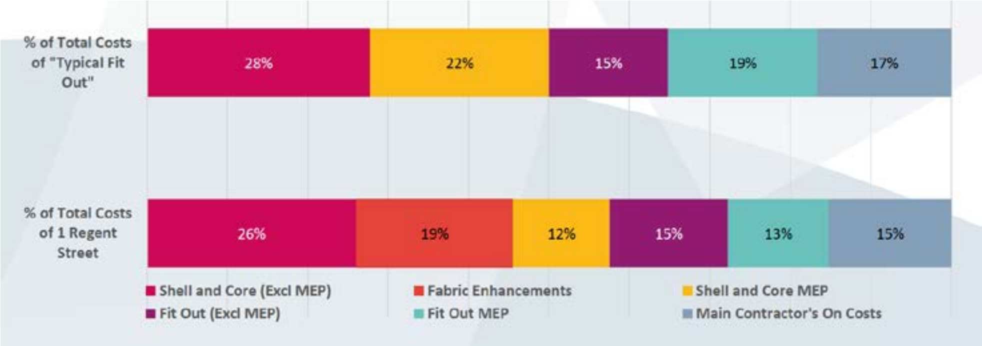


Figure 7: Comparison of cost allocation for 1 Regent Street (1RS) / Entopia and a business-as-usual (BAU) case

Triple glazing pushes up costs
The high-performance triple-glazed windows represented an abnormally high cost due to bespoke manufacturing in Austria to meet the EnerPHit standard and planning requirements, and procurement during the pandemic when construction costs were volatile and generally inflated. Their total cost was £0.5m, representing a lifecycle cost that is 20 per cent higher than double-glazed (and less energy efficient) equivalents; however, this does not reflect the expected savings in energy costs and maintenance associated with these windows. This experience suggests that a tightening of the energy performance requirement in the UK Building Regulations (Part L), which is likely to spur demand for triple glazing, may be impeded by a lack of a domestic manufacturing capacity.

Health and wellbeing predicted to improve financial return
Financial benefits are likely to flow from improved occupant satisfaction and productivity resulting from the health, wellbeing and sustainability performance of the building. Although these benefits were not assessed formally by the project team, research in analogous buildings suggests that considerable benefits are likely to accrue (Licina, 2021).

© ISG

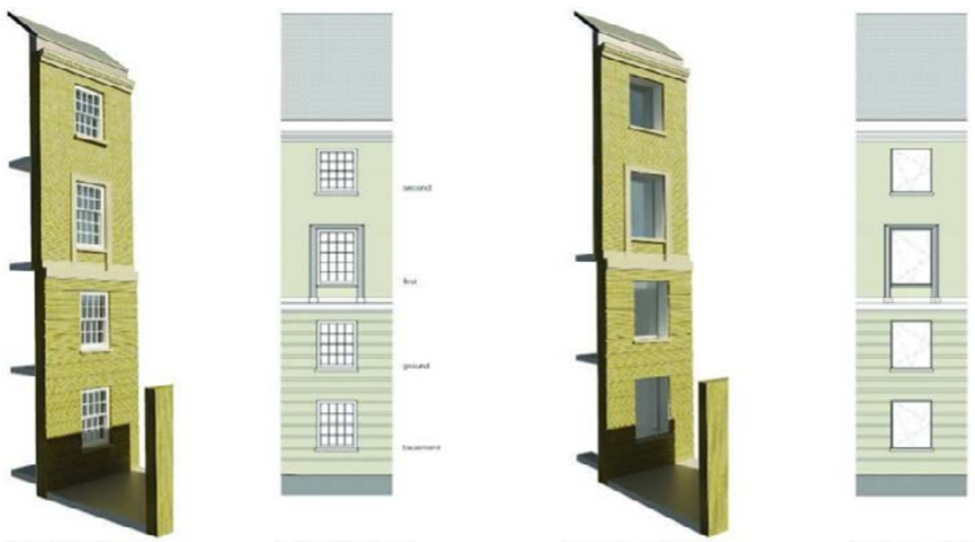
Balancing sustainability and conservation

"Entopia has set a precedent in Cambridge for balancing conservation concerns against energy and carbon concerns, based on clear evidence of climate benefits resulting from moderate flexibility on heritage concerns."

77%
increase in natural light

35%
cut in heat loss (max)

3/5
councillors voted for sustainable designs



© Architype

Figure 8: Design implications of proposed windows: pre-construction (left) and post-construction (right)

Impact on streetscape
Engagement with the local planning authority at RIBA Stage 2 (Concept Design Stage) highlighted that the proposed Entopia Building works were felt to have a significant impact on the streetscape given the central Cambridge conservation area location. Consequently, an early recommendation for non-approval was made. This led to design changes such as reducing the area of solar panels on the roof terrace to eliminate their visibility from the street (and thereby reducing their generation potential). The proposed window design, which removed the traditional sashing and mullions as shown in Figure 8, was flagged as a potential concern given the heritage value of the sash and mullion elements (no concerns were raised about the windows being recessed into the building).

"Entopia demonstrates how local councils and planning authorities can experience trade-offs between sustainability and conservation/heritage priorities. Early engagement with the planning authority ensured there was support while going through the process."

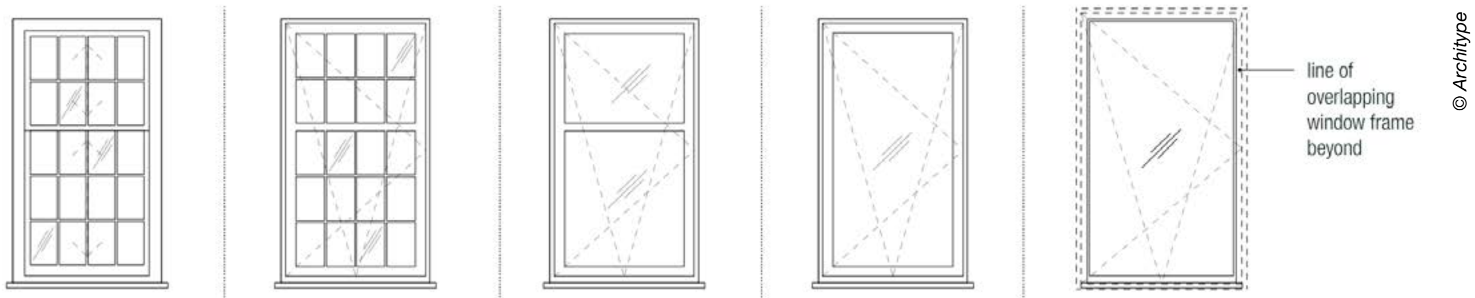
Justifying visual change

Coincidently, Cambridge City Council formally recognised the existence of a ‘climate emergency’ shortly before Entopia’s planning application was submitted. The design stage architect, with support from the leadership team, highlighted the implications of this commitment when the planning authority was evaluating the application for planning consent. The concern about window design pointed to a potential tension between the planning authority’s twin commitments to environmental sustainability and heritage. To support the planning application, the design stage architect developed an evidence-based argument to justify the visual change to the external façade. The argument that, amid a climate emergency, innovative solutions for low carbon performance should be prioritised was persuasive, and this ultimately helped to secure planning consent. Members of the project team noted that had this design element not been accepted by the planning authority, achieving the EnerPHit certification would have required greater effort, with less potential daylighting provided to the internal space.

Window design cuts energy use

Evidence to support the above argument came from predictive analysis that suggested that, relative to four other window styles, the proposed window design (Option 5, shown in Figure 9.) provided a lower demand for energy for heating, cooling and lighting. This window design minimised heat transfer through the frame area, which was recessed and behind the insulation wall, and avoided transfer through transoms and mullions, which are typical of traditional windows but were omitted. These elements also maximised daylight values, and reduced the demand for electric lighting and associated carbon emissions. The selected option, Option 5 (see Figure 9), increased the glazed area by 60 per cent relative to the original windows, which allowed for a 77 per cent increase in daylight levels (see Figure 10). Modelling the window details for Option 5 in the Passivhaus Planning Package (PHPP) software showed that heat losses through window Option 5 were as much as 35 per cent lower compared to Option 1 (a double-glazed sash with a traditional appearance).

