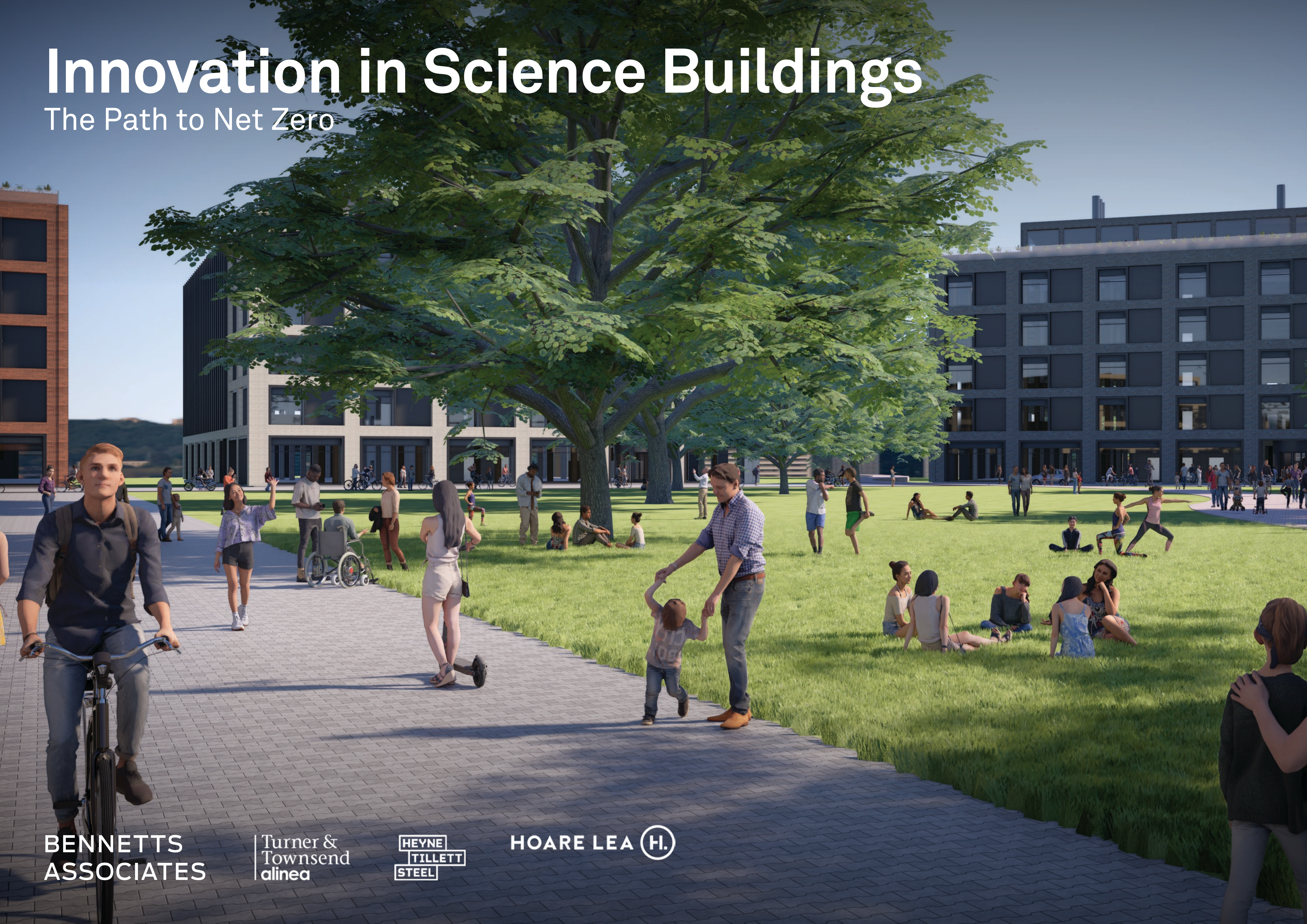
Innovation in Science Buildings

The Path to Net Zero



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Our Vision

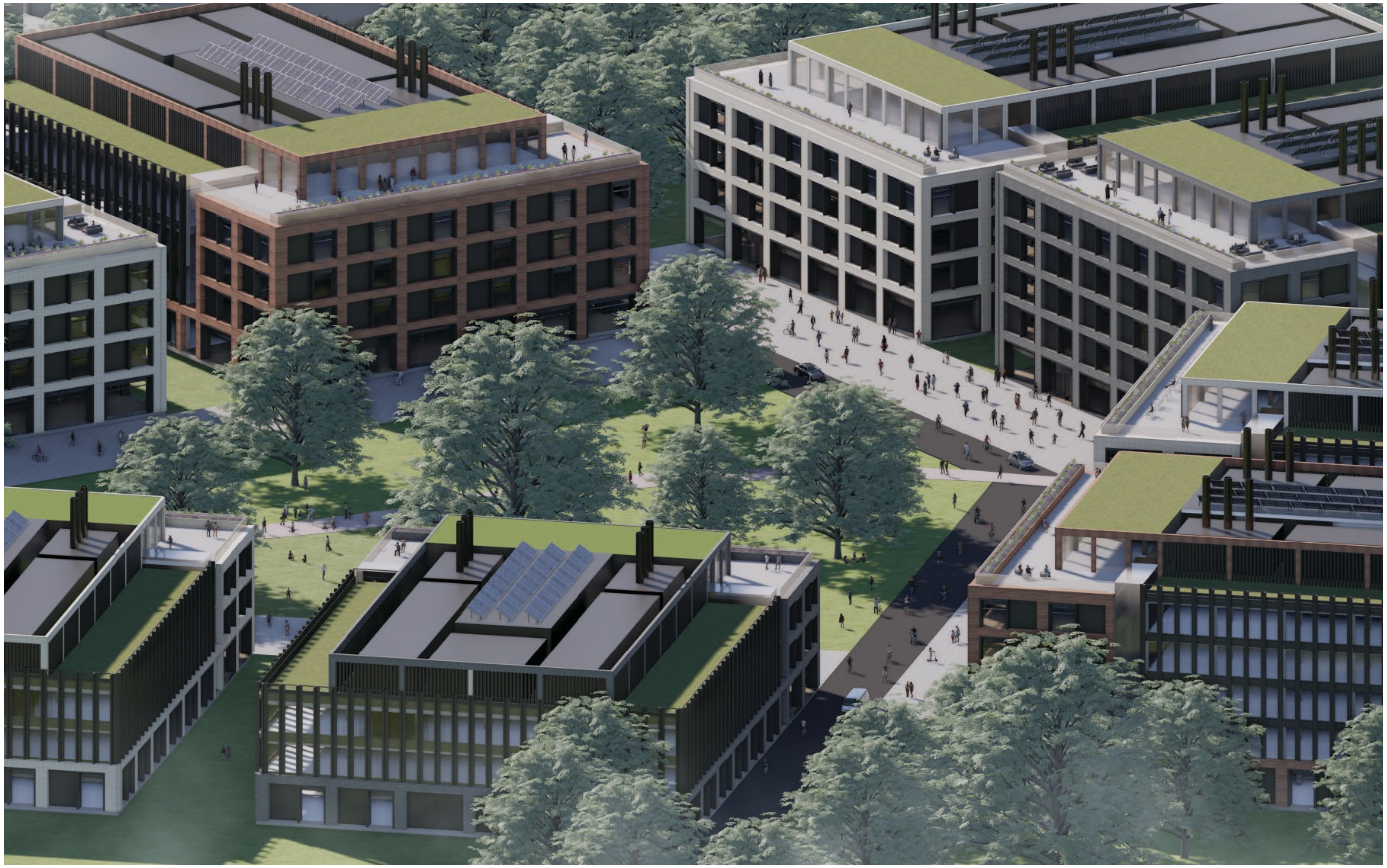
We want to see a science and innovation sector that is leading the way in sustainability and the fight against climate change. Scientists are passionate about the environment, but we know that many of the buildings they currently use have some of the worst lifetime carbon emissions of any sector in the built environment.

