Accelerating low carbon curtain walling
Impactful solutions for now

ARUP PERMASTEELISA GROUP Turner & Townsend alinea

Contents

Foreword	3
Six actions for low carbon curtain walling	4
The process	5
Breaking the cost–carbon disconnect	6
From business as usual to low–carbon façades	8
Action 1: Effect of bay design	9
Action 2: Shading fin impact	10
Action 3: Slab edge deflection limit	11
Action 4: Extrusion thickness	12
Action 5: Wind driven glass build ups	13
Action 6: Glass build up requirements	14
Roundtable insights	15
What's next?	18
Appendix	20

Delivered in partnership: Arup, Permasteelisa and Turner&Townsend Alinea

This collaboration brings together façade design engineers, façade specialist sub-contractors and cost consultants, drawing on the unique expertise each party brings, industry know-how, and existing tools to explore tangible actions for carbon reduction in curtain walling that can be applied to projects right away.

Foreword

The urgency for climate action is beyond dispute, and the façade industry must play its part by reducing the embodied carbon in its products and solutions. Over the past year, our cross-disciplinary investigation has challenged assumptions, tested innovative ideas, and identified practical strategies for carbon reduction. What stands out most is the spirit of openness - an eagerness to rethink established norms, question aesthetic conventions, and prioritise long-term value over short-term convenience. Curtain walling systems are often treated as standard technical solutions. However, our work demonstrates that design decisions remain crucial and they can significantly influence outcomes. This publication is not a manifesto; rather, it presents a set of real, tested options. It serves as a reminder that reducing carbon need not mean compromise. Instead, it can unlock new opportunities, especially when the right people are engaged early in the process with a shared goal. In essence, less carbon typically means less material, which often translates to lower costs. Which can be a win for everyone.

We hope this work inspires others to do the same: to challenge, to collaborate, and to act. Because the time for evolutionary change has passed. We need to really engage, right now.

Tristram Carfrae
Arup Fellow

Six actions for low carbon curtain walling

Curtain walling façades play a critical role in the carbon footprint of modern buildings. As the industry shifts focus from operational carbon to whole life carbon, unitised systems present a major opportunity for impact but also require a rethink of how we design and deliver them and to dispel the myth that lower-carbon solutions inevitably drive higher costs.

This publication is the result of a year-long collaboration between Arup, Scheldebouw, and Alinea, aimed at accelerating low-carbon solutions in curtain walling. By 2030, the built environment is expected to halve its carbon emissions.

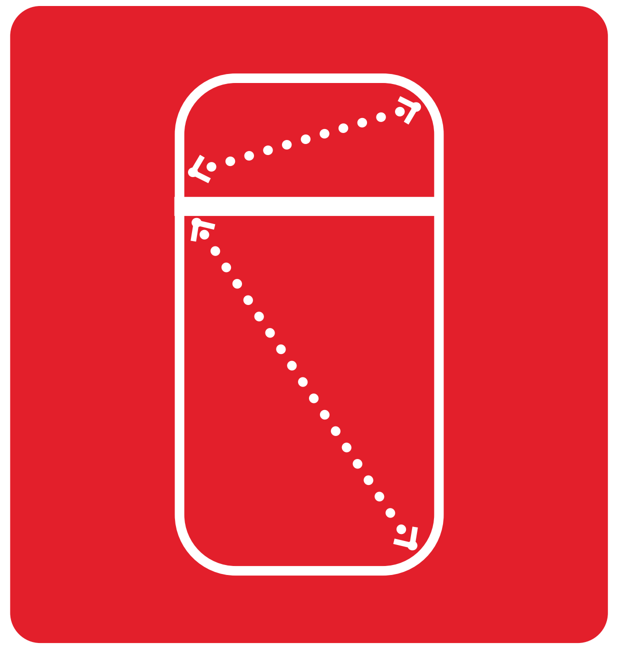
This milestone is no longer a distant ambition, it's a fast-approaching deadline: buildings designed today will be under construction by the time that 50% reduction is required.

The imperative is clear: we must design better buildings now.

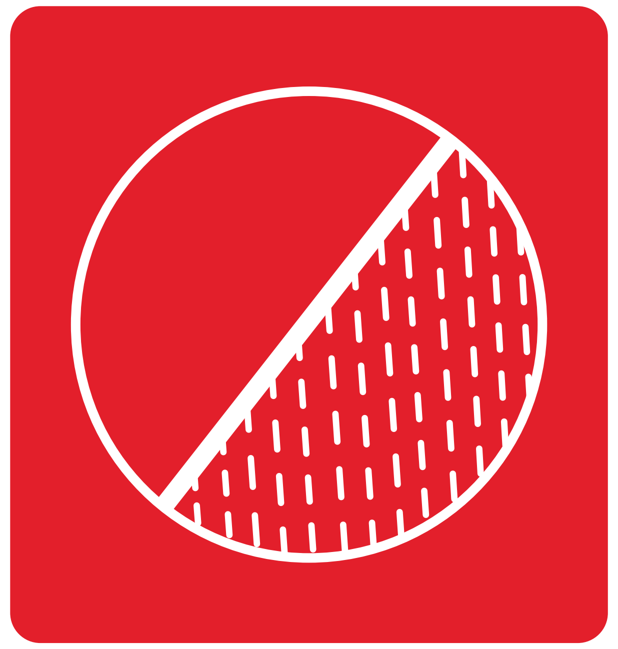
By applying these actions, you could achieve a 20% cost saving and 55% embodied carbon saving on your project today.

We've developed a set of practical, design-led actions that can be implemented immediately. These were tested through dialogue with clients, architects, and investors, sparking valuable conversations around feasibility, compromise, and shared responsibility.

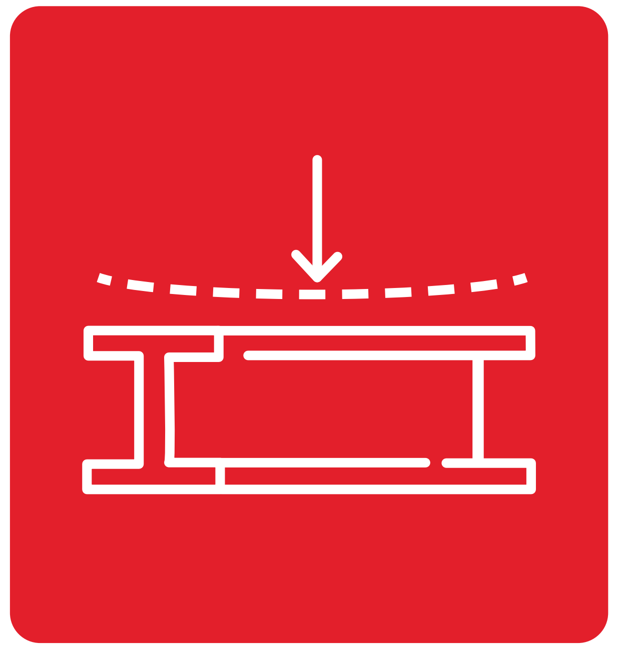
This publication is a call for collective action: every stakeholder - from designers and engineers to developers, manufacturers, clients, and investors - has a role to play. By sharing this work, we hope to expand the application of simple, effective principles that can be widely adopted, and to open up a broader conversation across the industry about challenging the status quo. We can design façades that are not only lower carbon, but also enduring, adaptable, and loved, with the industry working together to accelerate meaningful change.



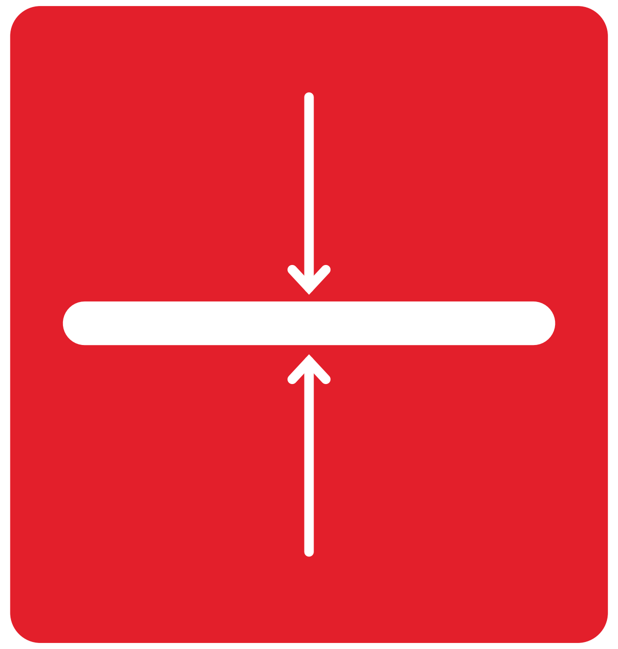
Action 1
Effect of bay design



Action 2
Shading fin impact

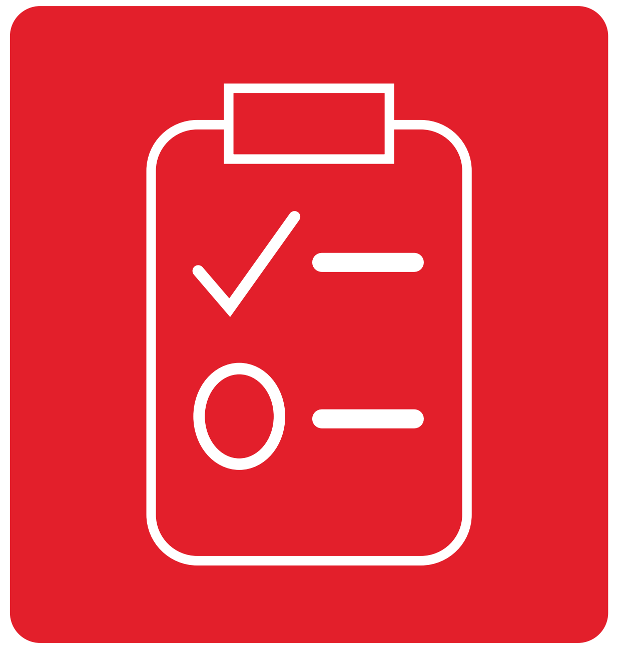


Action 3
Slab edge deflection limit



Action 4
Extrusion thickness

Action 5
Wind driven glass build ups



Action 6
Glass build up requirements

The process

In this collaboration, our goal was to explore what can be done immediately to reduce embodied carbon in curtain walling, not through speculative technologies or long-term material innovations, but through smarter system design. We set out to create a practical “low carbon menu” of design-led strategies, guided by the principles of build less, build light, build wise. Rather than focusing on the specification of low-carbon materials, we concentrated on how façade systems themselves can be designed more efficiently and intelligently.