Typical ground floor windows



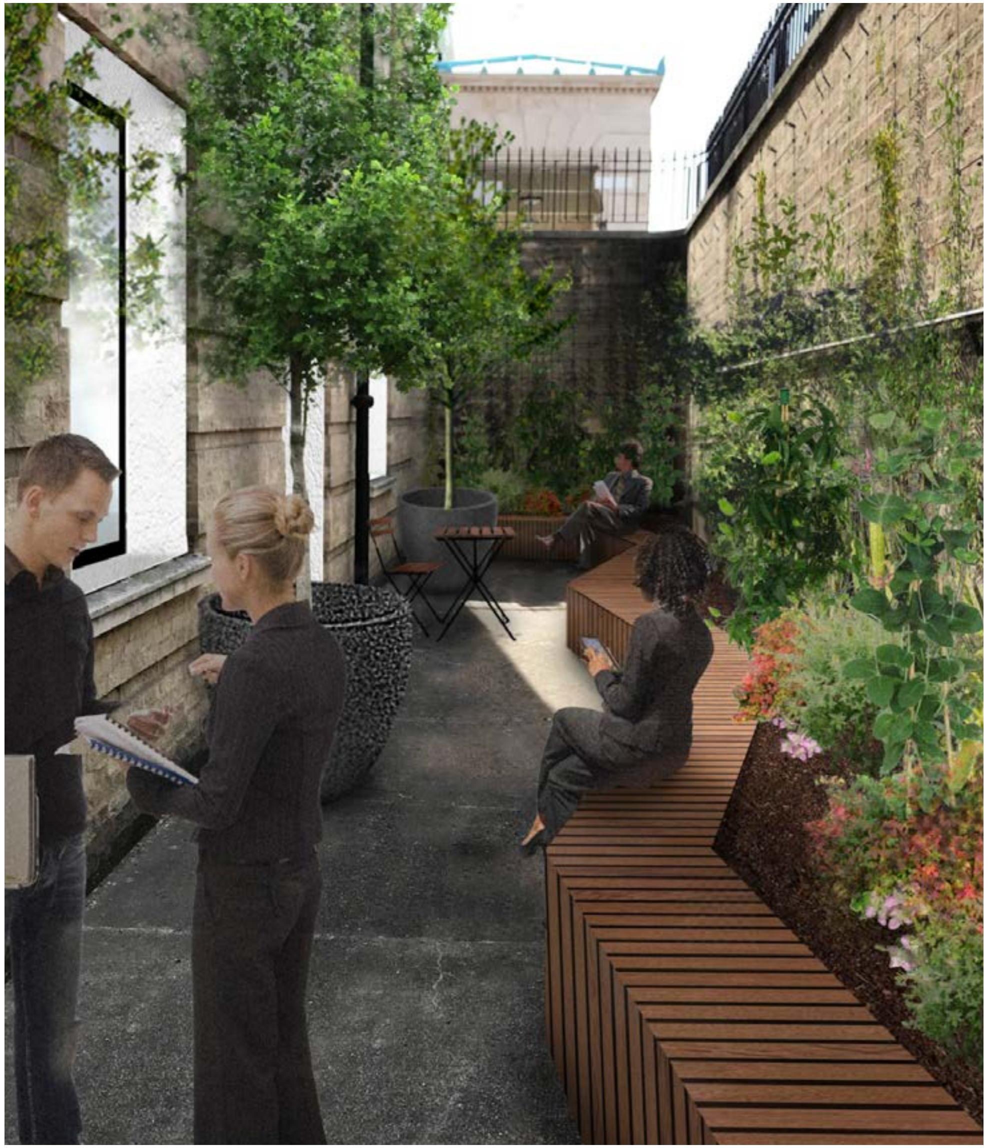
Option 1	Option 2	Option 3	Option 3	Option 3
Double glazed sliding sash	Triple glazed mock sash - central horizontal glazing bar with subdividing mullions & transoms	Triple glazed mock sash - central horizontal glazing bar only	Triple glazed tilt and turn Passivhaus window (open-in)	Triple glazed tilt and turn Passivhaus window with frame overlapping wall (open-in)
Average glazed area: 57.0%	Average glazed area: 61.5%	Average glazed area: 66.2%	Average glazed area: 69.3%	Average glazed area: 92.4%
U-value*: U(w) 1.5W/(m^2K0	U-value*: U(w) 0.95W/(m^2K0	U-value*: U(w) 0.93W/(m^2K0	U-value*: U(w) 0.76W/(m^2K0	U-value*: U(w) 0.69W/(m^2K0

**U-values given are based on U(w) for a 1230 x 1480 window in accordance with ISO 10077*

Majority councillor support
Once the planning application was submitted – including a supporting document describing the carbon assessment of the window options submitted on the planning authority's request – three out of five planning committee members voted in support of the sustainability argument, the other two rejecting it on conservation grounds. Thankfully the proposal was carried.

"I'm very pleased that the City Council had a part in ensuring that this project could proceed. The planning process recognised the public benefit locally, nationally and internationally of the scheme. The City Council will work with and encourage partners to bring forward exceptional projects like this one to ensure that Cambridge remains at the forefront of innovation in all the disciplines that contribute to a better built environment."

Ward Councillor Trumpington & Executive Councillor for Planning Policy and Open Spaces



© Architype

Achieving sustainability standards

"Early design and site coordination are essential when targeting multiple certifications, as the potential impact of changes or alterations needs to be reviewed carefully to check that performance criteria will be met."

20%
Cut in whole life embodied carbon between RIBA Stage 3 and 4

6,340kg CO_2e/m^2
GIA saved over 100 years

409kg CO_2e/m^2
Entopia whole life embodied carbon value at handover

21,000kg
furniture was given to the community

Charting new territory
The design stage team was familiar with the relationship between the BREEAM and Passivhaus standards and how they could be addressed in parallel based on direct experience of doing this at the UEA Enterprise Centre. However, as a refurbishment project rather than new build, Entopia presented fewer opportunities to control the parameters of design, prompting a re-evaluation of the team's past assumptions and experiences.

Detailed modelling
Achieving EnerPHit certification was particularly challenging as it necessitated an understanding of existing structural elements and the likely constraints. Similarly, detailed modelling using the PHPP software to predict the energy performance of building elements was reliant on a degree of understanding of the existing structure that was not fully available without a comprehensive intrusive survey involving the stripping back of surfaces to reveal internal structure. As a result, the site investigation information collected at RIBA Stage 4 revealed that some of the assumptions made in RIBA Stage 3 (Spatial Coordination) were inaccurate.

Passivhaus Planning Package (PHPP) design tool
The Passivhaus standard is a quality-assured methodology for low-energy building. Passivhaus buildings provide a high level of occupant comfort, using very little energy for heating and cooling, all Passivhaus-certified work must use the Passivhaus Planning Package (PHPP) design tool. This complex spreadsheet-based model contains all of the building envelope parameters required to model energy performance over a building's lifespan with sufficient accuracy for high-performance design.

Risk of moisture accumulation discovered
In RIBA Stage 3, we discovered that we needed to physically test the brickwork to improve confidence in WUFI hygrothermal modelling analysis that would inform the final design. Assumed values were used in the interim. In RIBA Stage 4, the project team performed the analysis based on data derived from intrusive testing of the wall. This suggested a significant risk of moisture accumulation in the interstitial spaces that existed within the walls when using the initially proposed solution. Adapting to subsequent design changes delayed the programme and added additional costs. This was a missed opportunity for the leadership team, as the building had been vacant well ahead of site mobilisation. However, access for intrusive surveys had been limited.

"Intrusive survey information must be collected as early as possible in deep retrofit projects to ensure that challenges associated with an existing building can be understood and addressed and risks can be designed out or a management strategy developed before relevant contractors are mobilised fully."

Value of comprehensive surveys

Funds to conduct more comprehensive surveys were not released before the project was fully funded, and CISL did not have control of the decision, nor the independent means, to conduct these surveys. It became apparent that the presumption – or default decision – that more comprehensive intrusive surveys were not required (based on the experience of more conventional refurbishment projects) was incorrect, impacting progress and costs at subsequent stages. As the building had been vacant well ahead of site mobilisation, the opportunity to conduct more thorough surveys could have been taken, but it had been assumed these were not justifiable in cost. During the period in which the Entopia project took place, the Estates Division in the University began a practice of routine reflection on lessons learned during projects. Some participants in this research from outside the Estates Division reviewed the importance of gathering more comprehensive survey information early in a deep green project, which was not fully achieved in the Entopia project. They also reported hopes that future projects would be less encumbered by complex negotiations of ownership, decision-making authority and interests within the University, such as those that, in their view, impeded gathering more comprehensive survey information earlier in the Entopia project timeline.