We want to help the science and innovation community by investigating why their buildings are more carbon-intensive, and applying a fresh, holistic approach to the design of science buildings with carbon reduction in mind.

We have assembled a team with expertise in the field of sustainability and in the commercial property sector including life sciences. The breadth of our cross-sector experience has allowed us to question the norms of specification, and to research the benefits that might result from different approaches.

The life sciences and innovation sector encompasses a wide range of building types and uses, In the UK the sector is growing quickly, and there is high demand for speculatively built accommodation to house the most commonly used types of spaces such as flexible wet labs and write-up space.

Common standards and specifications for speculative buildings are not yet fully formed or adopted, and we see this as an opportunity to investigate the implications of the choices that are often made right at the outset of a project but have wide-ranging implications for the whole life of the building.



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The Challenge of Net Zero

The UK science sector is just beginning to face up to the challenge of achieving net-zero carbon. Science investors and occupiers are becoming more discerning, and the sector is likely to follow others in commercial property with a flight to quality led by ESG and user wellbeing.

To achieve net-zero, the operational and embodied carbon performance of all buildings will need to be within the UK's built environment carbon budget.

This will require carbon emissions from the construction and operation of science buildings to reduce significantly, and targets are currently being developed as part of the emerging UK Net Zero Carbon Building Standard. These targets align with a science-based approach to meet the goals of the Paris Agreement.

Meeting these targets will require radical change to the way science buildings have been specified and constructed, much in the same way that we have seen in the office sector where the most progressive 'net zero' office buildings have become test beds for innovation in materials, environmental design and user experiences.

We have developed a lean and efficient prototype lab building to test our ideas and measure the effectiveness and cost of a range of carbon-reduction measures.

This prototype building is a test-bed for ideas and has allowed us to evaluate design ideas and measure carbon emissions

To achieve net zero, science buildings will need to bring into the mainstream design approaches which are already being used in more progressive proposals, including mass timber structures and alternative masonry products such as earth blocks

The Opportunity

Science and innovation is an active sector across the UK with thirty million square feet* of science buildings under development in Oxford, Cambridge and London alone.

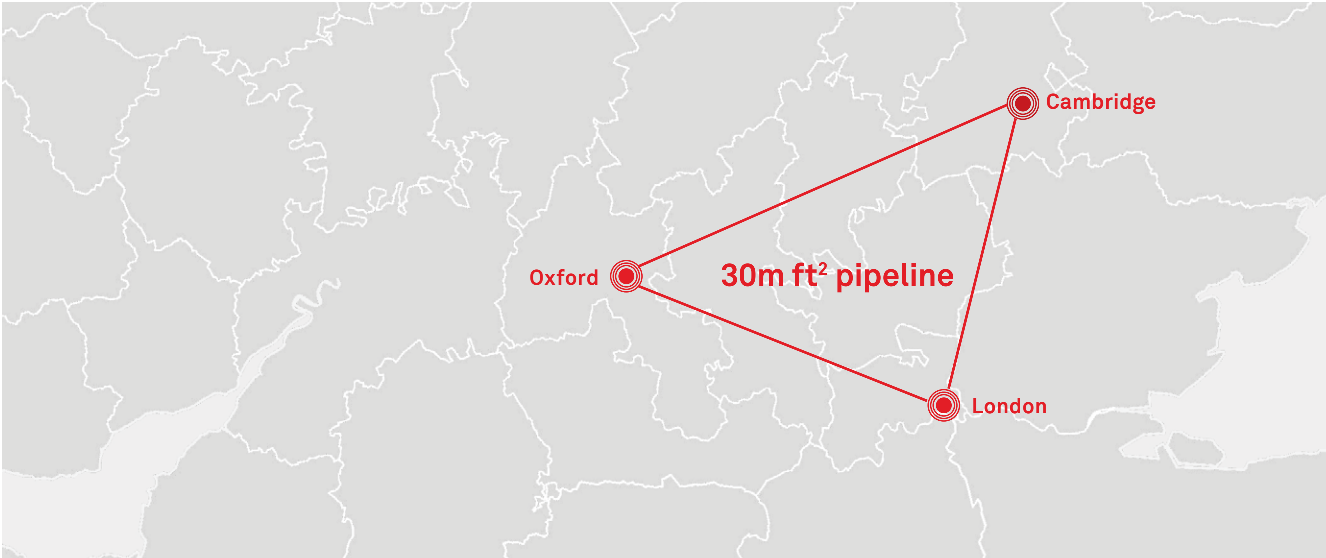
The delivery of this pipeline using conventional construction specifications could result in over 2m tonnes of upfront embodied carbon.

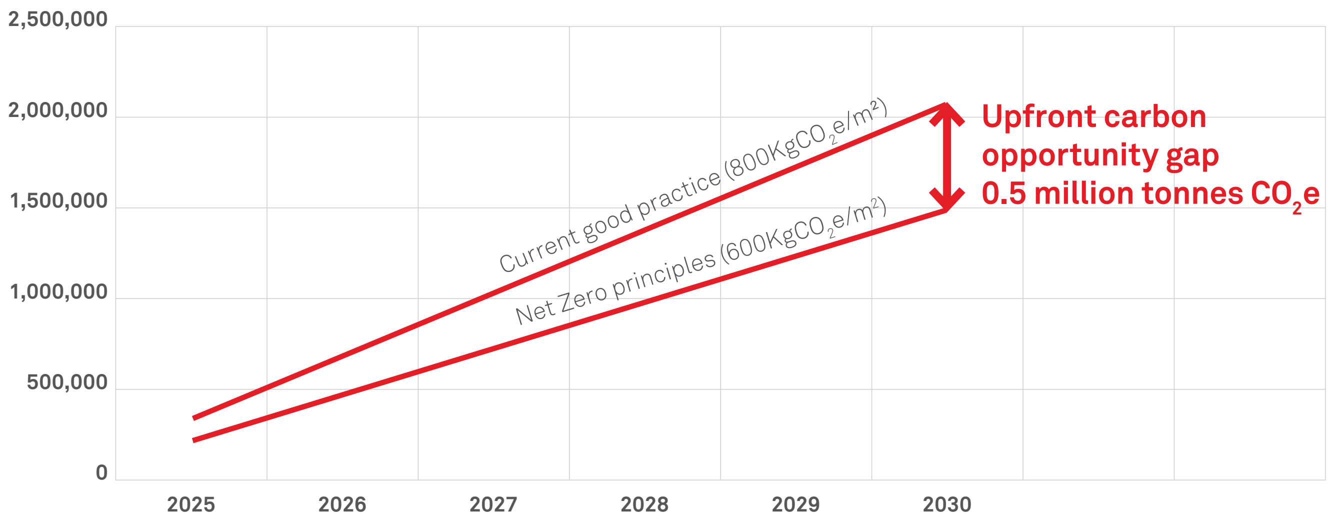
The scale of this gives us a huge opportunity to reduce carbon emissions through design and specification. For instance, reducing the upfront embodied carbon emissions of this pipeline from a current good practice figure of 800kg/CO_2e/m^2 to an optimised approach with a target of 600kgCO_2e/m^2 would result in a saving of 0.5 million tonnes of carbon emissions over the next six years alone.

Refurbishing existing buildings will make up a proportion of this space, and with the right donor-buildings presents an excellent opportunity to save carbon, cost and time. However, the retrofit approach doesn't work everywhere, so a more considered evaluation of the carbon impacts of new-build development remains an imperative.