To do this, we brought together specialists from different roles, creating a group who understand the façade system from concept to construction, to co-develop practical solutions. Our discussions centred on the design process, serviceability, design criteria, materials and reuse opportunities. At the end of this exploratory phase, the team identified six key carbon-saving actions within curtain walling design that can be delivered immediately. These actions represent clear, scalable and achievable changes that can be implemented now to support the 50% reduction target.

To strengthen and validate the outcomes of our collaboration, we convened a roundtable discussion with key industry decision-makers - clients, developers, investors, architects, and other influential stakeholders. The purpose was to bring these voices into the conversation at a critical moment: to test the practicality, appeal, and viability of the proposed carbon-saving actions with those who shape projects both financially and creatively. Their perspectives added necessary realism to the discussion, grounding our proposals in the broader realities of project delivery, design ambition, and commercial viability.

The roundtable created a rare opportunity for open, cross-disciplinary dialogue, where technical insight met strategic decision-making. It allowed us to explore not only what is possible, but what is acceptable, desirable, and scalable.



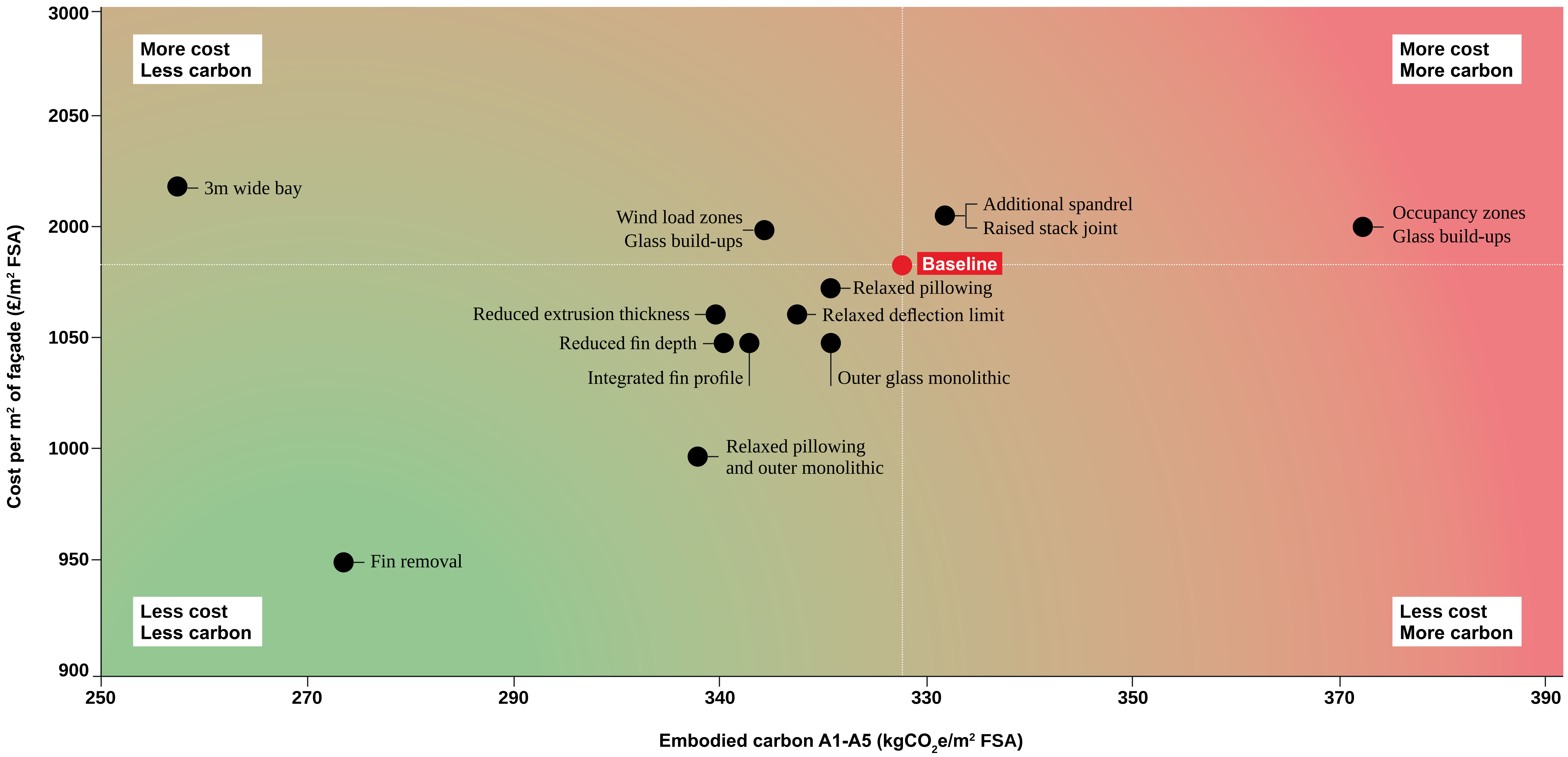



Breaking the cost–carbon disconnect

Reducing embodied carbon in curtain walling must not come at the expense of project viability.
If lower carbon solutions consistently lead to higher capital costs, we would risk undermining the very objective we're trying to achieve. That's why this work has focused not only on carbon savings, but also on the cost implications of each design decision. Each of the six proposed actions has been assessed not only for its carbon-saving potential but also for its cost implications.

The cost analysis did not concern procurement or material substitution, the cost of low-carbon materials or alternative supply chains is not considered. Those are important considerations, but they belong to a different stage of the project lifecycle. Our focus here is on design: how the geometry, detailing, and specification of curtain walling systems can be optimised to reduce carbon without compromising cost-effectiveness.

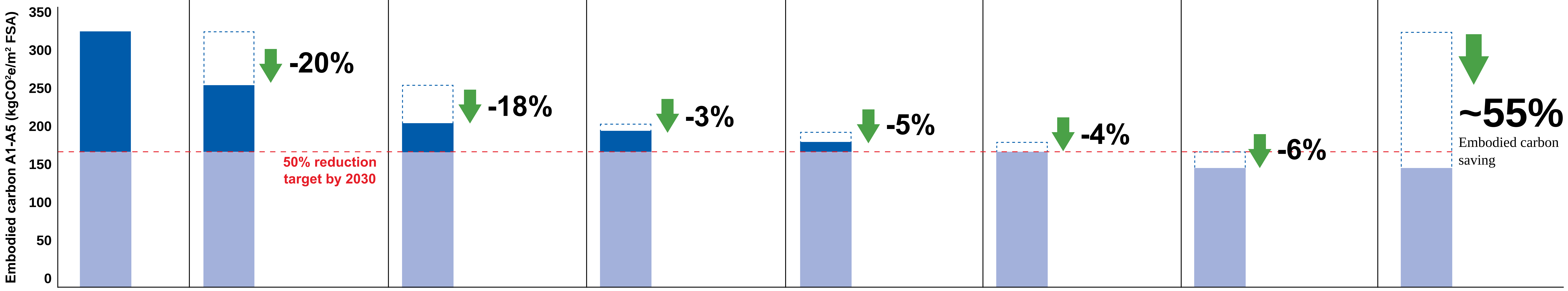
The results of our study demonstrate that lower carbon does not have to mean higher cost, making a low carbon curtain walling accessible to all projects. While not every intervention leads to cost savings, many offer a neutral or even positive cost impact. This reinforces the importance of early, informed design decisions - where carbon and cost are considered together, not in isolation.



Carbon reduction and associated cost impact, for each of the options analysed.