> **"I haven't seen another project that's embracing all of these different elements of sustainability in the built environment all at once on one project. That's quite challenging because it's [a refurbishment] of a building that's nearly a hundred years old."**

Whole life carbon targets

At the outset, Entopia's whole life embodied carbon target was established at 300 kg CO_2e/m^2. While this was originally thought to be achievable, the carbon assessment at RIBA Stage 2 suggested the final number might be 578 kg CO_2e/m^2, driven partly by the window specification. Following successive redesign and the construction process, Entopia ultimately achieved a value of 409 kg CO_2e/m^2 at handover. This compares favourably with benchmark values for commercial office buildings; for instance, the London Energy Transformation Initiative (LETI) suggests a baseline value of 1000 kg CO_2e/m^2 for new construction (lifecycle stages A1-A5, including substructure, superstructure, MEP, façade and internal finishes) (LETI, 2020), which does not include the operational carbon (associated with the energy and inputs into operating the building during its service life). Entopia's assessed embodied carbon from life cycle stages A1-A5 is 130.5 kg CO_2e/m^2.

Reducing embodied carbon

The main contractor was able to reduce whole life embodied carbon by 20 per cent between RIBA Stage 3 design to Stage 4, which equated to 58kg CO_2e/m^2 avoided through design improvement. This was achieved by omitting items such as the proposed floor finishes at Stage 3, saving 19 kg CO_2e/m^2, and by changing the ceiling finish, saving 6 kg CO_2e/m^2. More than 21,000kg of existing furniture and 19,000kg of other materials removed during construction were collected and distributed to the local community for reuse. It should be noted that assessing embodied carbon relies on data describing production processes, and such data vary in quality and reliability. One participant noted that this is particularly relevant to mechanical, electrical and plumbing elements, and underscored the limitations to full confidence in embodied carbon assessments.

Circularity, nature-positive and material choices

"What I found almost liberating about this project is that for the first time, a client was willing to consider the use of reused materials, second-hand materials in particular. That really opens your mind to what's possible and allows us to think differently."

BDP Project team member

350
LED lights reused

1
Reception desk recycled from Netflix

48%
Percentage of bio-based materials incorporated by volume

Designing out waste and pollution

Entopia illustrates many circular economy principles in its design and construction. In lieu of a universally accepted definition of 'circularity' in a building design context, the design stage team was asked to focus on designing out waste and pollution, maintaining products and materials in use, and using bio-based materials where these were available. In particular, secondary materials (i.e. reclaimed materials) were prioritised, and any new materials were selected for durability and design strategies that extended material service life.

The main contractor was critical in identifying and developing opportunities to procure secondary materials. This stemmed from familiarity with an extensive network of suppliers and contractors in other projects. In interviews, members of the main contractor's team described their disappointment at the failure of some of their circularity proposals, which suggested they had considerable motivation to meet this element of the brief. It was reported that despite strong connections between the project team and the design and construction sectors, it was difficult to identify procurement options for secondary (i.e. reclaimed and reused) materials.

"As architects, we didn't necessarily have the connections to procure secondary materials, but the contractor was able to reach out and find those products."

Reclaimed and reused

The following reclaimed items were reused within the project in line with its circularity objectives:

- More than 500l of paint: one quarter of the paint used contained 35% recycled content, which reduced the embodied carbon of the paint by approximately 10% compared to the use of a similar product without recycled content). Recycled paint was available in white and subsequently incorporated into the design. A quantity of recycled paint was supplied free of charge by Dulux.
- 350 LED lights: the main contractor was engaged with another client in a CAT A fit-out in London, which mandated that any materials removed from the project should be reused where possible. The original supplier of the lights agreed to test and re-warrant the lights, and new endplates for the fittings were 3D printed to allow them to be installed on the exposed ceiling.
- Main reception desk: a high-quality wooden reception desk was reclaimed from the UK Netflix office. The desk was designed by a top London interior designer and was acquired through the main contractor's supply network. Minor modifications to the desk were required before it was installed.
- Roof canopy steel: steel was reclaimed from a film set that was due to be scrapped. The structural engineer on the project redesigned the steel canopy to accommodate the dimensions of the reclaimed materials. By avoiding the need for new steel elements, this action eliminated 3.7 kg CO_2e/m^2, approximately one per cent of the total whole life embodied carbon of the refurbishment.
- Raised access floor: the existing raised floor in the building was re-used by stripping off its carpet tiles, cleaning off the adhesive, and reinstalling without any of the usual finishes, with an estimated saving of 27.1 kg CO_2e/m^2.

Measures that didn't make the cut
Examples of circularity measures that were considered but not implemented include:

- the reuse of existing toilet pans and washing basins (disregarded due to water-use inefficiency when considered over their lifespan)
- the repurposing of a kitchenette from the same source as the reclaimed reception desk (disregarded because it was poorly aligned with the design)
- reusing of secondary materials from the wider University campus (the University's Estates Division team searched, but no opportunities were found).

Bio-based materials
The target to use bio-based materials in the fit-out was critical to the brief. This was met by including bamboo kitchens, plywood and hemp lockers and joinery, linoleum flooring, wool faced acoustic wall panels as well as timber and hemp furniture with largely hemp and wool upholstery. Evaluation criteria for material selection included design performance, impacts associated with reclaim and reinstallation, and material sustainability credentials or third-party Environmental Product Declarations (EPDs). A key challenge in reusing furniture, fixtures and equipment (FF&E) was that EPDs and comparable information across manufacturers were unavailable for many materials. Without costly testing, the WELL standard requirements relating to indoor air quality were difficult to ascertain. However, the practise of sourcing second-hand furniture significantly cut down exposure to off-gassing and therefore had a positive impact on indoor air quality in place of new furniture.

Environmental Product Declarations (EPDs)
Environmental Product Declarations (EPDS) provide a standardised way for manufacturers or suppliers to assess and report on lifecycle environmental impacts associated with a product. EPDs help users understand a product's sustainability profile, which is essential to designing and constructing a sustainable building. The number of published EPDs has increased in recent years and exceeds 7,000 as of August 2022.

Interior design built on reuse principles
The interior design team employed a specification process based on circular principles:

- Over 60% of furniture in the project was reused.
- Additional furniture was prioritised from the second-hand market.
- Any new furniture was selected with maximum sustainability credentials.
- Furniture is flexible with long warranties and can be additive, to allow evolving needs to be met over time
- Furniture is designed for disassembly and refurbishment, ensuring spare parts will be available over a long period of time.
- Focus on classic design and motifs that are less likely to go out of fashion.
- Use of bio-based materials as per the project brief.
- Interior finishes such as ceramic wall tiles and kitchen worktops from recycled content.
- Use of materials with proven durability in higher traffic locations; more innovative materials in areas that present less risk of damage.
- Prioritise procurement from UK sources and suppliers.

Hemp chairs and barstools, hemp-based ply lockers, biobased sofa and chair upholstery, and tabletops made from waste wood chips have all been adopted within the design.

"This job has probably the least amount of materials we've ever come across because it's been stripped back to the bare minimum requirements. But it's never been more challenging because of the types of materials that have gone in, not only to meet EnerPHit but also to meet the WELL requirements."

Challenging bio-based materials target
The original bio-based target of 70 per cent of total materials by mass was inherited from the Enterprise Centre, a key inspiration for the project. This target was highly challenging, and no less so due to the considerable quantity of windows and dry lining (which typically contain limited bio-based material) required for the refurbishment. Although this target was ultimately not met, considerable achievements were made in maximising the use of bio-based materials. These were made by prioritising the specification of bio-based materials in design and procurement decision-making. For instance, the introduction of wood fibre insulation was highly significant, as insulation represented one sixth of the total volume of materials (less by mass). A decision to use timber studwork for linings and partitions was also important. Selecting a dry lining product that contained 15 percent bio-based material (Fermacell) also added to the project totals.

At RIBA Stage 3, the proportion of bio-based material was estimated to be 38 per cent of total new materials by mass and 56 per cent by volume. At RIBA Stage 5 (Construction), it reduced to 34 per cent by mass and 48 per cent by volume. In short, the intended target was missed, indicating that a 70 per cent bio-based material target may be more challenging in a refurbished masonry building than in a new timber-framed building.