**Source: Savills, December 2023*

Typical schemes under delivery include the 1m ft² Tribeca development in London's King's Cross Knowledge Quarter





Six-year delivery timeline

How do Lab and Office Specs Compare?

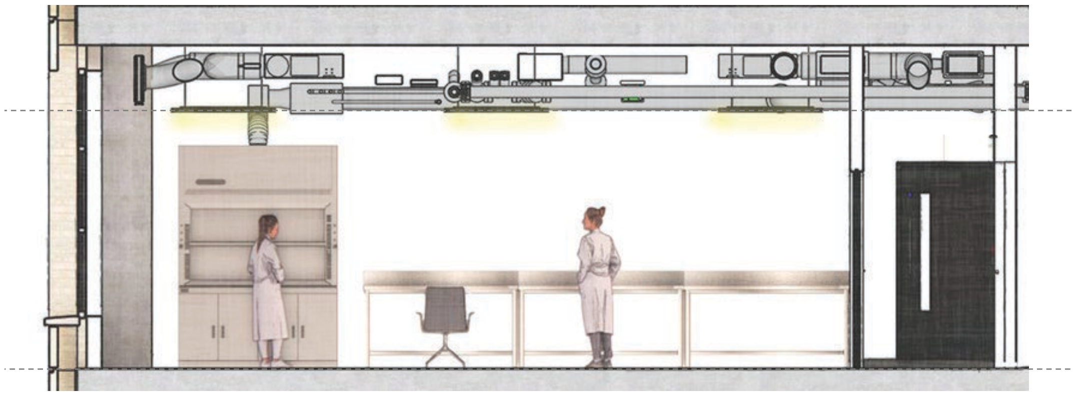
Whilst they occupy similar types of space, the performance requirements of lab buildings result in heavier, more carbon-intensive buildings than a typical net-zero office building.

Lifetime carbon emissions of buildings are made up of embodied carbon from construction and maintenance alongside carbon emitted by the energy used in the operation of the building.

In the UK, lab buildings are built with heavy reinforced concrete frames and thick floor slabs, driven by the need to accommodate heavy loads and eliminate vibration. MEP is extensive. Embodied carbon is higher than conventional workplace buildings of a similar scale.

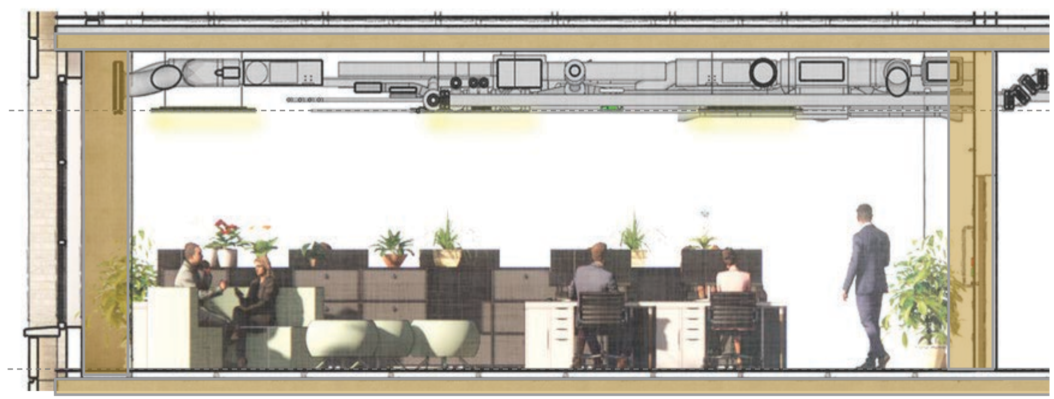
Compared to workplace buildings, labs will have significantly higher operational carbon emissions. Building systems are required to circulate large quantities of air and safely eject them at roof level, facades are sealed, and occupant comfort requires mechanical ventilation and cooling.

Lab, Current Best Practice



Floor to Floor	4,200
Loading	5+1
Vibration	R=1 or 2
Ventilation	6 ac/hr
Structure	Concrete
Upfront Embodied Carbon	750kgCO_2e/m^2
EUI (Base Build)	98kWh/m^2/y

Typical Net Zero Office



Floor to Floor	3,800
Loading	2.5+1
Vibration	R=8
Ventilation	14l/s/person
Structure	Timber or timber hybrid
Upfront Embodied Carbon	LETI Target 475kgCO_2e/m^2
EUI (Base Build)	Target 60kWh/m^2/y

Baseline Design Principles

We have created a prototype building to test our ideas and to understand the carbon benefits of taking a holistic approach. It represents a typical speculative lab building with a net area of around115,000ft².

The prototype uses the following design principles to achieve a baseline level of efficiency:

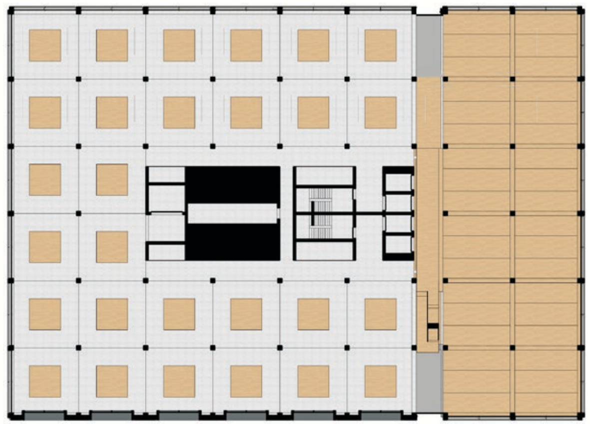
- **Efficient Floorplate Design:** A simple centre-core design creates the most efficient floorplate of around 20,000ft² and maximises perimeter space for the occupier. Regular grids of 7.5m or less suit lab layouts and create efficiencies in structure and foundation design. Multi-tenanted with cellular labs from 1,000ft² up to half or whole floorplate of NIA 20,000ft², to suit growing tenant ecosystem and potential high level of churn.

- **Creating Zones for Labs and Write-up:** Design the building with the assumption that in a typical science building only around 60% of the net space will ever be used for wet labs, with the balance of floor area given over to write-up space, circulation and social spaces. Defining the amount and approximate location of this space from the outset allows the structural and MEP design to be simplified and embodied carbon to be reduced. Areas for sensitive or shared lab equipment can be located on the ground floor.

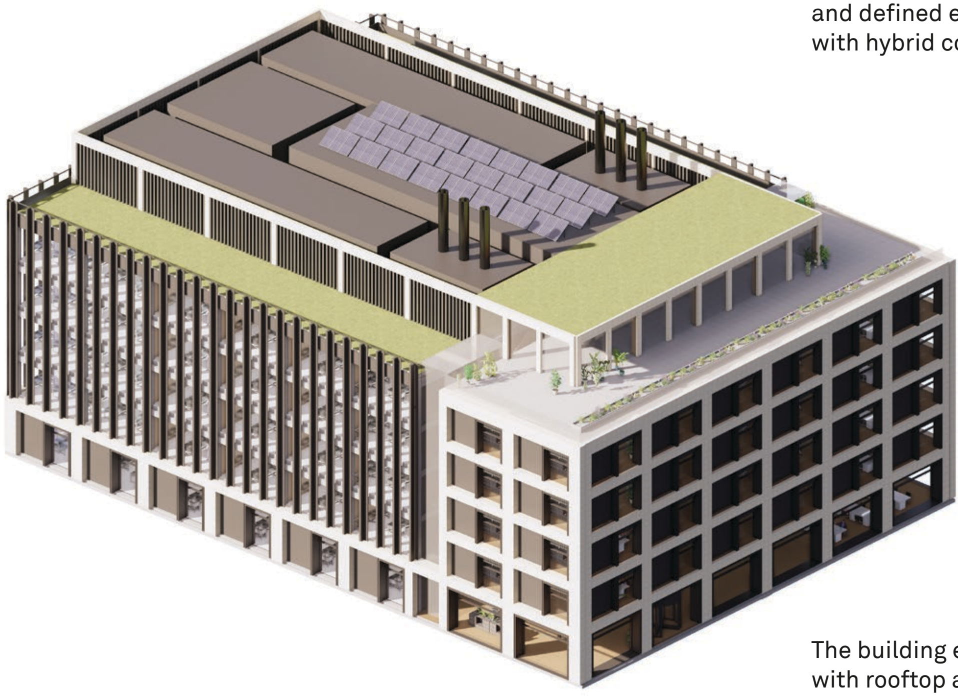
- **Efficient Form Factor and No Basement:** a building of ground plus four storeys with no basement has an efficient form factor, optimises vertical circulation and allows options other than curtain wall for cladding design and construction. Storey heights of 4.2m allow flexibility for servicing.