Cost and embodied carbon savings

Baseline	Action 1	Action 2	Action 3	Action 4	Action 5	Action 6	
Business as usual	**Effect of bay design**	**Shading fin impact**	**Slab edge deflection limit**	**Extrusion thickness**	**Wind driven glass build ups**	**Glass build up requirements**	
1.5 x 4 m bay curtain wall with vertical fins	○ 1A. Additional spandrel ○ 2B. Raised stack joint ● 1C. 3m wide bay	○ 2A. Reduced fin depth ○ 2B. Integrated fin ● 2C. No fin	● 3. Reduced deflection: Span / 500	● 4. Reduced thickness: 20% reduction	○ 5A: Wind load zones ● 5B: Occupancy loading zones	○ 6A: Outer monolithic ○ 6B: Relaxed pillowing ● 6C: Combined	
£1,085 £/m² FSA*	+2%	-12%	-2%	–	-2%	-8%	~20% Cost saving



Footnote: Embodied Carbon delta A1–A5, measured by $kgCO_2e/m^2$ Façade Surface Area
*Cost estimation delta based on 1Q2024 rates, measured by £/m² Façade Surface Area

From business as usual to low–carbon façades

To identify a path toward reducing embodied carbon in curtain walling, we identified and defined a clear baseline, a “business as usual” scenario against which improvements could be measured. This baseline reflects a typical aluminium unitised curtain wall system, commonly used in commercial and high-rise developments. This configuration represents a widely adopted approach in contemporary façade design.

More detailed assumptions on the methodology used for the assessment is presented in Appendix A; the assessment results are presented in the summary below and further information is presented in Appendix B.

Our approach focused on the system’s geometry, detailing, and performance criteria, and to identify opportunities that are both technically feasible and commercially realistic.

Some of the opportunities identified:

– Rationalising mullion and transom spacing and the ratio of opaque to glazed

– Rethinking the use and scale of external fins and shading devices

– Reducing over-specification of structural slab edge deflection criteria

– Optimising the structural performance of the framing

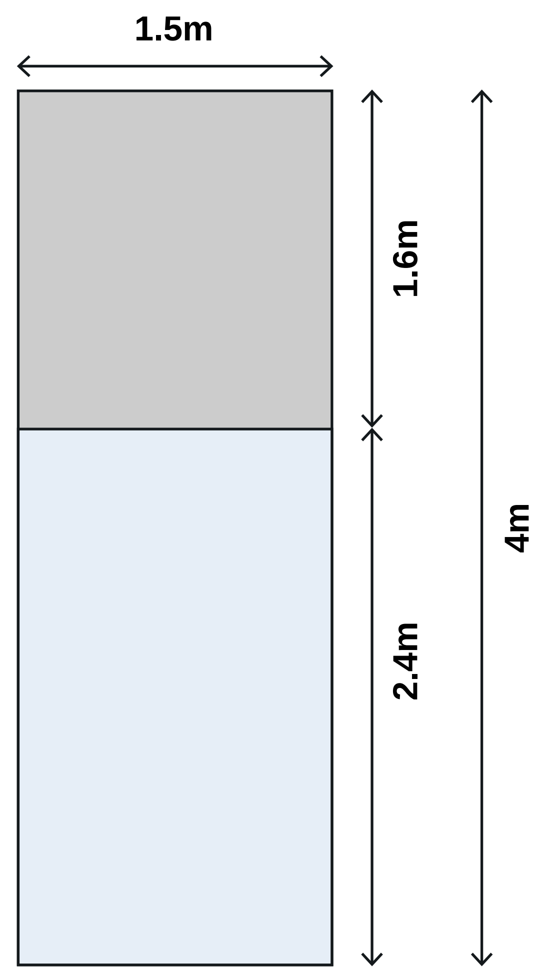
– Minimising redundant or purely aesthetic elements

– Challenging default assumptions around glazing ratios and system depth

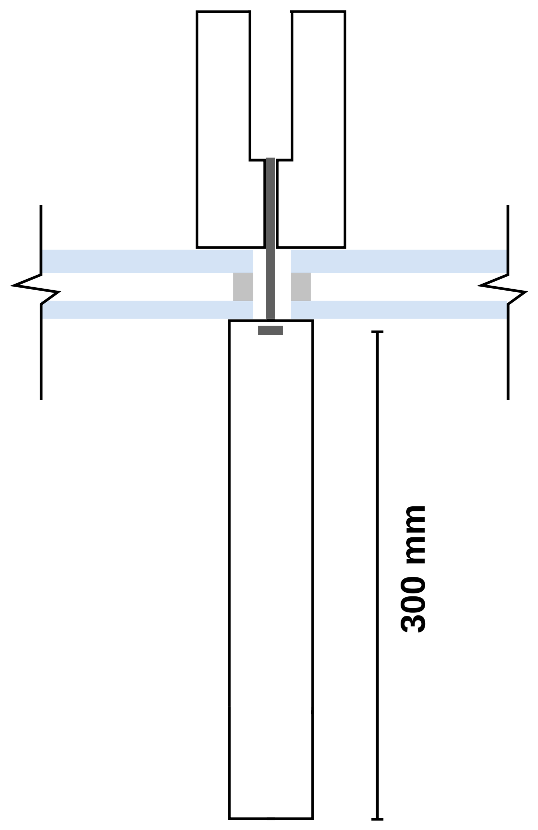
Each of these strategies was evaluated not only for its carbon-saving potential but also for its impact on design quality, buildability, and long-term performance. The result is a practical, adaptable “low carbon menu” with six design actions that can be applied individually or in combination, depending on project context.

Baseline

System description and performance	
Façade type	Unitised curtain wall system
Window to wall ratio	60%
Glass build up	DGU, 66.2 AN - 16 - 55.2 AN
Solar performance (g value)	0.28
Thermal performance	1.2 W/m²K
Acoustic performance [RW (C;Ctr)]	41 (-3; -7) dB
Visual light transmission (VLT)	60%
Façade frame depth	220 mm
Shading fins depth	300 mm
Windload	Zone A: 1600 Pa Zone B: 2400 Pa
Baseline Embodied Carbon (EC)	330 $kgCO_2e/m^2$ Façade Surface Area (FSA)
Baseline cost	1,085 £/m² Façade Surface Area (FSA)



Façade bay module assessed - Baseline



Horizontal diagramatic section of façade assessed, with 300 mm deep fins

Action 1
Effect of bay design

Understanding the effect of the general bay design, considering the dimension of the bay, the positioning of the spandrel and the stack joint. This effect extends beyond embodied carbon to include performance criteria such as acoustics and thermal efficiency.