Several participants advised that a clear and measurable target for circularity would have been useful, and that while the circular economy policy in the project brief was useful. Some reported that the targets were not achievable in a masonry construction or project of this context, and so they were deemed unhelpful.

4 Working practice

Leadership / Collaboration

"In an ambitious project of this kind, a strong sustainability representative should be involved at every stage, at every level, and from every stakeholder. This provides sustainability advocacy from beginning to end of a project, which is of critical importance. It encourages all parties to develop in-house sustainability expertise and capacity-building and maintain awareness of sustainability drivers."

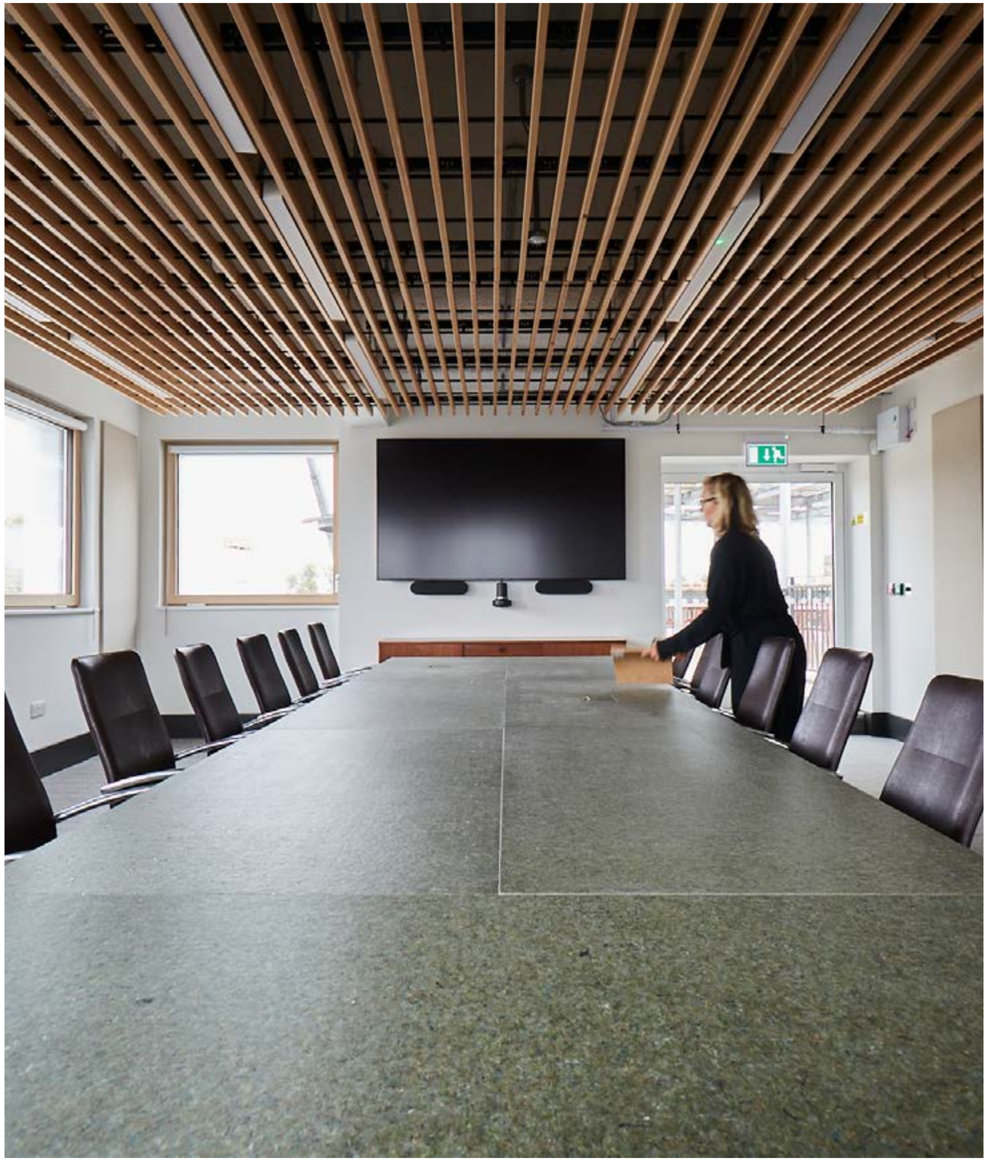
Prof John French CISL Associate and Senior Project Advisor

Strong leadership

Client central to decision-making
In a typical project, clients rely on design and construction consultants to put forward recommendations for improving sustainability performance. As a project progresses, there is a real risk that the proposed approaches are de-prioritised as costs escalate within a constrained budget (value engineering). In the case of Entopia, CISL was more integrally involved in design strategy and decision-making than a typical client. As such, the leadership team articulated its goals for the project and asked the design stage team for sustainability targets and credentials would deliver them. All options put forward were considered with a view to maintaining alignment with the strong sustainability vision established at the outset.

"Sometimes, when we are designing a project, there's an initial period where we have to convince the client or the users that they want to go down the Passivhaus route. Obviously, that's always been a complete given on this project, it's kind of like, 'yeah, fine, you want to do it, we want to do it, done'."

Sustainability ambitions defended throughout
We knew strong client-side leadership was needed from the outset to keep the project team focused on a highly ambitious brief. One means of achieving this was having a member of the leadership team who would defend the sustainability objectives brief consistently throughout the process of design and delivery. Among other roles, Prof French fulfilled this function for CISL, providing 'cradle-to-cradle' oversight, from the development of the original brief, to team formation, project workshops and quality management. This approach proved to be essential in maintaining sustainability ambition amid the inevitably cost pressures experienced throughout the project.



© SOLK Photography Ltd / Architype

It was critical that everyone involved in the Entopia project shared its vision and goals. This started with the leadership team, which ensured that sustainability was treated as an imperative – not a nice-to-have – informing strategy development and the selection of the design stage team and delivery team members. This provided continuity of CISL's vision and empowerment throughout the project and ensured that its aspirations were maintained without dilution during key decision points when obstacles inevitably arose.

"The leadership team possessed a balance of leadership, technical knowledge and experience. CISL was able to champion the project within the institutional structure of the University of Cambridge and through external fundraising relationships. It provided in-house technical expertise and was tasked with leading the development of the brief and overseeing its implementation."

Championing exemplar ambitions
The aspiration of the project to be a sustainability exemplar was shared across CISL's staff and, importantly, by its major donor, Envision Group. It was championed by CISL's director at the time, Dame Polly Courtice, who, with her senior team, was determined to turn it into reality. CISL was fortunate to recruit Prof John French to develop the practical vision and project strategy necessary to achieve this, based most immediately on his experience leading the award-winning Enterprise Centre at the University of East Anglia (UEA).

Polly later described the project as an "an ideal opportunity to demonstrate just what is possible without it costing an arm and a leg". Members of the project team recalled how early in the project she offered motivation by explaining the project would demonstrate how buildings could be created for the next hundred years, while developing critical capacity in the industry to meet stringent sustainability targets.

"When Polly comes to site, she's so engaging, which is really appreciated. The team feel they can speak to her openly and honestly."

Low embodied carbon as an industry standard
Ambitions such as the use of circular economy principles and low whole life embodied carbon were considered by all to be 'at the very heart of this building', with CISL willing to challenge norms at an institutional level while relying on members of the project team to advise on what was possible.

"This project provided a great example for the rest of the University in terms of what can be done, but it is also really important that we provide an opportunity for others in the built environment sector to see what is possible in terms of new materials and approaches. The goal is to encourage recognition that these things are possible, but also to recognise that they're going to have to really build skillsets and find supply chains that can make it the new normal, as opposed to what I have to admit has been, for us, quite challenging to pioneer in this project."

Dame Polly Courtice Founder and Emeritus Director, CISL

Collaboration and communication

"Consistent messaging from the leadership team throughout the project aligned all the key stakeholders towards the goals and inspired them to see the larger impact of their work. This led to a highly motivated team that was willing to take on the challenges associated with completing such a complex project."