- **Open Circulation Spaces and Rooftop Amenity:** Entrance lobby café and floor-by-floor amenity space connected by open stairs to encourage active circulation. Shared rooftop amenity space and roof terraces.

If we assume a relatively conventional construction and specification for this building, a reinforced concrete frame, unitised curtain walling, typical internal finishes and conventional lab specifications for MEP then we have a building which represents current day good practice. Calculating the upfront embodied carbon of this baseline prototype suggests a figure of around 800kgCO_2e/m².



The prototype 20,000 ft² floorplate with centre core and defined entrance/write-up zone, shown here with hybrid concrete/timber structure



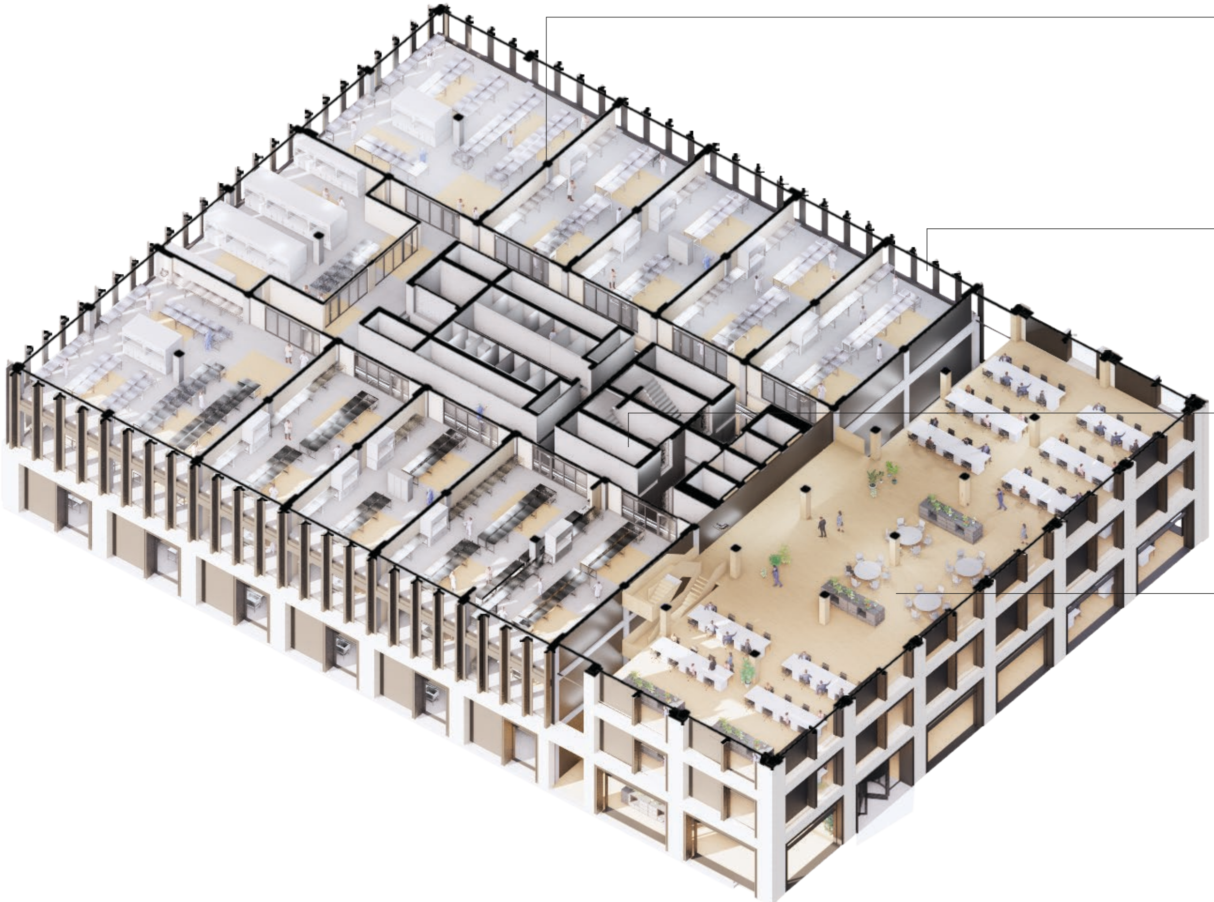
The building extends to ground plus four storeys with rooftop amenity and plant areas

Four Focus Areas for Carbon Reduction

Our study focuses on embodied carbon emissions in the first instance, then considers approaches to improve operational energy performance.

We are seeking a reduction of around 20-25% of the upfront embodied carbon emissions compared to current best practice.

We are taking a holistic approach which covers the whole building by looking at four areas of impact:



1. **Structure:** Containing half of the total embodied carbon, the lean design of the superstructure offers the biggest potential to decarbonise. Mixing materials allows the use of structural timber where possible, adding the stiffness and mass of concrete where this is required.

2. **Enclosure:** Put together, facades and finishes contain around a quarter of the embodied carbon in a typical building. Carbon metrics can be used to optimise the design of these elements. Proven alternatives to curtain walling.

3. **MEP:** Applying lean thinking to MEP systems reduces the risk of over-engineering. Adding smart controls, and heat recovery units on the fume extract also significantly reduces operational energy demands.

4. **Finishes:** Looking at alternatives to standard interior elements like blockwork and metal studding that are available could offer substantial carbon savings. Modular partition systems with timber frames and components would help to further reduce embodied carbon.

Our approach to each of these focus areas is covered in detail on the following pages.

Structural Optimisation

There are viable opportunities for substantial embodied carbon savings through introducing sustainable structural materials within the life sciences building typology. Efficiencies are achieved through balancing the use of traditional, 'inert' materials with modern, more sustainable alternatives where they are best suited, facilitated by intelligent massing such as that proposed by Bennetts Associates for this study.