Key considerations

– Glass vs aluminium volumes

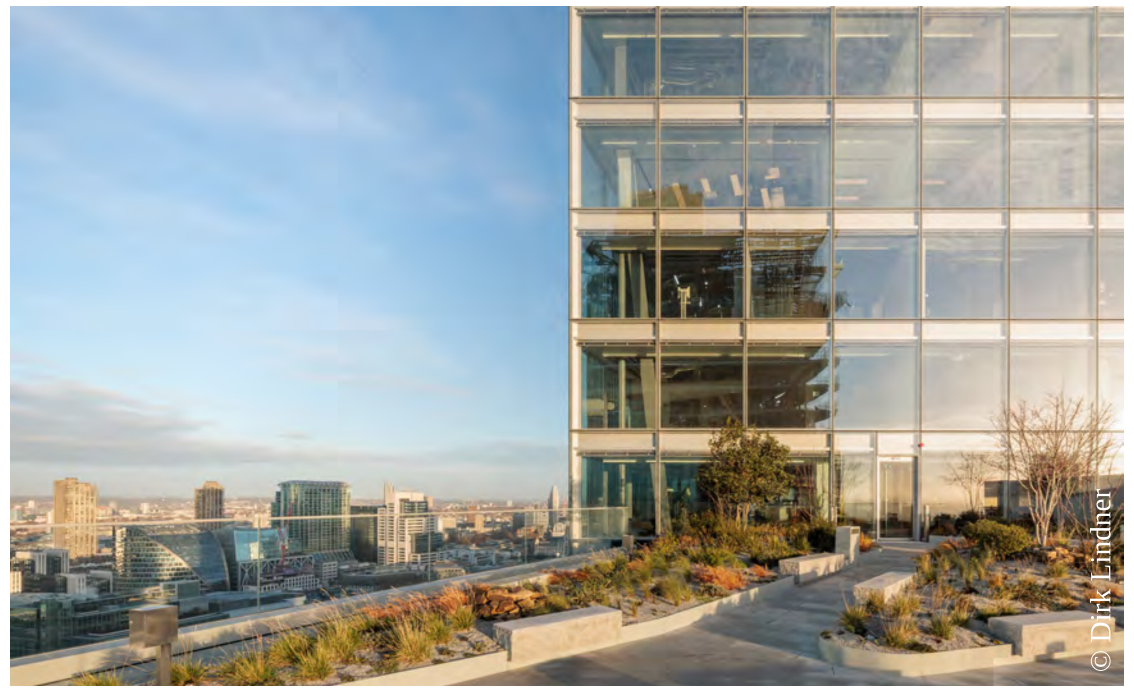
– U-value variation

– Light transmission

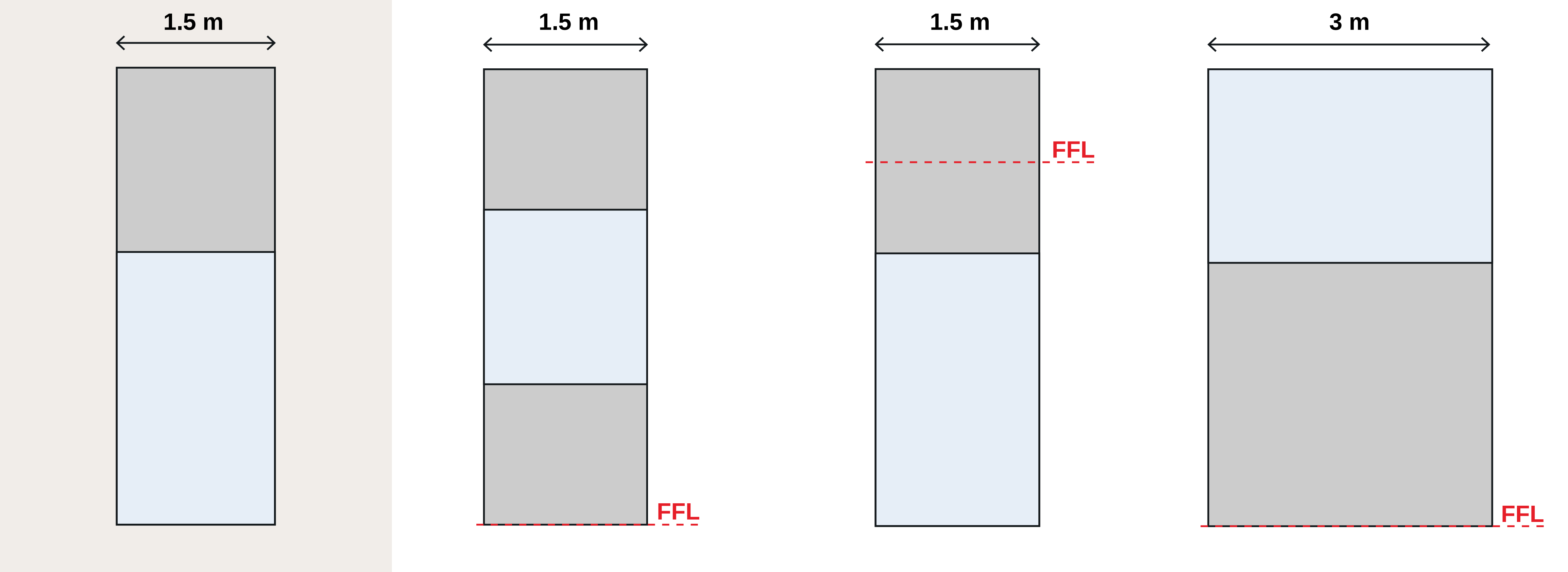
– Visual appearance

– Bracket quantity

– Solar gain implications



8 Bishopsgate, London



	Baseline	Option 1A Additional spandrel	Option 1B Raised stack joint	Option 1C Increased panel width
Embodied carbon (A1-A5)		+1%	+4%	-21%
Operational carbon (B)		-0.2%	–	-0.2%
Cost		+2%	+2%	+3%

21%
Embodied carbon saving

Insight

Q What are the barriers to using wider bays?

A Wider bays can significantly reduce the amount of framing and associated embodied carbon. The primary barriers are logistical – including transport, hoisting, and handling – rather than manufacturing cost.

Design Principles

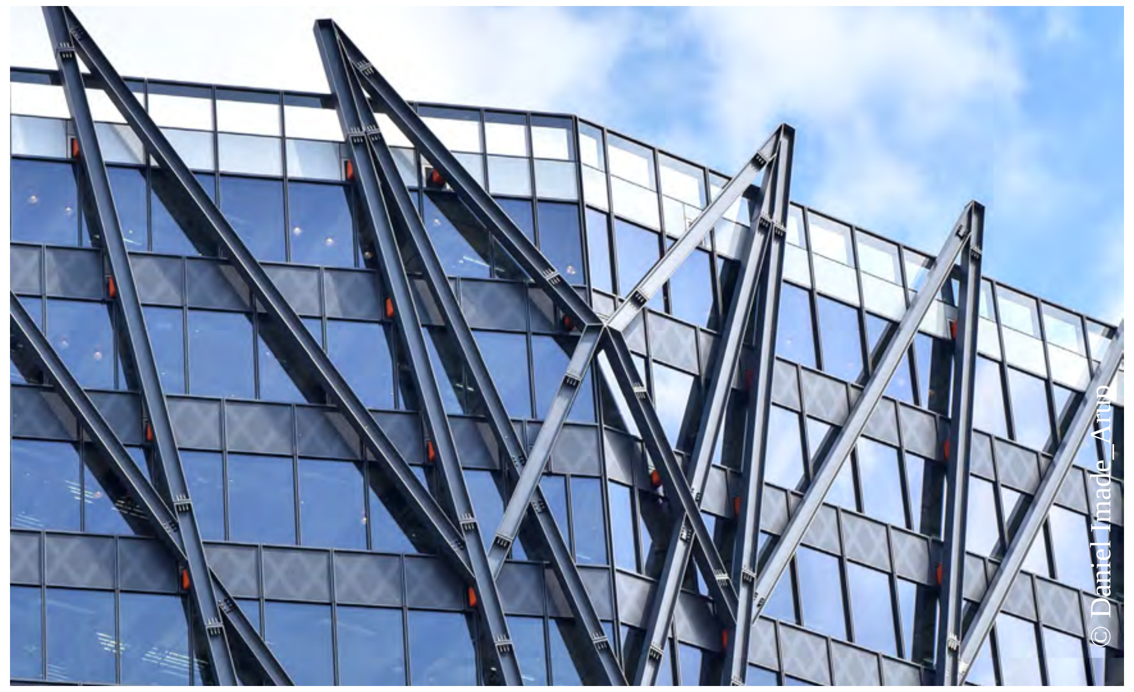
Grid spacing should be treated as a fundamental design decision from the outset, with structural frames optimised to their practical limits.

Action 2
Shading fins impact

Understanding the effect of the shading, focusing on the operational vs the embodied carbon saving. Fins have been considered as aluminium extrusions, with options to reduce, remove or integrate the fin within the curtain walling profile.

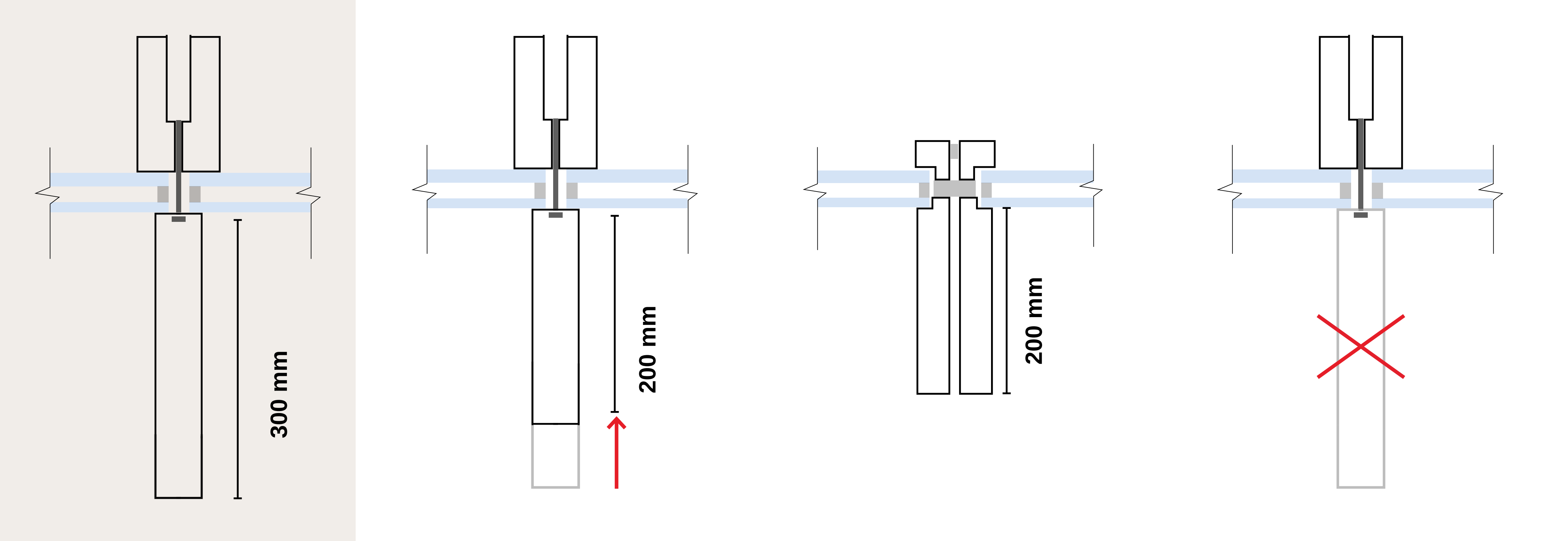
Key considerations

- Material saving
- Transport volume reduction
- Site installation of fins
- Visual appearance
- Solar gain implications
- OC vs EC – time value



Brunel building, London

Baseline	Option 2A Reduced fin depth	Option 2B Integrated profile	Option 2C Removal of fins



	Option 2A	Option 2B	Option 2C
Embodied carbon (A1-A5)	-5%	-5%	-17%
Operational carbon (B)	–	-0.1%	-0.3%
Cost	-3%	-3%	-12%

17%
Embodied carbon saving

Insight

Q What is the impact on planning? Can our buildings be interesting without adding fins?

A Removing features and fins can reduce material use, but this is perceived as a risk of creating uninteresting “boring” façades. This should be seen as an opportunity to rethink architectural expression - using form, proportion, and materiality to create interest.

Design Principles

Design features should serve a clear purpose, if this is purely aesthetic, it should have a clear contribution to the building’s longevity and purpose. Solar shading benefits are different on all elevations and embodied carbon benefits need to be compared against the payback of operational carbon benefits of shading.