Open communication
The leadership team ensured that anyone on the project team could contact any other team member for advice or consultation without hesitation or permission. A norm was established early in the project that team members should feel welcome to communicate freely, unencumbered by group hierarchy, structure or power. A member of the leadership team described this as, "If you need an answer, if you have a question, pick up the phone, email, get in contact with the right person and get the answer you need to move on. That made it a collaborative process." This was also embraced by the project manager, who was conscious of the risks of acting as a 'gatekeeper' between the client and other members of the project team (though at later stages of the project, this aspiration was reined in to streamline intense communications).

Effective coordination keeps project on track
Coordination and collaboration within the project team were essential to achieving the project's vision and objectives while maintaining a tight project timeline. For example, wall penetrations for items such as ventilation equipment, external lighting and CCTV cameras needed to be planned very early in the project to avoid compromising the airtightness layer of the building. Drainage installation required that all pipes were routed through a single roof penetration, which again required early planning and careful alignment between parties to avoid changes during construction. A further example of the value of close coordination was the need for the delivery team to verify the introduction of all new materials in the design against the requirements of the core standards and targets. To aid effective coordination, the project team developed a common understanding of the project brief and the steps required to meet it and address associated risks.

Workshops keep brief central to process
Workshops were used to engage the project team, review progress and develop strategy, discuss proposed innovations, and, as necessary, adapt the project brief to accommodate new demands. The workshops were held regularly throughout the project, and the project brief would typically be referenced frequently. Interviewees described the brief as always on people's minds, with members consistently assessing progress against it. This included raising when a target was not being met, or a concern existed that it could be off track. A member of the design stage team highlighted that they felt that "ultimately CISL wanted to be part of this process", which gave team members confidence to explore ideas and experiment.

Identifying and addressing issues
The workshops and open communication norms enabled discussion between team members to identify issues and develop strategies together to address them. The leadership team remained willing to revisit the project's sustainability targets (but not its vision or objectives) and reassess what was realistic or achievable. The goals in communication were always to examine or explain the reason for problems, work through the implications and options to address them and, as necessary, re-evaluate the brief.

The project's ambitions were routinely shared and reviewed with the wider client and contractor side teams. A member of the project team commented that the aspirations were "raised every single time we met for a meeting or a design team meeting; it was something on the radar all the time". It was reported that the leadership team was very clear from the earliest stages on its vision of Entopia being an exemplary building. Another project team member relayed that CISL was present during its meetings, which is not typically the case with many clients. This was felt to be "really useful just to see the way they were thinking about the building and the approach that we were taking and their enthusiasm for it".

"One takeaway from the project is the client has stuck to their principles about what they want to achieve… and they haven't allowed them to be value engineered away or dumbed down."

Implementing project charters and fostering collaboration
The use of collaborative workshops and virtual working enabled a faster, more productive workflow. Collective development of vision was used to set the tone of the project. It was described by one team member that "a different outlook and culture" needed to be embraced for the project to succeed. The tendency to work to – but not beyond – contractual requirements that is typical of many construction projects often engenders transactional relationships and self-serving motivations. This was considered incompatible with the aims of Entopia. What followed was later described as a "collaborative process to come up with a scheme that we'd all be proud of at the end".

Motivation and alignment
It was almost universally reported in interviews with members of the project team that they felt passionate about delivering the Entopia project and that they were personally and corporately committed to achieving its vision and objectives. It was said by many that they felt personally aligned with the aspirations of the project. As one member described, "this makes it a lot easier because everyone is in it for the same reason." Members consistently expressed sentiments such as wanting the project to "show that it can be done… not that it's easy, but that it's possible". Another member described the experience of implementing new techniques and strategies as getting "back to basics" and, using a "different mindset" to deliver results. Numerous interviews recorded a sense of pride in the outcome and the collective surmounting of challenges by the team. This was vitally important in the context of such a complex project with numerous risks and uncertainties. The shared ethos of the project helped to unite disparate stakeholders around common aims.

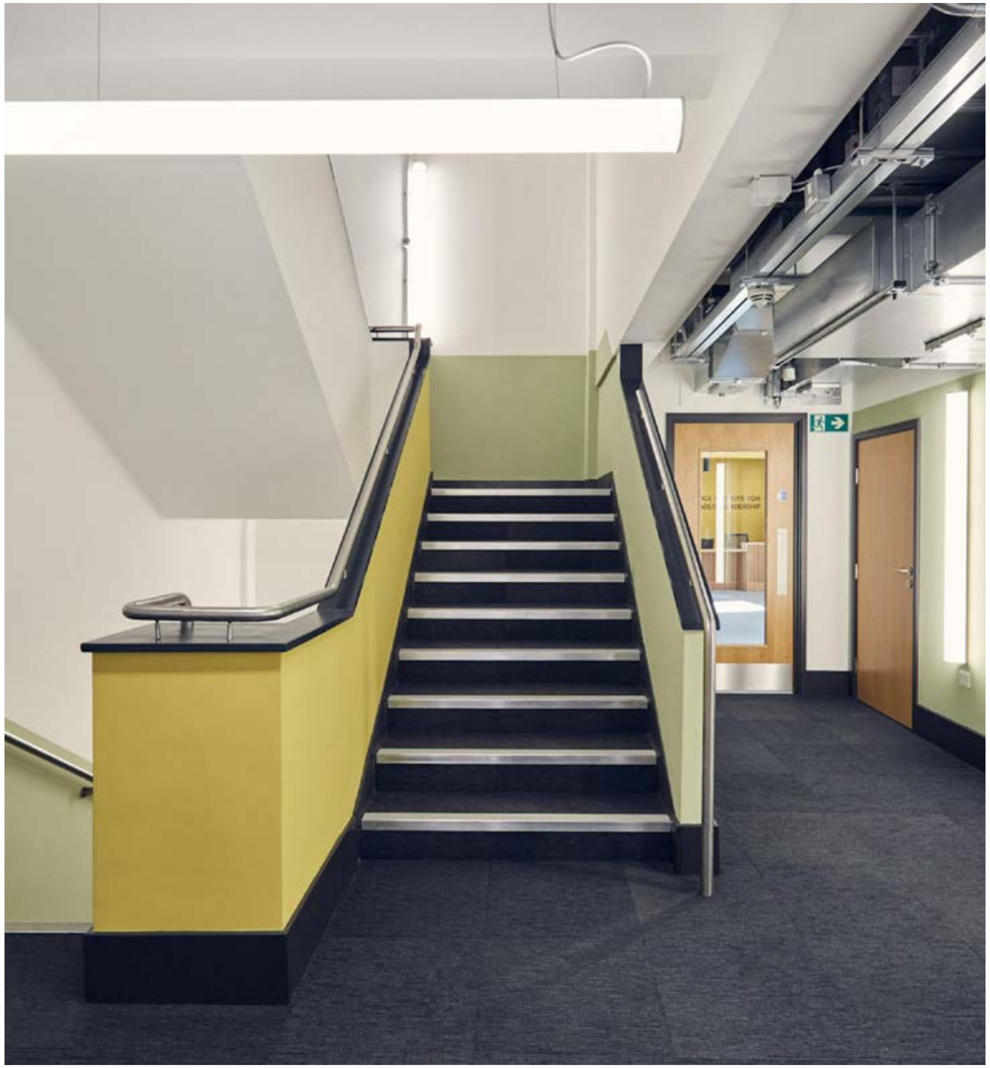
"Ultimately, we're looking at what's best for the building and what's best for the design, and it's quite nice to have that as a driver from the client."

© SOLK Photography Ltd / Architype

Leadership team sets tone
The leadership team partly inspired this ethos of commitment and pride and set the tone for the project with consistent communication to reinforce its goals. There was also evident determination from the project team to achieve the aspirational targets, reflected in how it responded to the challenges presented. A delivery team member commented, “Nobody has ever asked me to compromise. They’ve always said, ‘Okay, how do we find a solution that meets these requirements?’”. In turn, the commitment from the project team was praised by the leadership team, noting that they were “incredibly motivated and inspired” and that it felt like they were “a hundred per cent wanting” to reach the goals of the project.

Collaborative culture
Members of the delivery team noted that they had to adopt a “different outlook and culture” for this project, which met sustainability aspirations through a collaborative approach that “we could all be proud of at the end”. This collaborative culture was credited with giving the main contractor sufficient motivation to implement what was needed to deliver the project’s objectives at minimal cost impact. A member of the delivery team member commended the leadership team for not wavering on its sustainability goals.

“The client said, ‘Nope, we are going to stick to our principles. We’re going to deliver on our principles, and we’re going to have an office we can be proud of.’ And I think our project team has bought into that, culturally, and our senior management are happy not to compromise on that”.