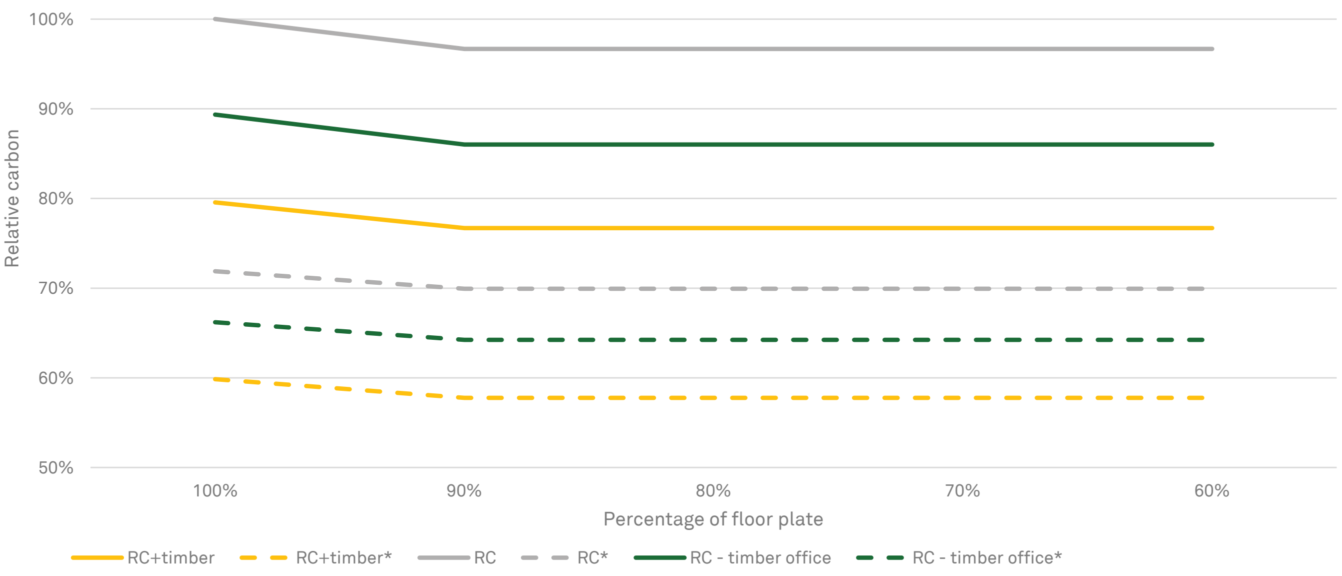
Comparative performance figures have been produced through consolidating vast amounts of data, and comparing merits in terms of embodied carbon, cost and dynamic performance. Patterns emerging from the large data set provide evidence that sustainable, competitive and robust structural alternatives are available today.

Construction practices in this sector have been established over several decades, resulting in established practices and streamlined supply chains. Understandably this results in stagnation and scepticism toward novel typologies which appear riskier in this context. The science sector is also uniquely reliant on dynamic performance and structural functionality making it harder to challenge traditional practices, particularly for speculative developments where end user requirements carry some uncertainty.

However, facing the climate emergency we can no longer passively accept the convenience of tradition when presented with viable alternatives. As this study suggests, there is now little preventing us from taking steps to reduce embodied carbon through specifying sensible design parameters and reimagining material selection.

A series of structural materials and composites have been interrogated as part of the study, focusing on cross-laminated timber as an engineered and robust alternative to concrete construction with significant sustainability benefits.

Using data from the on-going study we can see that using timber appropriately can save upward of 20% of the structural embodied carbon. This without considering the additional benefit of carbon sequestration.



Analysis of different structural options to show relative carbon-intensity of each option to achieve a response factor of 2 for varying percentages of the floorplate

Prototype Building: Baseline RC frame for labs and offices

Prototype Building: Optimised with hybrid RC/timber lab frame and all-timber office area

Enclosure Optimisation

Cladding and roofing account for over 20% of the embodied carbon in our baseline proposal, the second highest element in the building after the superstructure.

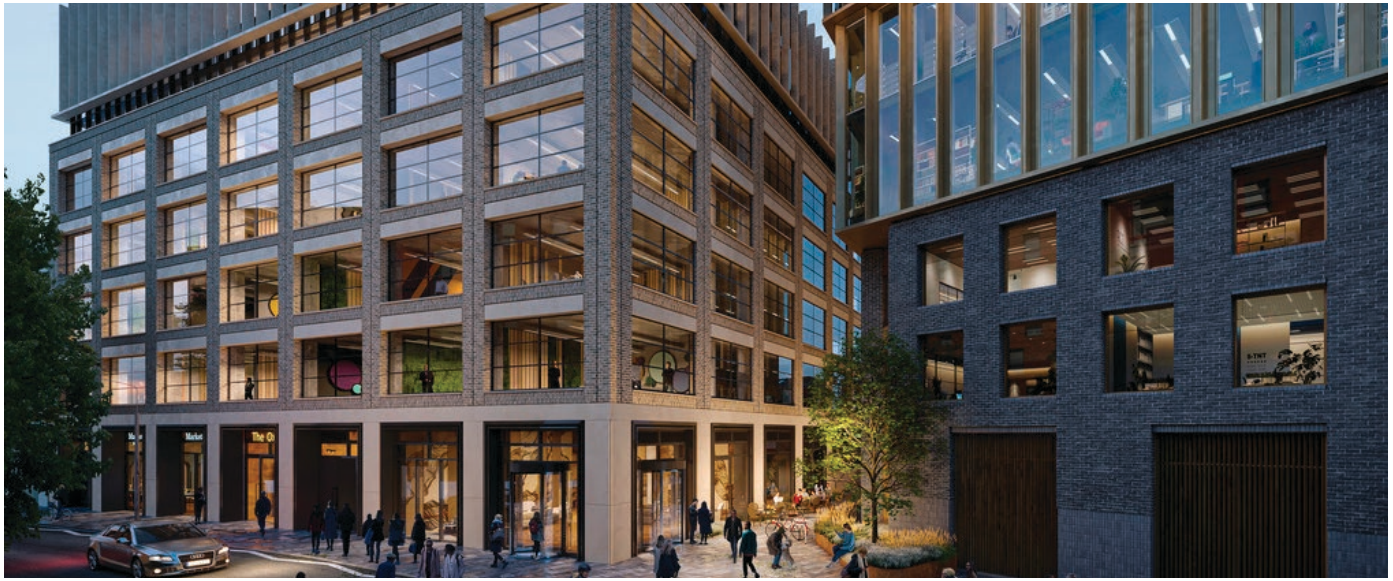
Aluminium framed curtain walling is commonly used on buildings of this scale and height; it is prefabricated and can be installed easily without scaffolding. However, it is one of the most costly and carbon-intensive types of cladding with upfront embodied carbon of around 250kgCO_2e/m² of façade for glazed and solid elements. Our baseline embodied carbon figures take this into account.

The format of the building allows a choice of cladding systems which can move away from higher-carbon solutions such as curtain walling. Simpler solutions such as hand-set facing brickwork, timber cassettes and timber-framed windows offer lower carbon alternatives.

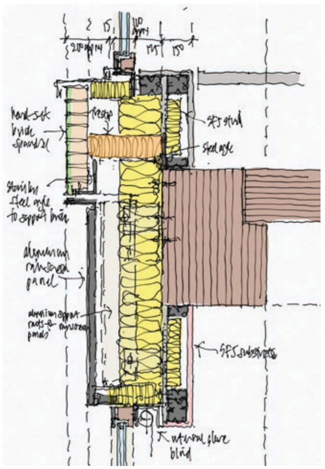
Brick and SFS Framing
Using hand-set brick on SFS framing has the potential to reduce the upfront embodied carbon of the solid areas of façade by around 50% to around 125kgCO_2e/m². Costs are also reduced even though the installation is more time-consuming and requires scaffolding access.

Timber Curtain Walling or Windows
Timber framed curtain walling systems are now becoming available alongside the more established solution of timber framed or hybrid timber/aluminium windows. The upfront embodied carbon of timber framed glazing is around 170kgCO_2e/m² of façade.

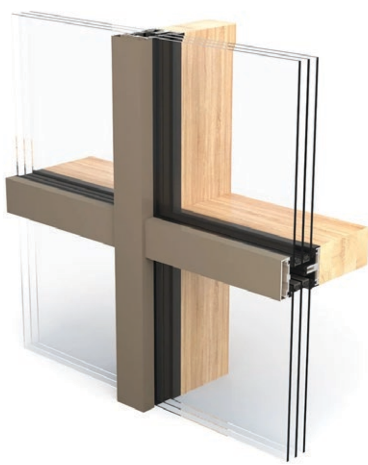
Roof Finishes
Roof finishes and insulation specifications can also be optimised to reduce embodied carbon, for instance by using ballast in lieu of precast slabs.