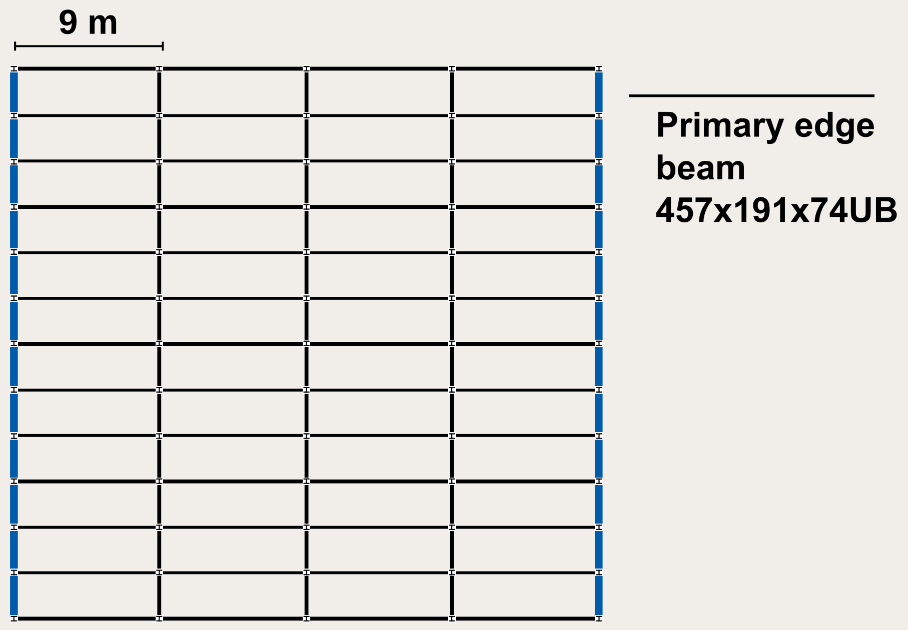
Action 3
Slab edge deflection limit

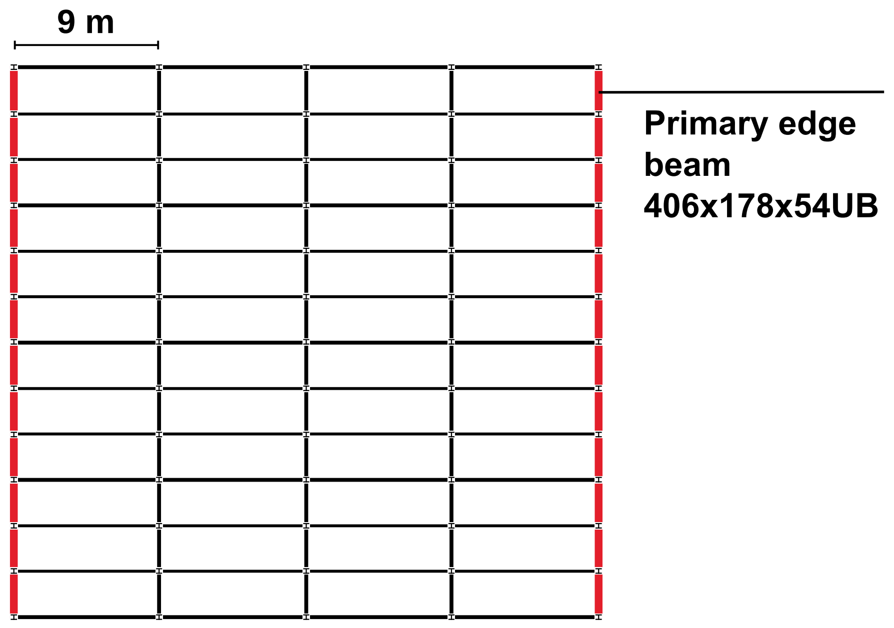
Understanding the effect of relaxing the slab edge deflection limit and how this can reduce the size of the primary edge beams at the perimeter. Example based on a 9x9 grid.

Key considerations
– Local effect to primary beams only
– Visual considerations on joints

Ruskin Square, London

Baseline	Option 3 Relaxed deflection
Span / 1000	Span / 500
Primary beam: 457x191x74UB	Primary beam: 406x178x54UB
Slab: 130 mm + composite deck	Applied to primary edge beams only





Embodied carbon (A1-A5)	-3%
Operational carbon (B)	–
Cost	-2%

3%
Embodied carbon saving

Insight

Q **Is a slightly larger joint worth 3% carbon saving and 2% cost saving?**

A While this may have a visual impact, joint sizes are not always prominent or perceptible. In the context of urgent carbon targets, aesthetic preferences around joints should be reconsidered. Design priorities must shift toward performance and impact, especially when the visual trade-off is minimal.

Design Principles

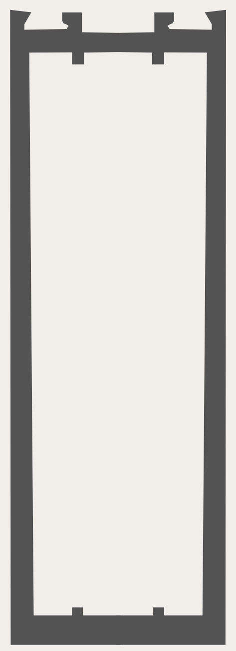
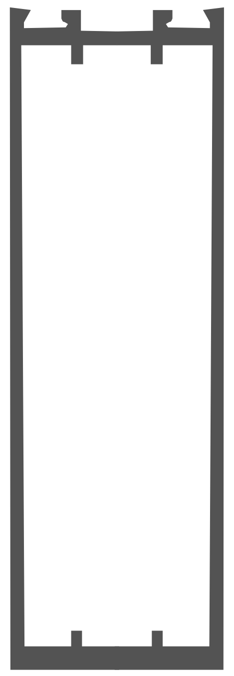
Consider strategies such as recessing joints, concealing them with spandrels or fins, or integrating them into the architectural language. Prioritise visual refinement only in areas where joints are prominently visible to occupants or the public realm, and allow greater flexibility in less visible zones such as upper floors.

Action 4
Extrusion thickness

Understanding the effect of reducing the extrusion thickness in an optimiszation process during die design and trial extruding. On typical extrusions, this can be reduced by 20%.

Key considerations
– Material and weight reduction
– Feasibility based on programme
– Longer lead time
– Increased technical trials and optimisation against die lines

White collar factory, London

	Baseline	Option 4 Reduced thickness
	Wall thickness of 2.5 mm on all aluminium extrusions (framing, shading fins etc) 	20% reduction Wall thickness assumed as 2 mm 
Embodied carbon (A1-A5)		-5%
Operational carbon (B)		–
Cost		–

5%
Embodied carbon saving

Insight

Q How important is visual perfection of mullions?

A This requires early engagement with extruders during the design phase. Visual perfection should not override the opportunity for meaningful impact – relaxing requirements for die lines should be accepted as part of a more sustainable design language.

Design Principles

Start early engagement with contractors to explore optimisation of extrusion thickness. Consider accepting minor visual imperfections like die lines and integrate this into the design language, where subtle imperfection is embraced and celebrated over aesthetic uniformity, as it is with natural materials such as stone.

Action 5
Wind driven glass build up

Understanding the effect of optimising the glass build-ups using location specific zones on projects. The two options analysed looked at wind load zones on elevations and occupancy zones on floors.