© ISG

5 Lessons learned

Strategy / Team / Challenging cost perceptions / New practice / In use

“Numerous lessons were learned, and many may be transferable to projects with similar objectives and in analogous contexts.”

Anna Nitch-Smith COO, CISL

The Entopia building was a complex project delivered over more than four years, with the first project board meeting held in February, 2018 and the handover completed in July, 2022. The project challenged the accepted norms of practice in design and construction and the limits of sustainability performance – even for those routinely involved in delivering retrofit and sustainability-oriented projects.

Lesson 1: Define an ambitious sustainability strategy

Targeting BREEAM Outstanding, EnerPHit Classic and WELL Gold in one project, in combination with a set of holistic sustainability objectives, has delivered a deep sustainability retrofit that outperforms nearly any existing building in energy efficiency, contains a fraction of the whole life embodied carbon of typical new construction, minimises adverse sustainability impacts, and maximises usability and wellbeing for occupants. Despite the many objectives present in the three standards, we needed to define targets for the following areas deemed critical for the project separately: circularity, a high proportion of bio-based materials, and minimised whole life embodied carbon.

In terms of meeting the sustainability ambitions of the project, the following learning points were identified by members of the team:

- Adopting a fabric first approach is essential to achieving the fabric energy performance demanded by a high-ambition brief, and this requires extensive understanding of the existing building early in the project timeline. In the case of Entopia, if this had been undertaken earlier, it would have been easier to mitigate the risks associated with pre-refurbishment defects and irregularities in the building.
- Triple-glazed windows are required to provide the energy performance expected in a high-ambition project. Windows of the required performance are generally not specified in larger non-domestic buildings in the UK. In the case of Entopia, they had to be procured from an Austrian supplier Internorm.
- Circular economy opportunities require access to potential streams of secondary and reclaimed materials from other projects and contexts. In the case of Entopia, the contractor suggested a range of helpful proposals, not all of which would work given the complexities and constraints associated with the building. Patience, flexibility and understanding were required from the client in this respect.
- At present, a lack of information about how and from where secondary materials and reclaimed products can be sourced is a key constraint on delivering circular economy principles. In the case of Entopia, it was often difficult, if not impossible, to make use of available secondary materials due to the lack of EPDs or other information describing a product's makeup and potential effects on WELL certification.
- Similarly, it remains challenging to define the correct proportion of bio-based materials in complex refurbishment projects. In the case of Entopia, an initial target of 70 per cent by mass was ultimately deemed too high. A more realistic target for analogous projects might be 35 per cent by mass (50 per cent by volume), unless alternatives for the windows (including window panes) and dry lining can be found.

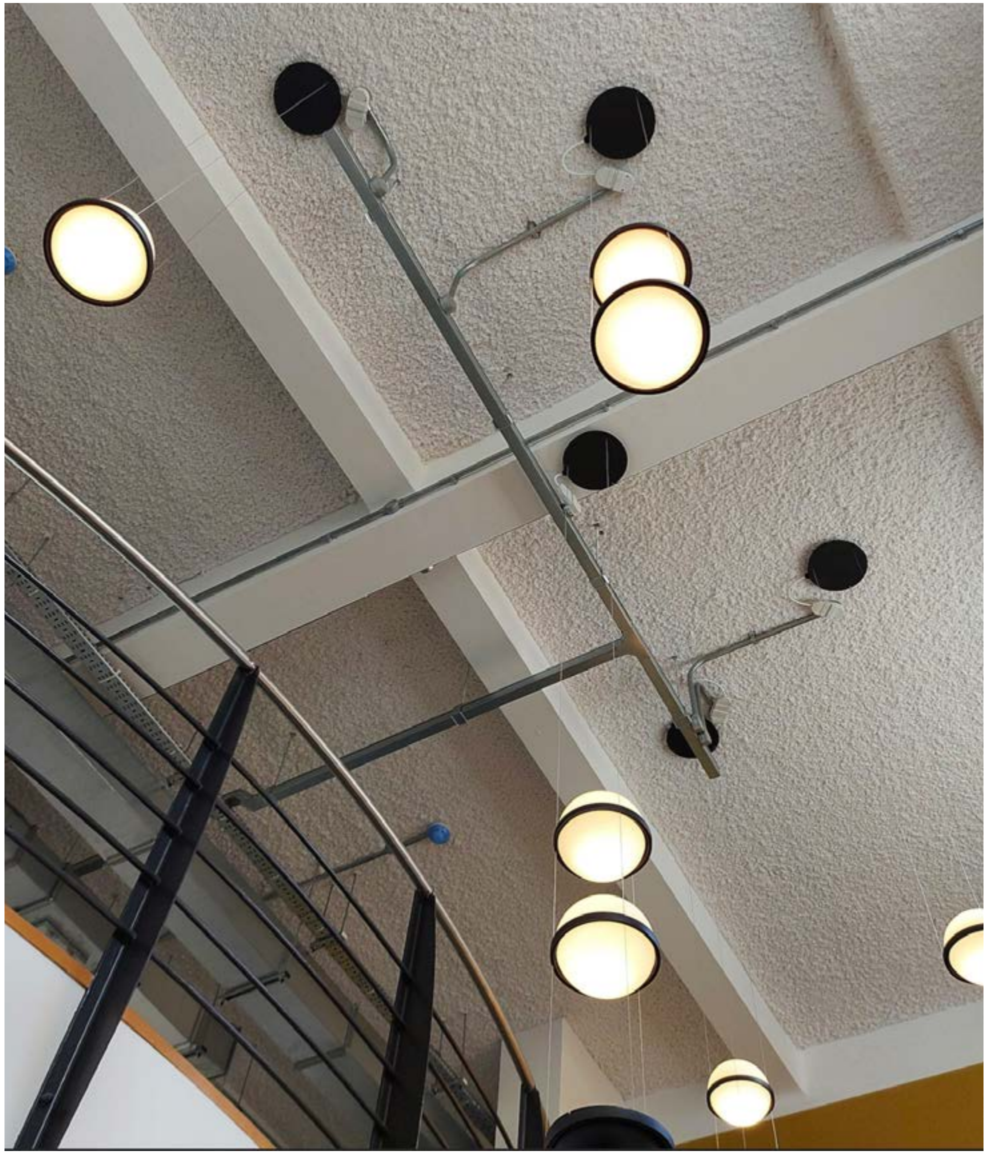
© ISG

Lesson 2: Form an aligned and motivated team

Effective sustainability advocacy from the earliest stages of the project to handover was provided by the presence and involvement of a nominated and empowered sustainability representative at every stage, at every level, and from every stakeholder. This advocacy needed to be accompanied by clear client ambition, shared leadership and good governance to ensure that the project's objectives were realised.

The leadership team focused on promoting an ambitious sustainability vision and fostering collaboration across the project team to create a constructive tone and atmosphere in the project. The client-side design team interacted more with the delivery team as the project progressed, helping to ensure that the project brief remained a priority for all parties. The project managers turned the brief into a one-page project charter that all project team members signed during RIBA Stage 4 to ensure alignment with the project vision and objectives. The project charter was considered a working document, and the leadership team remained open to it being challenged or refined throughout the project.

One delivery team member commented, "a different outlook and culture" needed to be embraced for the Entopia project. The use of collaborative workshops and virtual working enabled a faster, more responsive and more productive workflow. Notably, interviewees agreed that these outcomes were contingent on client-side leadership and its influence on key decisions. The openness to new ideas about delivering the sustainability ambition was described as "liberating"; for some, it was the first time a client had shown willingness to listen to and consider explanations of challenges or limitations encountered in a project, such as access to secondary materials. Project members reported that they felt connected to the aspirations of the project and generally enjoyed working on it throughout, which they related to open communications and collective problem-solving.



© ISG

Lesson 3: Challenge the belief that sustainable buildings cost more

Entopia shows that a deep sustainability retrofit of a historical building can be delivered with a minimal uplift in cost relative to a traditional fit-out if cost decisions consider lifecycle cost, rather than only upfront capital cost. An initial cost estimate of 25 per cent above conventional levels (at RIBA Stage 1) was shown to be inaccurate.

A non-standard process was necessary to assess the true costs of the building, breaking from past assumptions and experiences. In addition, including the sustainability ambition within the contractual arrangements ensured that it remained visible and central to all parties throughout the project, rather than being a costly add-on, extra or nice-to-have.