Hand-set brick on SFS framing at Tribeca London



Hand-set brick/SFS on timber structure



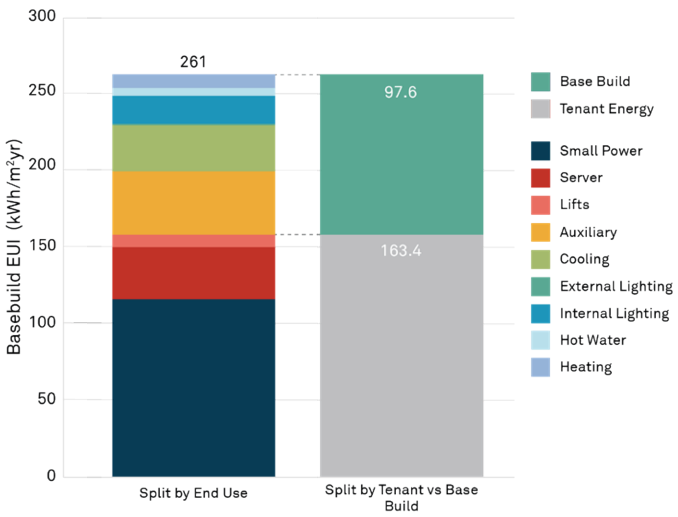
Timber composite curtain walling

MEP Optimisation

With the prototype building design, MEP systems can be designed to reflect the zoned floorplate layout, reducing overall plant requirements with radically simplified solutions in the write-up areas. In the lab areas, the impact of reduced air-change rates can be tested. In this section we discuss the baselines for operational energy and embodied carbon and address a series of optimisation options.

Operational Energy

Buildings with life science labs tend to generate a lot of carbon emissions. This makes sense given the processes carried out in scientific research. For instance, to enable nanobody research, a large amount of fresh air must be conditioned and circulated; high-resolution spectrometers give off a lot of heat that requires cooling; laser labs need high levels of vibration isolation.



Base build operational energy by end use (left) and split by landlord and tenant (right)

The type of research focus and the stage of an occupier's research journey will impact ventilation requirements, scientific equipment and operating hours, and in turn energy use intensity and embodied carbon. Setting targets can therefore be challenging, but how can we unlock carbon savings without comprising scientific utility or safety?

Base Build and Tenant Energy

At present a suitable target for new design labs would be ~260 kWh/m²/yr GIA ±10%. This has been benchmarked from a range of Stage 3-4 operational energy models for CL2 labs.

The figures below show the split of base build and tenant energy, with 63% of the total energy forecast relating to tenant energy use and 38% down to base build energy use.

At this stage in the study, we are focusing on reducing the energy demand of the base build whilst leaving maximum flexibility for tenants.

Energy End uses	kWh/m²	%
Small	115	44%
Server	34	13%
Lift	8	3%
Aux	41	16%
Cooling	30	12%
Ext light	1	0%
Int light	18	7%
Hot water	5	2%
Heating	9	3%
Total		
Tenant energy	163.4	63%
Base build	97.6	38%

Where is the energy being used?

The table below presents a range analysis of nine functions which consume operational energy. It demonstrates the typical range and variation in energy end uses. It is expected that small power, followed by servers and ventilation, represent the biggest single sources of energy consumption.

End use	Min	Mean	Max	kWh/m² range
Heating	0.01	4%	0.07	2-20 kWh
Cooling	0.09	12%	0.14	21-40 kWh
Ventilation	0.14	16%	0.19	39-54 kWh
Landlord lighting	<1%	~1%	>1%	~1-3 kWh
External lighting	<1%	~1%	>1%	~1-3 kWh
Lift	<1%	~1%	>1%	~1-3 kWh
Small power	0.4	45%	0.49	93-140 kWh
Tenant lighting	0.05	6%	0.07	13-22 kWh
Server	0.09	14%	0.21	21-59 kWh

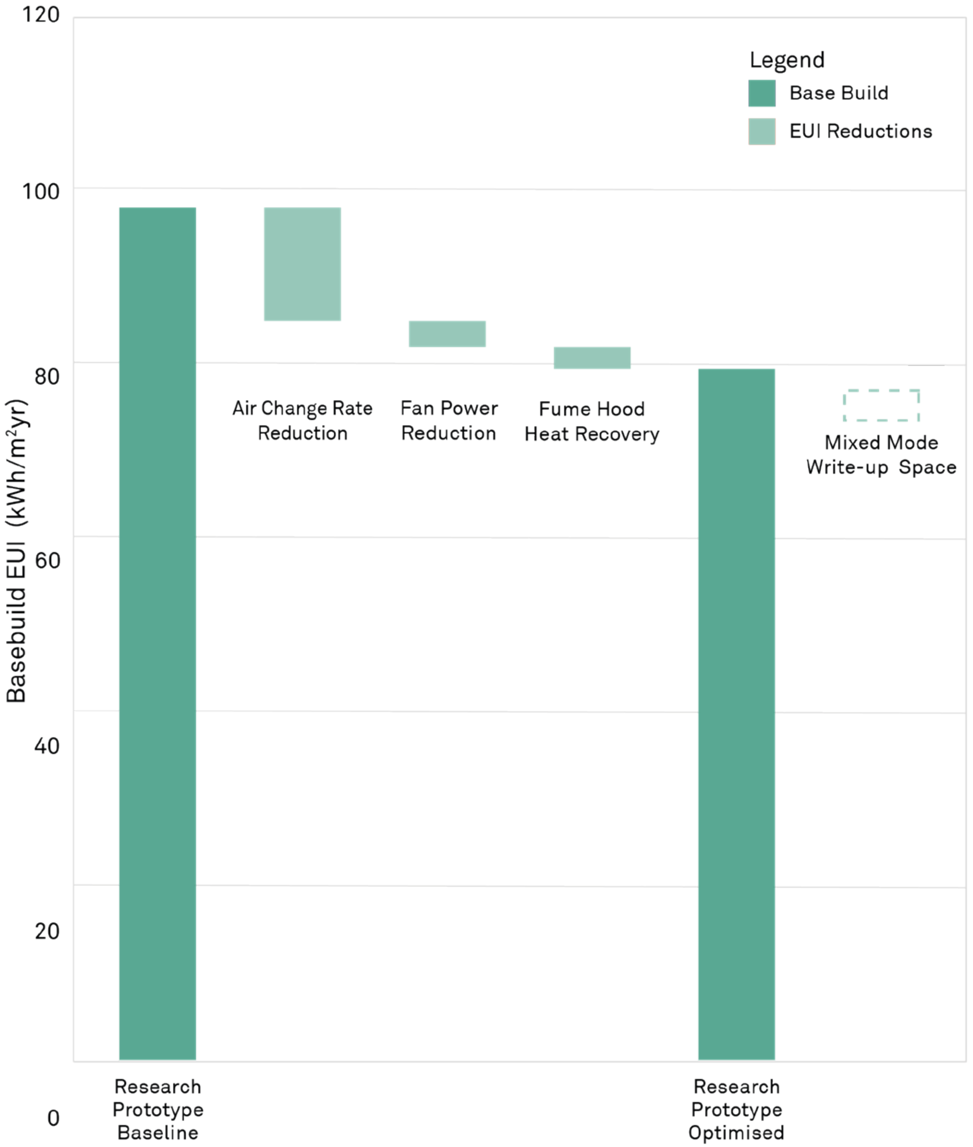
Upfront Embodied Carbon

An upfront carbon estimate has been made based on the high-level MEP servicing provision estimates for site. This has included the proposed reduced overall air change rate. The extent of the Cat A fit could have significant impact on this result. Tenant fit-out is excluded.