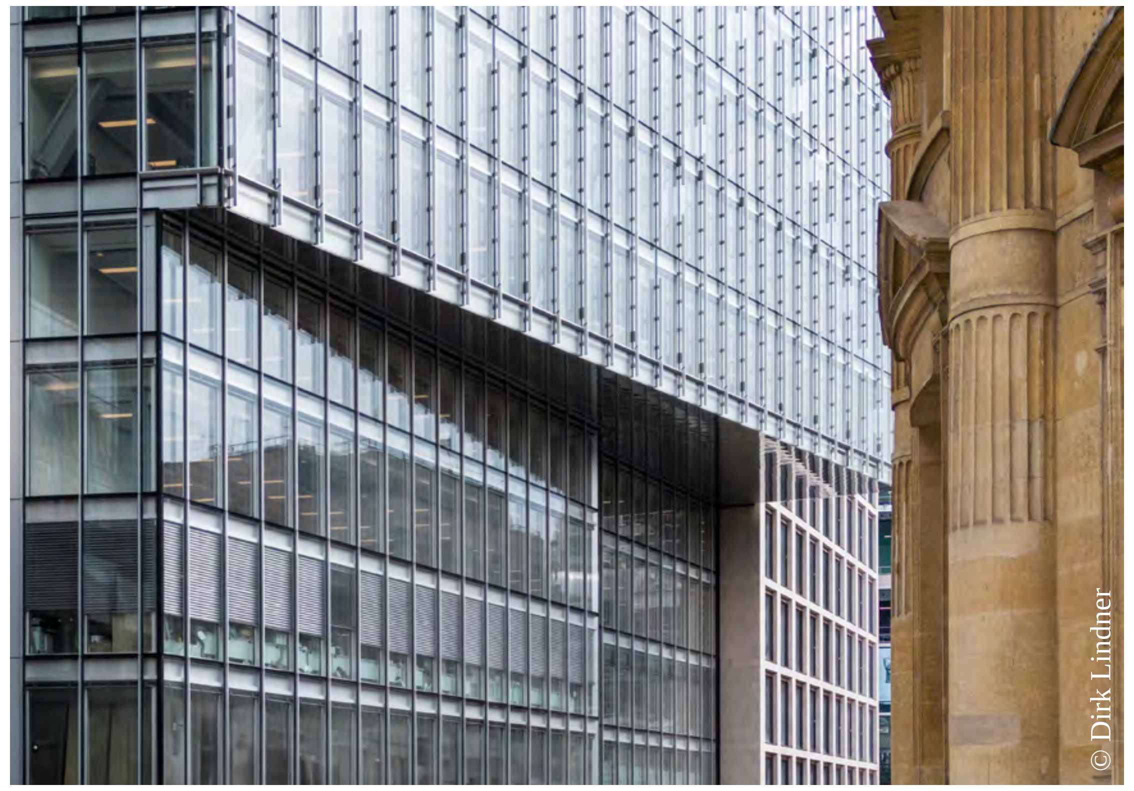
Key considerations

– Possible visual differences

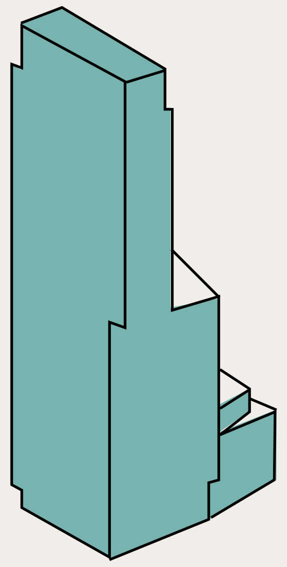
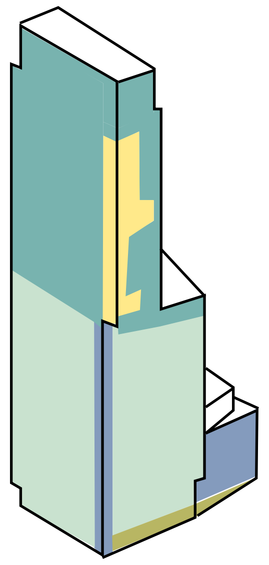
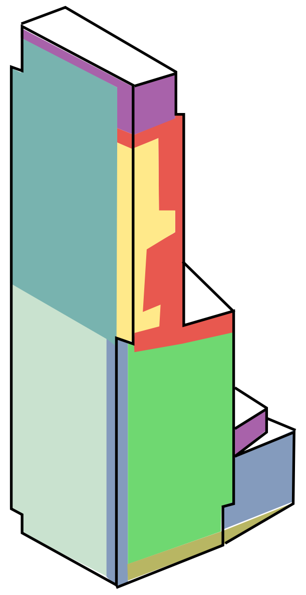
– More panel types

– Logistics in factory and on site

– Overall saving will depend on building layout/conditions



8 Bishopsgate, London

Baseline	Option 5A **Wind load zones**	Option 5B **Occupancy loading zones**
Wind-load: 2400 Pa throughout Glass: 6+6_5+5	Wind-load: Zone A 2400 Pa, Zone B 1600 Pa Glass reduces (in Zone B) 5+5_4+4	Publicly accessible areas require an increase of barrier loading Glass reduces (in Zone B) 5+5_4+4
		
Embodied carbon (A1-A5)	-4%	+14%
Operational carbon (B)	–	–
Cost	-2%	+1%

4% Embodied carbon saving

Insight

Q How important is visual consistency of glass?

A Visual consistency in glazing is often prioritised, but optimising glass-build ups by zoning is already used on tall buildings, demonstrating that logistical strategies can be applied more broadly. This approach should become standard practice on lower rise buildings as well.

Design Principles

For buildings with significant opaque elements, using glass of different thicknesses separately is an easy carbon saving win with negligible visual effects. Where glass variation is a concern, alternating materials or introducing design breaks can offer architectural solutions that reduce reliance on glass uniformity.

Action 6
Glass build-up requirements

Understanding the effect of relaxing glass requirements to minimise material usage and glass build-ups. Use of laminated glass vs monolithic on inner pane and relaxing of pillowing requirement.

Key considerations

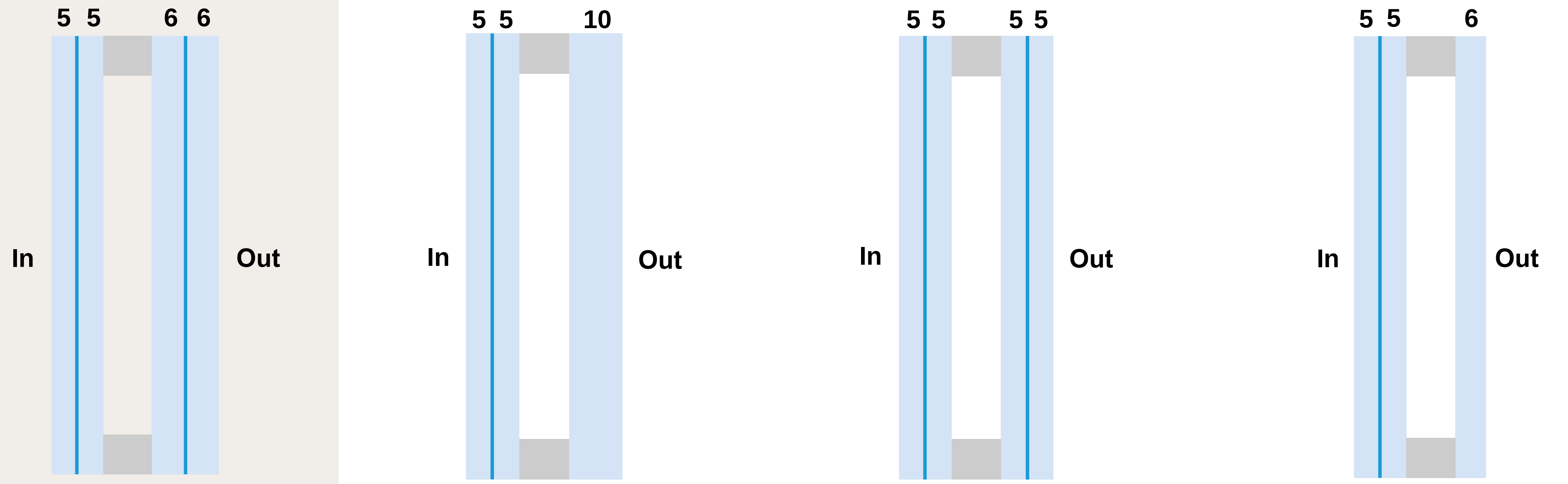
– Perception of safety vs actual risk

– Glazing visual effects

– Quality control of heat soaking process

80 Charlotte Street, London

	Baseline	Option 6A Outer monolithic	Option 6B Relaxed pillowing	Option 6C Combined
	Glass build-up: 6+6_5+5	Outer pane: 10 AN	Outer pane: 5+5 AN	Outer pane: 6 HS Inner pane: 5+5 AN
Embodied carbon (A1-A5)		-2%	-2%	-6%
Operational carbon (B)		–	–	–
Cost		-3%	-1%	-8%



6%
Embodied carbon saving

Insight

Q Can perception of risk be shifted and glass pillowing accepted as part of the glass aesthetics?

A An appropriate risk assessment should be evidence-based, not only on risk perception. Double laminated glazing is standard practice across more developed cities in the world whereas heat strengthened outer glazing is widespread beyond that. Visual effects like glass pillowing must be evaluated in the context of the full façade design, not in isolation.

Design Principles

Where aesthetics are a concern, design strategies such as avoiding glass-to-glass junctions or introducing deliberate breaks can mitigate the issue while reducing material usage and carbon.

Roundtable insights: voices from the industry

The roundtable brought together a diverse group of stakeholders, from clients and architects to façade designers, contractors, and investors, to respond to the proposed carbon-saving actions and share their perspectives on the broader challenges and opportunities facing the industry. The discussion was rich, candid, and constructive, revealing both alignment and friction across the group.

Four key themes emerged from the discussion:

– Integration over isolation: designing holistically

– Aesthetics and performance: finding the balance

– Policy, planning, and perception: aligning the system

– Culture, time, and value: changing the narrative

Roundtable participants

Alistair Law, Associate, Arup

Ayman El Hibri, Director, WilkinsonEyre

Benjamin Lesser, Head of Design and Innovation, Derwent

Janneke Verkerk, Sustainability Leader, Permasteelisa

Joe Burn, Development Cost Manager, Derwent

Jonathan Wilson, Director, Arup

Karen Cook, Founder, Spice

Laura Solarino, Senior Engineer, Arup

Neil Dobbs, Head of Façades, Multiplex

Paul Hargreaves, Construction Director, Lipton Rogers Developments

Rob Peebles, Director, Spice

Steve Mudie, Partner, Turner & Townsend alinea

Stuart Lipton, Founding Partner, Lipton Rogers,

Tim Debets, Lead Concept Design, Permasteelisa

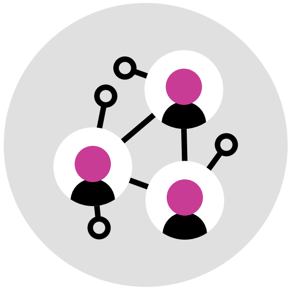
Tristram Carfrae, Arup Fellow, Arup

Vlad Tenu, Associate, AHMM

Key theme

Integration over isolation: designing holistically

There was a strong consensus that façades must be treated as an integral part of the building, not as an afterthought or a bolt-on system. Participants called for earlier collaboration, more joined-up thinking, and a shift toward holistic, performance-led design.