The members of the design stage team reported that the impact of various ‘unknown’ issues arising through the course of the project had a higher impact on the project budget than securing its sustainability ambition. That said, the requirements set by the three standards embedded in the project brief meant that design and specification changes had to be assessed against additional criteria to ensure certification compliance, which impacted the delivery timeframe.

© ISG

Lesson 4: Encourage planners and partners to absorb new practices

The Entopia project established a precedent in Cambridge for allowing exceptions to conservation restrictions on the grounds of environmental sustainability (helped by the Council's own declaration of a climate emergency). In this case, data were assembled to demonstrate with clarity the impact of various window specifications on energy performance, prompted the planning committee to rethink. More generally, this example suggests that planning authorities may need to re-examine how they manage trade-offs between increasingly urgent environmental concerns and conservation/heritage priorities, recognising that climate objectives – for example – may be unobtainable with conventional decision-making.

The need for change in the built environment industry and in government policy, conservation ordinances and building regulations is palpable given the challenges experienced in the Entopia project. Public authorities are well-positioned to enable the built environment industry to prioritise the refurbishment of existing buildings to meet the UK's sustainability and resilience ambitions, future-proofing the building stock against energy price volatility and climate change. Entopia illustrates the quality of the results that can be achieved through this strategy.

The message broadcast from the hoardings erected around the project during its construction said it all: "This is not an ordinary project. But it needs to be".

© ISG

Entopia in use: post-handover assessment

The performance of any design and construction project can only be assessed accurately by comparing predictions to measured values taken while the building is in use. Post-occupancy evaluation of buildings allows buildings to be 'tuned', so that problems or 'snags' can be addressed, building systems can be adjusted, behaviours can be informed, and thereby, energy performance can be optimised. In the Entopia project, plans for post-occupancy evaluation include a review of energy consumption patterns and performance against sustainability indicators, an occupant satisfaction survey (after the building has been occupied for at least one year), and a workshop-based review of lessons learned in the post-handover stage.

CISL will share updates to this report as the post-occupancy evaluation reveals new knowledge and insights.

> Find out more:

Click here for the latest news and updates about the Entopia Building: cisl.cam.ac.uk/about/entopia-building

© ISG

© ISG

6 Appendix

Glossary / Research approach / References

Glossary

Air handling unit (AHU) cooling coils – equipment to condition and distribute air within a building, by taking fresh ambient air from outside and transferring it to the designated areas.

Bio-based – products that are wholly or partly derived from materials of biological origin, excluding materials embedded in geological formations and/or fossilised.

Carbon – refers alternately to carbon dioxide ($C0_2$) or carbon dioxide and all greenhouse gasses (ie gasses that contribute to global warming through the greenhouse effect by absorbing and emitting radiant energy); in this report, 'carbon' is used to refer to all greenhouse gasses.

Direct expansion (DX) chilling units – cooling equipment that uses a refrigerant coil to lower the temperature of the supply air stream.

Dry lining – a system for cladding the internal faces of walls. In this project, Fermacell dry lining boards were used instead of conventional plasterboards. Relative to conventional dry lining products, Fermacell is denser and more resistant to damage in use, is more resistant to fire and offers is composed of gypsum (80 per cent) reinforced with cellulose fibre derived from recycled paper (20 per cent) without the use of chemical additives.

Embodied carbon (see whole life embodied carbon, below) – describes a 'carbon footprint', or the carbon emissions associated with life stages A1-A5: from extraction and processing of raw materials (or secondary material processing) to installation in the building (building handover).

Fan cooling units (FCUs) – equipment that uses a fan to draw room temperature air over cooling and heating coils to provide controlled air temperature into circulation.

Gross internal (floor) area (GIA) – the area of a building measured to the internal face of the perimeter walls at each floor level.

London Energy Transformation Initiative (LETI) – a network of more than 1,000 built environment professionals who are putting London on the path to a zero carbon future.

Prelims – the cost of the site-specific overheads of any given project, which are costs directly related to the running of the project that are not accounted for under labour or material.

Project programme – a timeline of activities that are required to deliver the project, including length of tasks, sequence of activities and required resourcing.

Refurbishment – the process of, or the result of, a renovation – ie bringing the building up to a state of repair or improved condition.

Retrofit – the process of, or the result of, adding a component or element to a building that was not present when it was originally constructed – typically conducted for the purpose of improving the building's energy efficiency or reducing its carbon intensity.

Whole life embodied carbon (see embodied carbon, above) – the embodied and operational carbon emissions over a building's lifecycle; 'embodied emissions' refers to greenhouse gas emissions associated with the extraction, transportation and manufacture of building materials and components, and 'operational emissions' refers to those associated with the building in use and its management and maintenance. Whole life assessment includes assumptions about future carbon values associated with energy supply and inputs for maintenance and building operation.

Research approach

This paper summarises the findings of a study undertaken by CISL to describe the evolution of the Entopia project and to document, understand and interpret the perspectives of stakeholders involved in its development and delivery.

The study followed an exploratory and open-ended case study approach based on one-to-one and small group interviews with stakeholders, a comprehensive review of project documentation, and observational research. Data were collected over 13-months from February 2021, and the findings presented in this report also draw on analysis of documentation analysis from earlier stages of the project.

Twenty-five primary interviews were conducted from October 2021 to February 2022, with 15 individuals drawn from principle contracting organisations and project stakeholders in executive and senior operational positions. Participants were chosen to provide a diversity of viewpoints from across the project team. Selection was based on participants' organisations, roles and responsibilities in the project, professional discipline or client-side position, and some open recruitment was conducted in project meetings. Interviews were conducted via video conference to accommodate the restrictions of the Covid pandemic – with the exception of one group interview conducted in person during a visit to the project site. Interviews typically lasted 30 to 90 minutes, and all interviews followed a semi-structured format that included pre-determined questions and open development of new questions during interviews.

Early interviews influenced the scoping of the study as they served to familiarise the authors with the project and contributed to the development of questions presented in subsequent interviews. Additionally, six interviews were conducted with key stakeholders prior to the research project, which included a discussion of the project and design elements. These provided the researchers with useful background information and guided the initial development of the research.

Project documents were collected for review throughout the study period. These included internal and external project communications, technical drawings, sustainability reporting associated with BREEAM, EnerPHit and WELL standards, application for planning consent, and project management documentation.

Observational research was conducted as non-participant observers of regular project team meetings conducted for the purpose of design review, project management, strategy development, and routine problem solving. These meetings were exclusively conducted via video conference, during which the authors remained visible onscreen but silent unless questioned by participants.

Interviews were analysed by the researchers using an iterative process of qualitative coding and sorting into analytical themes. This analysis was conducted with the aid of Quirkos, a proprietary computer-assisted qualitative data analysis software (CAQDAS) package. Field notes from reviews of project documents and observational research were analysed qualitatively using the codes and themes developed in the analysis of the collected data.

The findings have been interpreted in the context of trends in the built environment sector and their significance for wider audiences, supported by the authors' subject matter expertise and experience in engineering, architecture and construction practice in industry.

This paper has been reviewed by a cross-section of the Entopia team, including participants in the interviews and observational research who provided critical reviews of the authors' interpretations and suggested additions or revisions. This has allowed the researchers to assess and validate the analysis through 'member checking' (i.e. participant validation) of findings.

References

Architype (2022). *The Enterprise Centre. Retrieved from:* https://www.architype.co.uk/project/the-enterprise-centre-uea/ [last accessed 12 March 2022].

Building Research Establishment (2022). *How BREEAM Certification Works. Retrieved from:* https://www.breeam.com/discover/how-breeam-certification-works/ [last accessed 20 March 2022].

Cambridge City Council (2019). *Agenda item. Councillor Moore: Tackling the Climate Emergency -. Meeting of Council, Thursday, 21st February, 2019 6.00 PM (Item 19/10/CNLc). Retrieved from:* https://democracy.cambridge.gov.uk/mgAi.aspx?ID=21684.

Dixit, M.K. (2017). Life cycle embodied energy analysis of residential buildings: A review of literature to investigate embodied energy parameters, *Renewable and Sustainable Energy Reviews 79*. 390–413. *Retrieved from:* https://doi.org/10.1016/j.rser.2017.05.051.