MEP Carbon	$kgCO_2e/m^2$
Base build upfront carbon	65.2
Typical range	100-130

MEP Optimisation

This section demonstrates the potential energy reductions that can be achieved by different optimisation options when compared to our initial assessment.



Base build operational energy (EUI) reductions

Description	kWh/m²	$kgCO_2e/m^2$
Air change reduction Typical briefing for UK buildings is to operate laboratory ventilation at 6ACH. This is typically applied on 60% of the NIA to allow maximum flexibility at development. However, if we were to consider corridors, stores and rooms that do not require 6ACH this can be reduced. Furthermore, CL2 laboratories do not require 6ACH from design guides and this could be reduced to 4ACH throughout the floorplate.	10.5-15.5	Would expect some carbon reduction but with lack of TM65 data, it is difficult to estimate.
Fan power reduction Building regulations limits fan energy to 1.6w/l/s and therefore, all selections should be below this value. As a matter of course we design all mechanically ventilated buildings (not just laboratories) to at least a 10% improvement on this figure. A realist target therefore is 1.3w/l/s. which would give a reduction of 3.17 -3.33kWh/m²/annum from the 1.6 w/l/s baseline. A stretch target which we have set ourselves is selections at 1w/l/s/. However, we find that this causes a number of problems, on part load fans stall, also due to reduced velocity we end up with laminar flow through heat exchangers and coils drastically reducing thermal efficiency.	2.8-3.3	Would expect some carbon reduction but with lack of TM65 data, it is difficult to estimate
Fume cupboard reduction Fume cupboard heat recovery is not normally utilised due to the complexities of installing heat exchangers in potentially corrosive air streams. Plastic heat exchangers can be utilised and if maintained properly are an effective method of recovering 40-50% wasted heat or coolth from the exhaust stream – this could have a potential saving of 1.6 – 3.1 kWh/m²/annum. But would have a minor upfront carbon addition of ~ 2 tonnes or 0.2 $kgCO_2e/m^2$ GIA per fume cupboard.	1.6-3.1	+ ~2
Mixed mode ventilation (write-up areas) Natural ventilation gives a potential opportunity for reduction in embodied carbon in the write-up spaces by removing all ventilation systems. However, if we consider that there is only a small portion of the year that the outside air is at a suitable temperature to ventilate the space, we often find the spaces are either not ventilated or at worst still ventilated whilst heating or cooling systems are operating giving a significant rise in operational energy. A potential energy reduction could be realised in the colder months by reducing the need for cooling to come on by natural ventilation, but this is extremely unlikely to have a major impact on energy or MEP provision.	2.6-5	Unlikely to be any reduction from MEP provision. It would be expected the openable windows would increase carbon emissions compared to fixed windows

Finishes Reductions

Lab buildings already perform relatively well in his area compared to a typical workplace spec because there are usually no ceilings or raised access floors in lab areas. Finishes in the shell/core building account for around 5% of the total upfront embodied carbon in our baseline assessment.

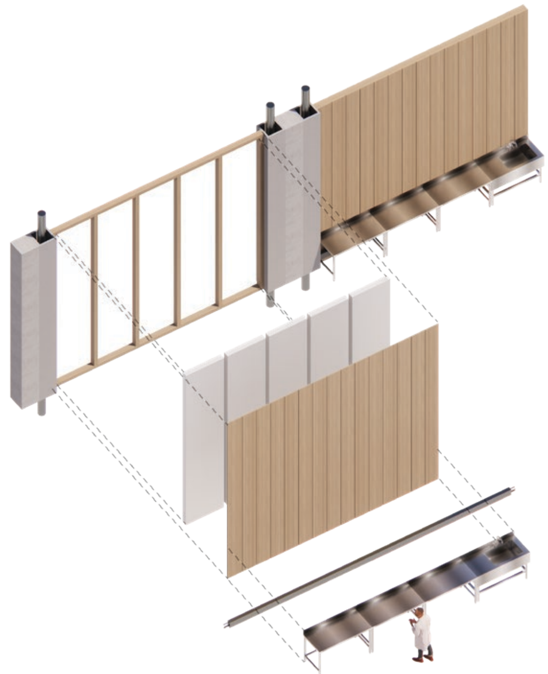
Further simplification to finishes includes the removal of raised floors in write-up areas, simplification of cores, use of low-carbon materials for internal walls such as earth blocks and timber-framed partition systems, and the use of demountable partitioning and furniture in the fit-out to reduce waste during layout changes.

Within the CAT A areas the lab zones will have a solid screeded floor whilst in the baseline scheme a shallow raised access floor is used in the write-up areas. Removing the access floor and reverting to a solid floor across the whole building results in a significant saving.

Whilst it is currently outside the scope of this study, the CAT B fitout is a significant contributor to upfront embodied carbon, with dividing walls and corridors creating the CL2 lab layouts. Building operators have reported high churn rates amongst some types of lab occupiers resulting in multiple layout changes and consequent wastage of more conventional plasterboard and stud internal walls.

A timber demountable and modular partitioning system with modular lab furniture could reduce the initial upfront carbon of the fitout and reduce the carbon cost of occupier-led layout changes.

Lean finishes and exposed timber framing create characterful and carbon-efficient interiors



Modular partitioning and furniture systems allow re-configuration whilst minimising waste

Measuring Embodied Carbon Savings

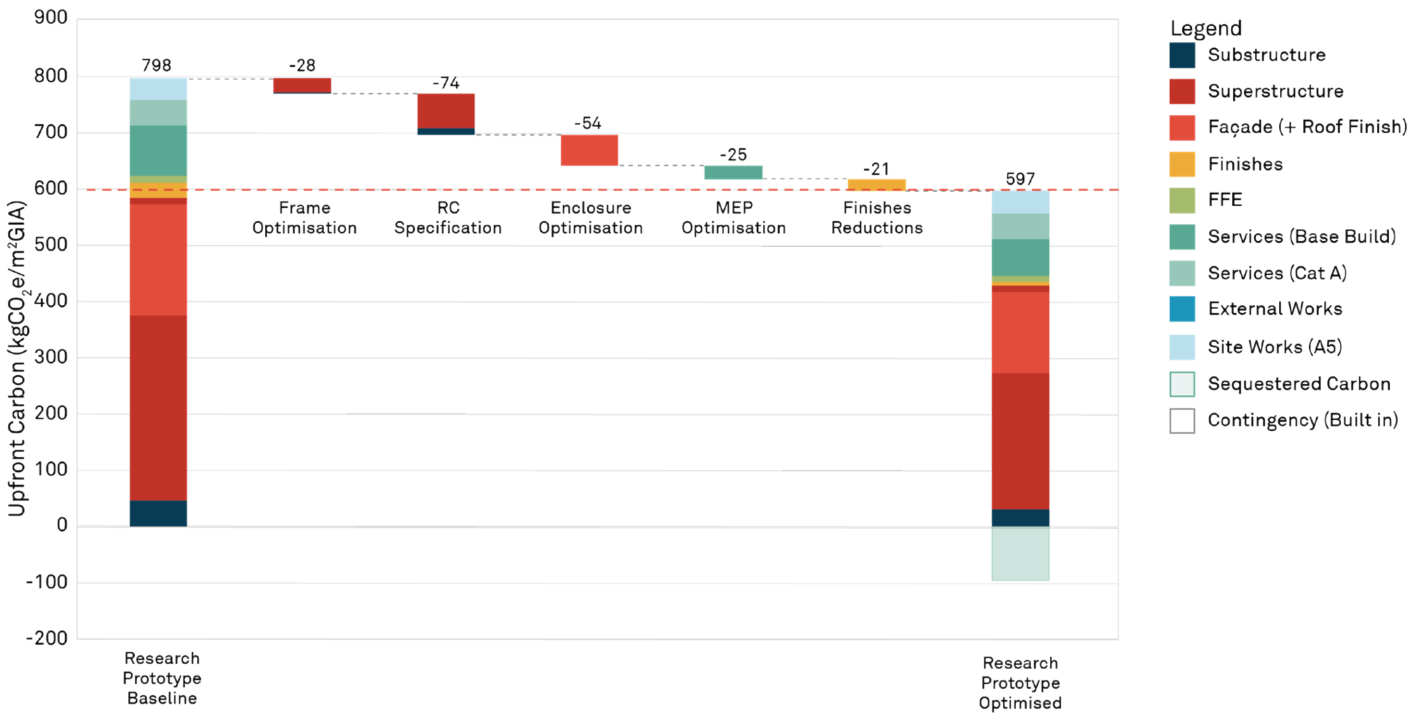
We have carried out an assessment of upfront carbon on the prototype to compare the 'current good practice' baseline with the adoption of our chosen optimisation strategies.

