

Textile Roofs 2024

The 26th International Workshop on the Design and Practical Realisation of Architectural Membrane Structures



Lightweight
Footprint

formfinder



The Pathways towards Zero Carbon for Tensioned Membrane Architecture: ongoing actions and next steps

April 28, 2024

This presentation is being shared for educational and informational purposes only.

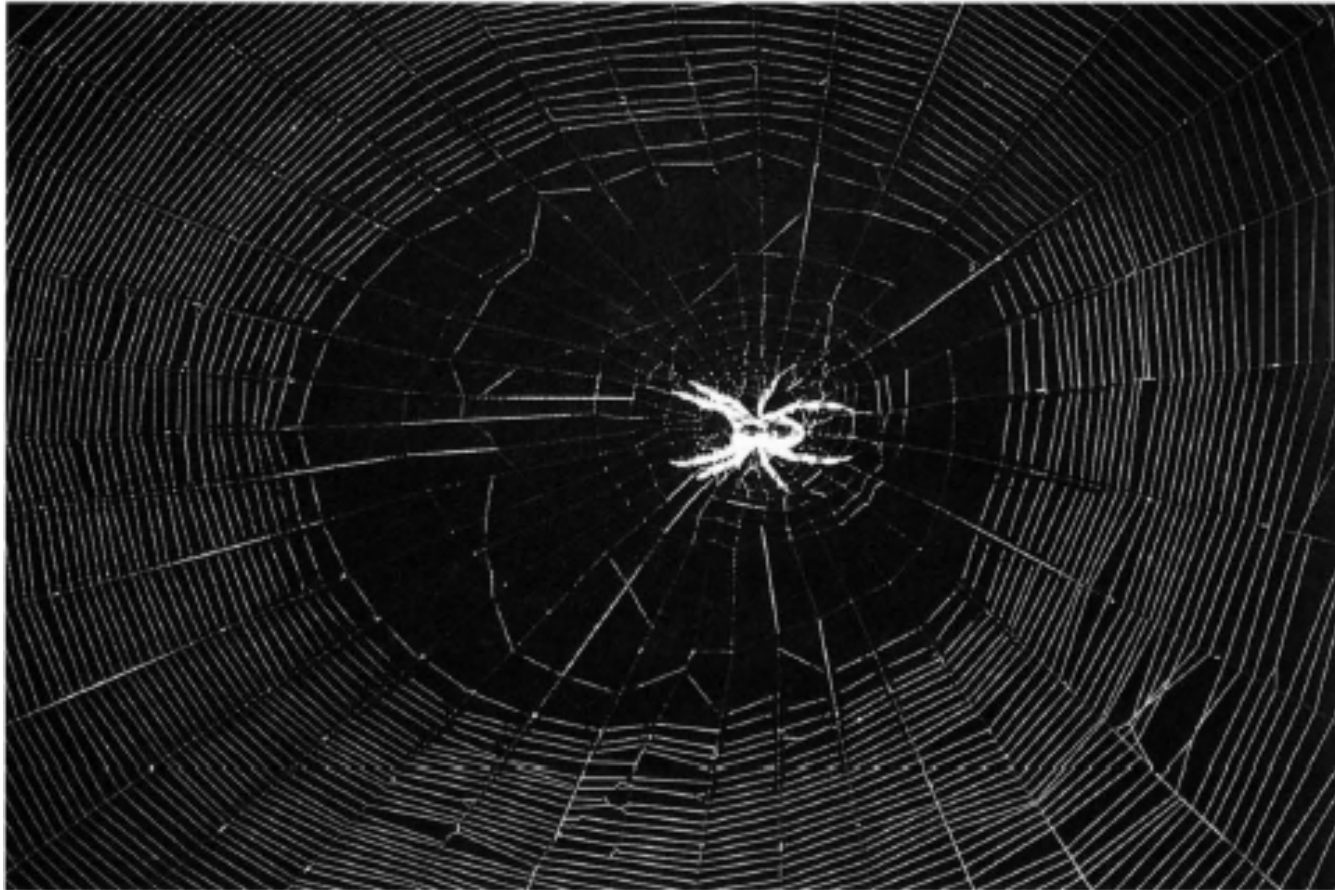
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Bruce Danziger, SE
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SPIDERS' WEBS