"There's a very important shift we see at the moment: in recent years we've been reducing operational carbon by actually adding more materials. It's interesting to see we're finally at the point where this is being challenged, we need to look at using materials in the most efficient way."

Janneke Verkerk
Sustainability leader, Permasteelisa

"There is appetite for what more can we do? And how can the façade and architecture interact to make more interesting and better buildings in the future? We spoke in favour of integrated design - so is a façade just a clip on element or is it an integrated part of the building?"

Tristram Carfrae
Arup Fellow, Arup

"We can only accelerate on using lower carbon solutions when we involve all stakeholders in drawing up the concept right from the start of a project and honestly show what the impact of our decisions is, in carbon, cost and time"

Tim Debets
Lead concept design, Permasteelisa

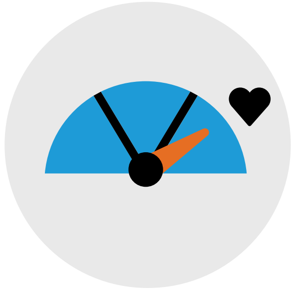
"We are beginning to see the emerging possibility of re-using salvaged large scale unitised façade elements on new projects, beyond just salvaging glass cullet or re-purposing insulated glass units. This will require strong will and very early engagement as the new building will have to be designed around what is available rather than the other way round. Floor to floor heights, planning module, slab edge deflection, building services etc will all need to be designed to incorporate what has been re-claimed."

Rob Peebles
Director, Spice

Key theme

Aesthetics and performance: finding the balance

The group acknowledged the tension between carbon performance and architectural expression but also saw it as an opportunity for innovation. There was a shared belief that beauty, efficiency, and longevity can co-exist, if the industry is willing to challenge outdated norms.



"There is a challenge between aesthetics and performance - they have to go hand in hand. If it just looks blank and flat, then nobody's going to like it. All of us around the table are in charge of the designs, we are driving what the end result is. We need to reverse the way we look at things and put everything on the table and then come to the right conclusions."

Ayman El Hibri
Director, WilkinsonEyre

"All the best buildings have a really long lifespan. So we've got to find that balance about how we put those buildings together, taking on board the carbon — and if we can save it, we should absolutely."

Paul Hargreaves
Construction Director, Lipton Rogers Developments

"It's interesting to look at the façade as a piece of clothing. If you buy really good clothes, that's going to last you for 20 years, but it needs to be fashionable, beautiful and timeless. If it is, then you would want to refurbish it, because it's still good, it still looks great. It applies to the façade as well, are we going towards fast fashion? Is there a trend in architecture where we're creating façades for 20 years?"

Vlad Tenu
Associate, AHMM

> "There is a challenge between aesthetics and performance – they have to go hand in hand."
>
> **Ayman El Hibri,** Director, WilkinsonEyre

Key theme

Culture, time, and value: changing the narrative

Beyond technical solutions, the roundtable highlighted the need for a cultural shift - in how we define value, allocate time, and make decisions. There was a call to rethink long-standing assumptions and to empower teams to make informed, carbon-conscious choices from the outset.

"There's a whole education piece about understanding where this architectural, energy and carbon driven design is taking us so that people understand why the building looks and performs as it does. And I think if people do understand that, they tend to actually enjoy it much more. Never forgetting that we're creating buildings for enjoyment and delight and for people to do their best work and to have their best day in."

Benjamin Lesser
Head of Design and Innovation, Derwent

"I think the purpose is almost the same as when working on a project. It's working our way through developing a top quality, sustainable façade to site. Lower carbon shouldn't mean increased capital cost. The design process is not all about carbon, it's part of it and we shouldn't lose sight of that. All stakeholders must play their part, from client down to the consultant team."

Steve Mudie
Partner, Turner & Townsend alinea

"There will always be trends in façade construction influenced by advances in systems, material capabilities and meeting the needs of building occupiers. The response to a brief sometimes requires introducing additional components. The challenge we have is extracting as much performance from these and the façade as a whole which will require greater collaboration and understanding of how the façade interacts with its environment and the buildings systems."

Neil Dobbs
Head of Façades, Multiplex

Key theme

Policy, planning, and perception: aligning the system

Planning authorities can be a critical and sometimes misaligned part of the equation. Participants urged for more education and engagement with planners to ensure that aesthetic requirements don't unintentionally undermine carbon goals.

"It is important for the industry, including the planners, to understand that when they stipulate they need modulation that comes with some additional embodied carbon implications. And it's not saying that's unacceptable, but it just needs to be a conscious choice when they're asking architects and developers to develop low carbon buildings."

Alistair Law
Associate, Arup

"We need to talk to the planners and say "ok, what do you want to do? You want socially acceptable and low carbon?". The planning authority has to understand what pure engineering skills will produce, possibly against the aesthetics of a design and their views on it."

Stuart Lipton
Founding Partner, Lipton Rogers

"Creating buildings that are both climate-conscious and culturally rich means aligning planning, policy, and design. That starts with inviting planners into the conversation not just as gatekeepers, but as co-creators of a sustainable future, recognising that every design demand, aesthetic preference, or regulatory constraint carries a carbon cost."

Laura Solarino
Senior Engineer, Arup

"Creating buildings that are both climate-conscious and culturally rich means aligning planning, policy, and design.

Laura Solarino, Senior Engineer, Arup

What’s next?

This cross-industry collaboration and roundtable discussion reaffirms a growing consensus across the industry: the shift from theoretical to tangible carbon reduction is no longer optional - it’s inevitable. Yet, despite the alignment in vision and aspirations, real implementation remains fragmented.

There are real technical, commercial, and regulatory challenges, but also a growing willingness across the value chain to engage with them.

The six actions we’ve identified are not a checklist of ready-made solutions, but a starting point for collective progress. They reflect what’s possible now, and where we need to go next - the opportunity is not just to reduce emissions, but to redefine value in façade design.

Three clear points emerged from the discussion: the need to bring the industry in the design earlier, to prioritise practical over purely academic approaches, and to interrogate our assumptions more rigorously as an industry. These are not just insights, they are invitations.

This is a call for participation: designers, manufacturers, developers, and policymakers each have a role to play in testing, refining, and scaling these actions.

What would it take to make low-carbon curtain walling the default, not the exception?

How can we better share data, risks, and learning across the supply chain?

What new forms of value, beyond cost and compliance, might emerge if we do?

We invite you to be part of this conversation, because only collaboratively can we align the sector and design a future that works for both people and planet.

This research has been delivered in partnership: Arup, Permasteelisa Group, Turner&Townsend Alinea.

Reach out to our team to continue the conversation - whether you're exploring a project, challenging a design norm, or simply curious about what's possible, we'd love to hear from you.

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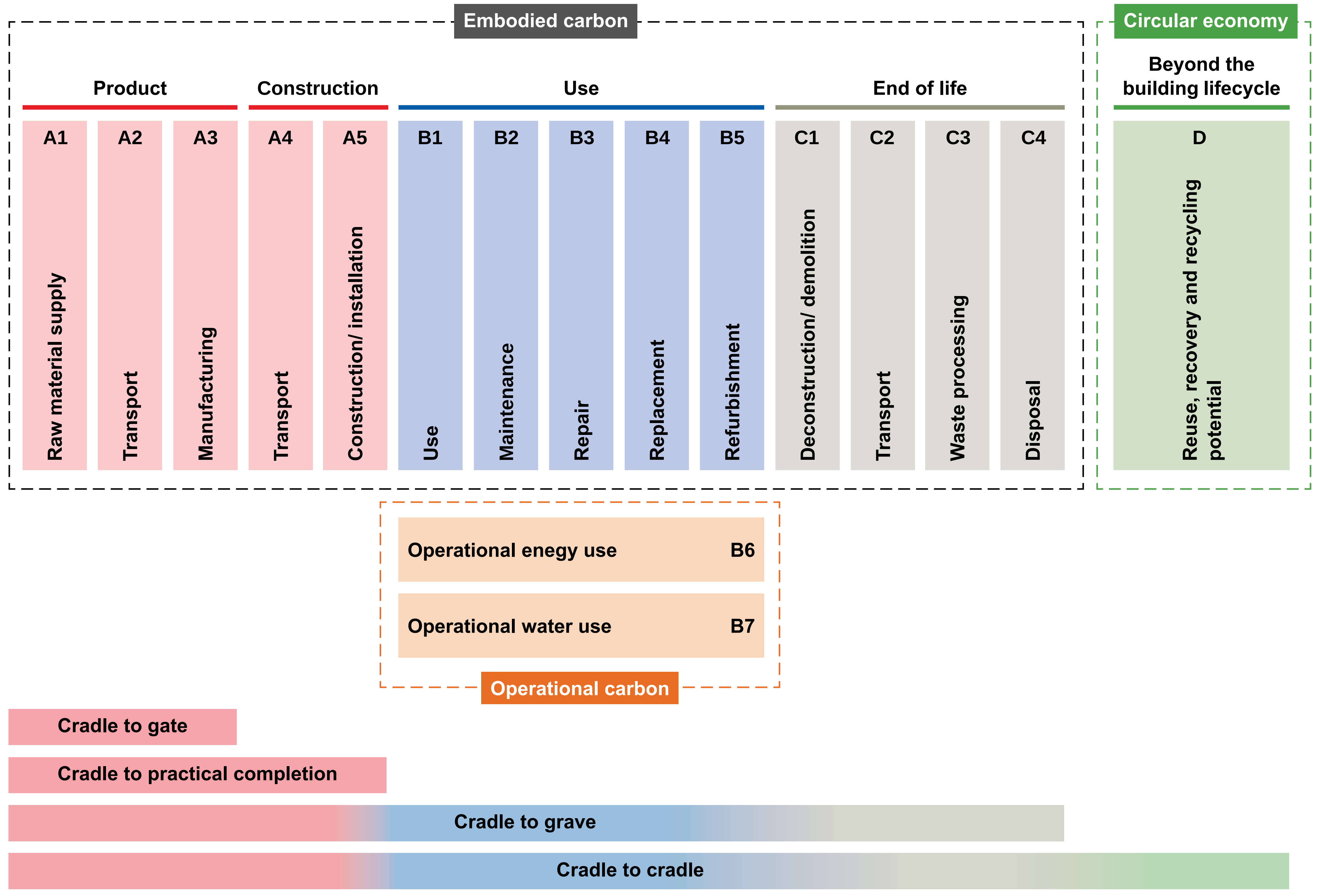
Appendix