Preliminary results show that it is possible to optimise the building to achieve a reduction in upfront carbon emissions by around 25% or 200KgCO_2e/m^2 from the typical baseline figure of 798KgCO_2e/m^2 to an optimised figure of just less than 600KgCO_2e/m^2.

In line with industry best practice our figures include a 15% contingency to account for the Stage 2 level of design detail in the prototype.

The optimised structural design considers Electric Arc Furnace Steel Rebar and cement replacement rates higher than the UK typical specification, which is assumed to be equivalent to the RICS PS (2023) Baseline Specification. Due to limited stocks of GGBS, its use on projects above the UK average would reduce the project's carbon footprint but would not reduce climate change impact at a UK level. As such, the true reductions in superstructure upfront carbon would be lower when using GGBS.

Upfront carbon relating to MEP remains difficult to quantify. A detailed study was undertaken using CIBSE TM65 data to ascertain an estimate of the optimisation reductions available in the Base Build MEP carbon, however the Cat A MEP fit out has been based off project data and industry benchmarks and is fixed at 45 kgCO_2e/m^2 in both scenarios.



Upfront carbon reductions from the baseline prototype (A1-A5) indicate that a 25% reduction compared to current good practice is possible

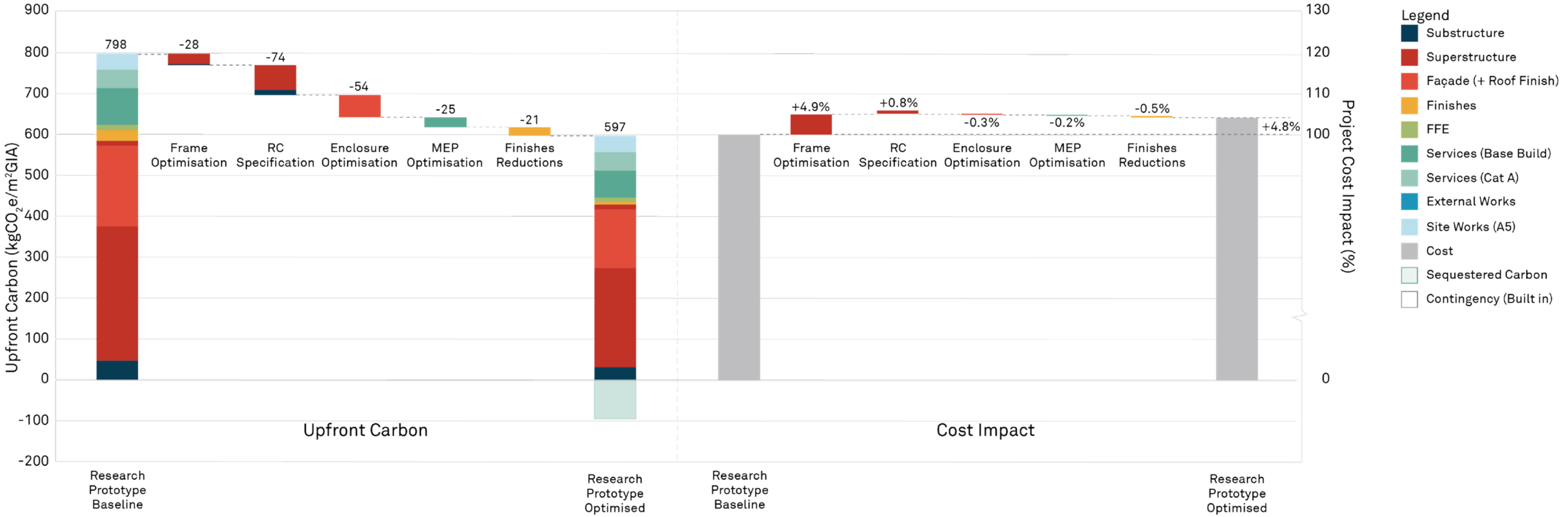
Cost Comparisons

Setting out a notional building enabled us to cost model a baseline position and then study the cost impact of each individual optimization. The graph shows a cost waterfall aligned to the optimizations made to reduce embodied and operational carbon.

It is sometimes the case the cost and carbon reductions come hand in hand but often bigger carbon savings can come with a price. That said, the study has demonstrated that it is possible to achieve an embodied carbon reduction approaching 25% for an overall cost increase (Shell and Core & Cat A) of 4.8%.

It is striking that much of the carbon reduction is achieved for a relatively cost neutral position (if accepting a brief change to 4 air changes per hour in lieu of the typically specified 6 air changes per hour). The biggest single cost comes with the fundamental structural change to timber for the offices/write-up space, which is one of the main remaining moves available once other brief and specification optimizations have been accounted for. Many of the other optimizations come with relatively small incremental costs, and some come with savings. The fundamental message from this is that making the most headway towards net zero requires challenging conversations about the brief and, in particular, the extent of flexibility that we bake into our buildings.

An interesting aside resulted from a high-level study of a steel and pre-cast plank structural option. It quickly became clear that, for a speculative life sciences building, a steel structure comes with a significant carbon and cost penalty (aside from the other well-known challenges of clear heights and achieving vibration criteria).



Cost Impacts vs Carbon Reductions from the Baseline Prototype

Conclusions

Our preliminary findings:

- Achieving net-zero buildings in the science sector will require a holistic approach which looks at each contributor to lifetime carbon emissions.
- By taking a view across the whole building, we have been able to identify a 25% reduction in upfront embodied carbon when compared to current best practice.
- The starting point is to design lean and flexible buildings which have inherent efficiency. All elements of the building then need to be assessed to achieve a meaningful reduction in embodied carbon.
- It is beneficial to identify zones for labs and write-up in the floorplate because this allows significant carbon savings through structural optimisation due to the reduced specification of office uses.
- Structural timber is an essential component in the de-carbonisation of commercial buildings including labs; its use has already become the norm in the most progressive buildings in the office sector and this learning must feed into science buildings.
- Operational energy use is also a significant factor, and we have established a series of measures to reduce base build operational energy by 20%. Comparisons for laboratory buildings should be undertaken as like for like to offices. i.e. LETI standard at 55kWh/m²/ annum is for landlord services only. A baseline of 97kWh/m²/ annum should be taken for laboratories.
- The overall optimisation process has resulted in a small cost uplift which is driven by the very carbon-efficient structural changes. However, some of the smaller carbon reduction measures are achieved with minimal uplift or even with cost savings.
- Most operational energy interventions will have an impact on embodied carbon or brief so we must always look at these holistically for the lifetime of the building.

About this research study:

This study has been carried out by consultants and their teams from across the life sciences and commercial property sector who have generously given their time and expertise.

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During the development of the study, the emerging thinking was shared with a wider group of peers in the industry including consultants and developers and we thank all those who took part for their input.

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