European Commission (n.d.). *Bio-based products. Retrieved from:* https://ec.europa.eu/growth/sectors/biotechnology/bio-based-products_en [last accessed 20 March 2022].

European Commission (2018). *Energy Performance of Buildings Directive. Retrieved from:* https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/energy-performance-buildings-directive_en [last accessed 10 March 2022].

European Commission (2022). *EU Buildings Factsheets. Retrieved from:* https://ec.europa.eu/energy/eu-buildings-factsheets_en [last accessed 20 March 2022].

International Energy Agency (2022). *Buildings. Retrieved from:* https://www.iea.org/topics/buildings [last accessed 13 March 2022].

International WELL Building Institute (2022). *WELL. Retrieved from:* https://www.wellcertified.com/ [last accessed 20 March 2022].

Licina, D., Yildirim, S. (2021). Occupant satisfaction with indoor environmental quality, sick building syndrome (SBS) symptoms and self-reported productivity before and after relocation into WELL-certified office buildings. *Building and Environment,* 204.

London Energy Transformation Initiative (LETI) (2019). *Embodied Carbon Target Alignment. Retrieved from:* https://www.leti.london/_files/ugd/252d09_a45059c2d71043cdbcffc539f942e602.pdf.

London Energy Transformation Initiative (LETI) (2020). *Embodied Carbon Primer. Retrieved from:* https://www.leti.london/ecp.

New Engineering Contract (n.d.). *NEC4 Dictionary. Retrieved from:* https://www.neccontract.com/About-NEC/NEC-Dictionary [last accessed 20 March 2022].

Passivhaus Trust (2022). *What is Passivhaus? Retrieved from:* https://www.passivhaustrust.org.uk/what_is_passivhaus.php#2 [last accessed 13 March 2022].

Pomponi, F. and Moncaster, A.M. (2016). Embodied carbon mitigation and reduction in the built environment – What does the evidence say?, *Journal of Environmental Management* 181 687–700. *Retrieved from:* https://doi.org/10.1016/j.jenvman.2016.08.036.

Royal Institute of British Architects (2022). *RIBA Plan of Work*. *Retrieved from:* https://www.architecture.com/knowledge-and-resources/resources-landing-page/riba-plan-of-work [last accessed 18 February 2022].

Royal Institute of Chartered Surveyors (2022). *SKA Rating. Retrieved from:* https://www.rics.org/uk/about-rics/responsible-business/ska-rating/ [last accessed 3 March 2022].

United Nations Department of Economic and Social Affairs (2022). *Sustainable Development: The 17 Goals. Retrieved from:* https://SDG's.un.org/goals [last accessed 15 March 2022].

United Nations Environment Programme (2021). *2021 Global Status Report for Buildings and Construction. Retrieved from:* https://www.unep.org/resources/report/2021-global-status-report-buildings-and-construction [last accessed 09 March 2022].

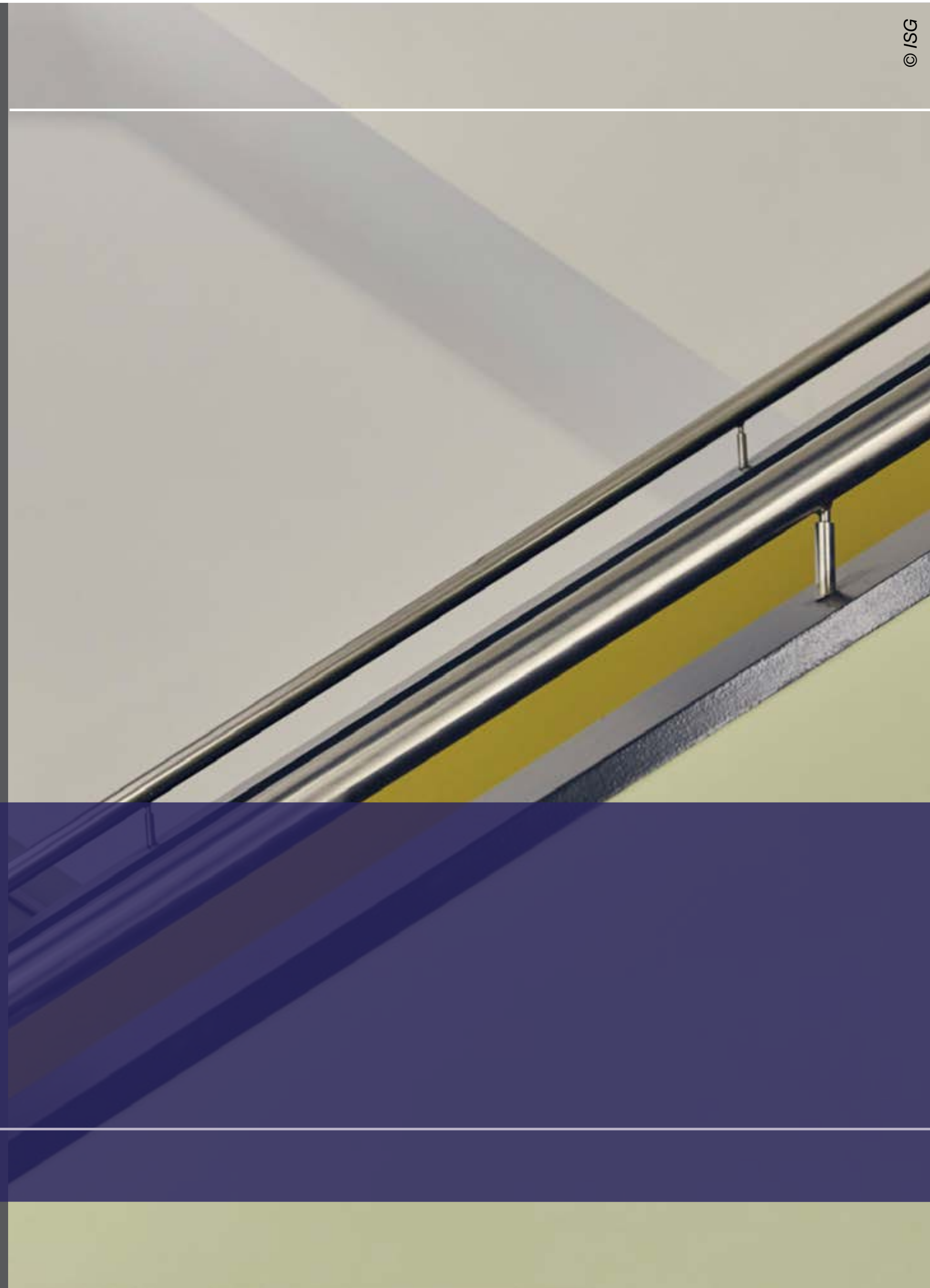
University of Cambridge (2020). *University of Cambridge Carbon Reduction Strategy: 2020 Update. Retrieved from:* https://www.environment.admin.cam.ac.uk/files/carbon_reduction_strategy_2020_update.pdf.

University of Cambridge (2022). *Cambridge Zero: a bold response to the world's greatest challenge*. *Retrieved from:* https://www.zero.cam.ac.uk/ [last accessed 21 February 2022].

UNIVERSITY OF CAMBRIDGE
INSTITUTE FOR
SUSTAINABILITY LEADERSHIP

Cambridge insight, policy influence, business impact

The University of Cambridge Institute for Sustainability Leadership (CISL) brings together business, government and academia to find solutions to critical sustainability challenges. Capitalising on the world-class, multidisciplinary strengths of the University of Cambridge, CISL deepens leaders' insight and understanding through its executive programmes; builds deep, strategic engagement with leadership companies; and creates opportunities for collaborative enquiry and action through its leadership groups. Over the past 30 years we have built up a leadership network of over 20,000 senior leaders and practitioners from business, government and civil society, who have an impact in every sector and on every continent. Their experience and insights shape our work, which is further underpinned by multidisciplinary academic research.



Head Office
The Entopia Building,
1 Regent Street, Cambridge,
CB2 1GG United Kingdom
T: +44 (0)1223 768850
E: info@cisl.cam.ac.uk

EU Office
The Periclès Building
Rue de la Science 23
B-1040 Brussels, Belgium
T: +32 (0)2 894 93 19
E: info.eu@cisl.cam.ac.uk

South Africa
PO Box 313
Cape Town 8000
South Africa
E: info.sa@cisl.cam.ac.uk

www.cisl.cam.ac.uk **@cisl_cambridge**