Methodology of research

The embodied carbon assessments in this document are an estimation based on the Life Cycle Analyses (LCAs) of previous projects in which the specific supply chain and production processes of Scheldebouw were investigated. The finished LCA calculations were sent to a third party for review. Once approved, Environmental Product Declarations (EPDs) were drawn up and published on ECO platform through the program operator MRPI. This approach has now been standardised within Permasteelisa Europe for the brands Scheldebouw, Permasteelisa and Gartner. For more detailed background information Permasteelisa's "Custom Curtain Wall EPD, Project Approach" document is available upon request with a description of the EPD process and underlying assumptions, illustrated by an officially published EPD. The full list of published EPDs by Permasteelisa Europe (13 at the time of writing) can be found here.

The Life Cycle Analyses were conducted using the software application R<THINK by NIBE, which is based on the LCA method EN 15804:2019+A2. This standard also serves as the core PCR, in compliance with ISO 14040:2006 and ISO 14044:2006. The R<THINK software assesses and reports all life cycle stages A to D and the whole list of environmental impact categories. From the list of environmental impact indicators in EN 15804 the total Global Warming Potential (GWP-total) expresses the impact on climate change, often briefly called "carbon". This document focuses on the life cycle stages A1-A5.



Life cycle stages of a Life Cycle Analysis (LCA)

Functional unit

The LCA has been conducted for a typical curtain wall façade element, including floor brackets and firestop, and the results are presented for 1 m^2 of façade. The functional unit is described in more detail in Appendix B.

Materials (A1)

In stage A1 all processes to make the purchased components are included (cradle to gate, so A1-A3 from the supplier's perspective). For the baseline calculation a combination and manipulation of processes from the EcoInvent database (currently version 3.6) is used to represent a conservative performance that can be delivered without specific supplier agreements.

The following materials are included with corresponding carbon factors:

Material	Carbon factor ($kgCO_2e$/kg material)
Laminated double glazing	1.89
Aluminium profiles, anodised	8.59
Thermal breaks	8.80
Steel sheets, pre-galvanised	2.69
Mineral wool insulation	1.07
Aluminium sheets, anodised	8.52
Steel brackets, galvanised	2.17
EPDM gaskets	2.40
Silicone sealant	2.02
Fasteners (stainless steel)	5.95

Transport (A2 and A4)

The transportation (A2) by lorry between the different suppliers and Scheldebouw's assembly facility in Middelburg is based on the average distance in the period 2016-2021 of the top three suppliers per material:

Average supplier distances (stage A2)	Distance (km)
Glazing	1000
Aluminium profiles	877
Aluminium sheets	372
Mineral wool	199
Steel sheets	161
Steel brackets	206
Gaskets	390
Fasteners	156
Sealant, incl. primer and cleaner	104
Wooden packaging	7.4
Plastic packaging	0.75

The transportation (A4) to a building site in London is outlined in the table below:

Transport conveyance (stage A4)	Distance (km)
Lorry (truck: Middleburg-Rotterdam	85km
Transoceanic ship: Rotterdam-Purfleet	282km
Lorry (truck): Purfleet-London	31km
Total:	398km

The transport is modelled using the following processes from EcoInvent 3.6:

Description	GWP-total (kg CO_2e)
Lorry (truck)	0.14 per tkm
Transoceanic ship	0.01 per tkm

Façade panel assembly and site installation (A3 and A5)

The processes in the assembly facility (A3) are based on the yearly consumption in the period 2016-2021 of the following materials divided by the area (m^2) of produced elements in that year and modelled using EcoInvent 3.6 processes:

– Ancillary materials (cleaner, primer)

– Packaging (wood, plastic)

– Energy consumption (electricity, natural gas)

The electricity use for site installation (A5) is based on an estimation for handheld tools.

Description	Amount per m^2 façade panel	Unit	GWP-total [kg CO_2e] per unit
Cleaner	0.015	kg	2.88
Primer	0.069	kg	2.01
Wooden packaging	2.05	kg	-1.31*
Plastic packaging	0.69	kg	2.98
Electricity NL	33.65	kWh	0.66
Natural gas	1.35	Nm^3	2.23
Electricity GB	0.37	kWh	0.39

* Negative value in A3 includes biogenic carbon uptake. Waste disposal of packaging is accounted for in A5

Waste rates of the façade materials are based on an analysis of the waste streams in our production facility:

– 3% for materials that arrive from the suppliers in the form that they will be used

– 15% for materials that undergo cutting and machining

– 50% for sealant

An additional 3% waste rate for prefabricated units is assumed on the building site.

Façade carbon assessment comparison

Option	Carbon reduction action	Window to wall ratio	Shading	Module (wxh)	Glass make up	Thermal transpittance	G value	Wind load	Weight kg / m² FSA	A1-A5 $kgCO_2e/m^2$ FSA	Delta from baseline $kgCO_2e/m^2$ FSA	Delta from baseline (%)
Baseline	N/A	60%	Yes: 300 mm	1.5 x 2.4 m	66.2 AN - 16 - 55.2 AN	1.2 W/m²K	0.28	2400 Pa	69	327.2	N/A	N/A
1A	Introduction of a spandrel, Floor + 1200mm	55%	Yes: 300 mm	1.5 x 2.4 m	55.2 AN - 16 - 44.2 AN	1.1 W/m²K	0.28	2400 Pa	58.9	331.2	+4	+1.2%
1B	Introduction of cantilever panel	55%	Yes: 300 mm	1.5 x 2.4 m	55.2 AN - 16 - 44.2 AN	1.1 W/m²K	0.28	2400 Pa	58.9	331.2	+4	+1.2%
1C	Combination of panels width 1.5m to 3m	60%	Yes: 300 mm	1.5 x 2.4 m	66.2 AN - 16 - 55.2 AN	1.0 W/m²K	0.28	2400 Pa	61.2	257.1	-70.1	-21.4%
2A	Reduction of fin depth 300mm to 200mm	60%	Yes: 200 mm	1.5 x 2.4 m	66.2 AN - 16 - 55.2 AN	1.2 W/m²K	0.28	2400 Pa	67.3	310.3	-16.9	-5.2%
2B	Integrated fin, fin depth 300mm to 200mm	60%	Yes: 200 mm	1.5 x 2.4 m	66.2 AN - 16 - 55.2 AN	1.1 W/m²K	0.28	2400 Pa	67.4	312.4	-14.8	-4.5%
2C	Removal of fins	60%	No	1.5 x 2.4 m	66.2 AN - 16 - 55.2 AN	1.2 W/m²K	0.28	2400 Pa	63.5	273.5	-53.7	-16.4%
3	Slab edge deflection limit	60%	Yes: 200 mm	1.5 x 2.4 m	66.2 AN - 16 - 55.2 AN	1.2 W/m²K	0.28	2400 Pa	69	317	-10	-3%
4	Reduction of extrusion wall thickness		Yes: 300 mm	1.5 x 2.4 m	66.2 AN - 16 - 55.2 AN	1.2 W/m²K	0.28	2400 Pa	67.2	309.7	-17.5	-5.3%
5A	Glass build-up: using wind load zones	60%	Yes: 300 mm	1.5 x 2.4 m	Windload (corner): 66.2 AN - 16 - 55.2 AN Windload Typical: 55.2 AN - 16 - 44.2 AN	1.2 W/m²K	0.28	Typical: 1600 Pa Cornwer: 2400 Pa	63	314.3	-12.9	-3.9%
5B	Glass build-up: using occupancy zones	60%	Yes: 300 mm	1.5 x 2.4 m	10.10.2AN-16-88.2AN	1.2 W/m²K	0.28	2400 Pa	90	372.4	+45.2	+13.8%
6A	Outer monolithic	60%	Yes: 300 mm	1.5 x 2.4 m	10 AN - 16 - 55.2 AN	1.2 W/m²K	0.28	2400 Pa	66	320.7	-6.5	-2.0%
6B	Relaxing pillowing	60%	Yes: 300 mm	1.5 x 2.4 m	55.2 AN - 16 - 55.2 AN	1.2 W/m²K	0.28	2400 Pa	66	320.7	-6.5	-2.0%
6C	Combined	60%	Yes: 300 mm	1.5 x 2.4 m	6 HS - 16 - 55.2 AN	1.2 W/m²K	0.28	2400 Pa	60	307.8	-19.4	-5.9%