A collaboration between Peter Rice, Ove Arup & Partners and Dr. Fritz Vollrath



"When I was invited by Fritz Vollrath and his team at the Zoology Department of Oxford University to join him exploring how spiders' webs work, I accepted immediately. Open ended research leads to the most exciting results and stimulus. So far we have discovered that the spider is using the techniques of the late 20th century engineer, but with much more elegance and precision. Here too we are at the beginning." PR 92

EXPLORING MATERIALS

The work of Peter Rice
Royal Gold Medallist 1992

Reduce the embodied carbon of lightweight structures

2 Year Plan - Nohmura Foundation Grant

**Nohmura Foundation for
Membrane Structures Technology**

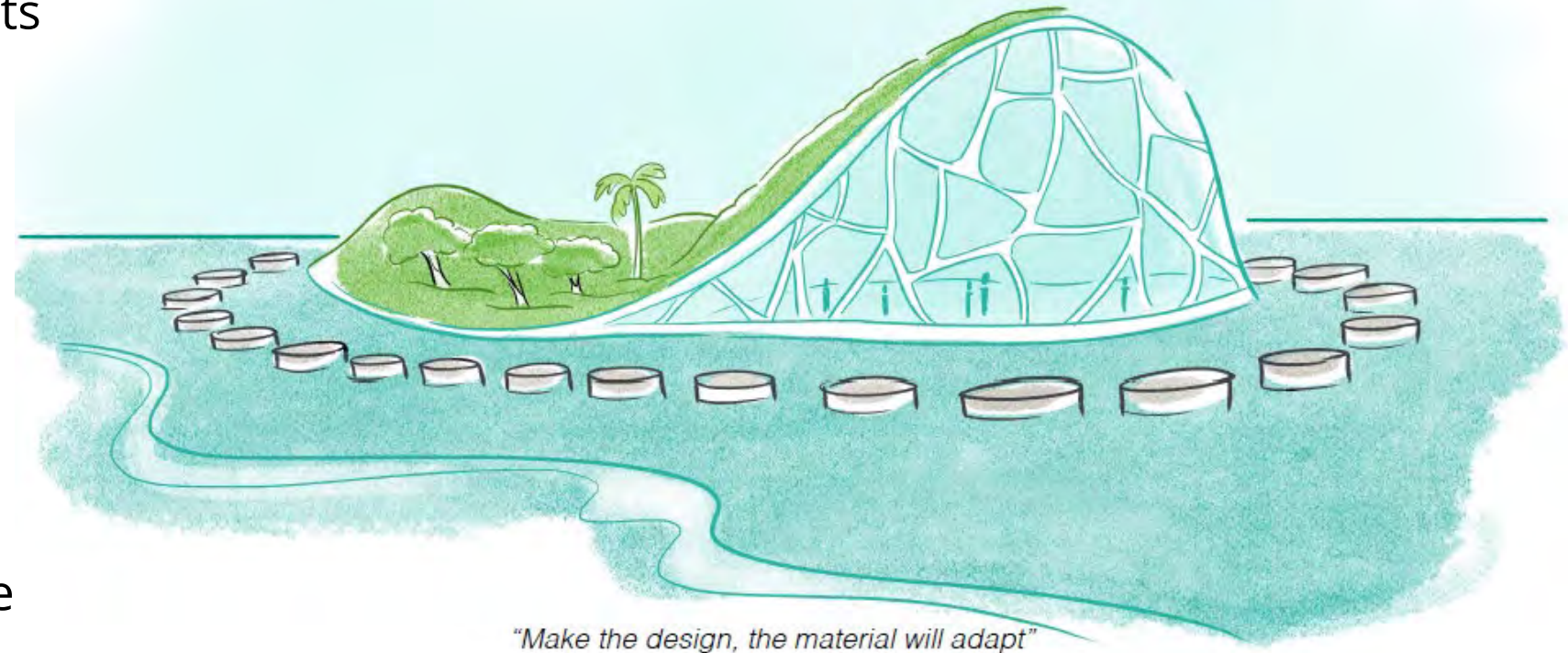
2024:

- Develop website
- Invite to industry participants
- Template Declarations
- Launch Website
- ECAPs & Collect data

2025:

- Promote website
- Solicit more industry colleagues to join with commitment letters
- Improve & Maintain website
- Collect & manage data – embodied carbon tracking and comparison studies

Lightweight Footprint



Members of Lightweight Footprint



Engineer



Björn Beckert
Dipl.-Ing.
(Msc)



Engineer



Bruce Danziger
SE



Architect



Beatriz Ferreyra
B. Arch.,
M.Eng.



Entrepreneur



Robert Roithmayr
Arch. Eng.
PhD

 *One of the biggest traps for smart engineers is optimizing something that shouldn't exist."*

Elon Musk

Overview

Lightweight structures should have less environmental impact than normal weight materials of construction

No one has proved this

It should not be difficult to prove

Our team of experts will prove it with help from industry

Industry = manufactures, fabricators & installers, designers & engineers

Lightweight Footprint



Mission/Vision 2020

Lightweight Footprint

Vision

Lightweight membrane structures are obviously sustainable – let's prove it

Mission

Provide quantitative scientific & engineering analysis to demonstrate the sustainable attributes of membrane structures

Plan

Determine the carbon footprint relative to the economic benefits considering different functions, programs and locations (case studies)

Deliverable

Produce calculations with material data from manufacturers



Value Proposition

Lightweight Footprint

Good for you, good for me, good for the planet

Everyone has to do their part to reverse or at least stall rapid climate change

Set Targets

Understanding the impacts and committing to incremental reductions

Our Industry Impact

Industry empowered to change through innovation

Growth

By demonstrating benefits, promotes and grows industry

Attract talent

More smart, motivated and creative people will want to join the industry

Finally it will be proved

Quantitative engineering & science to support the industry's claims of sustainability

Environmentalism and/or Industrialist

Materials Science



The Committee on the Environment (COTE)



Working Group 6:
Tension and Membrane Structures

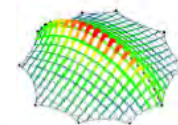


WG SUSTAINABILITY AND
COMFORT



Lightweight Footprint

Shady
Ventures



Nohmura Foundation for
Membrane Structures Technology

Textile Roofs 2024

The 26th International Workshop on the
Design and Practical Realisation of Architectural Membrane Structures

University for
Continuing
Education KREMS



Postgraduate Master's (M.Eng.) Program
LIGHTWEIGHT MEMBRANE STRUCTURES

ANNEX XV RESTRICTION REPORT – Per- and polyfluoroalkyl substances (PFASs)

Sectors	Properties	Applications
	and friction property	fuel hoses, power steering, transmission, lubricants, and coatings
Chemical industry	Chemical resistance, mechanical property, thermal property, and weather stability	Coatings for heat exchangers, pumps, diaphragms, impellers, tanks, reaction vessels, autoclaves, containers, flue duct expansion joints, heavy-wall solid pipe and fittings
Electrical/electronic	Dielectric constant, flame resistance, and thermal stability	Electrical insulation, flexible printed circuits, ultrapure components for semiconductor manufacture
Architectural and domestic	Weatherability, flame retardancy, friction property, thermal stability	Water-repellent fabric, architectural fabric, non-stick coatings for cookware, and fiberglass composite for constructions
Engineering	Mechanical property, thermal stability, chemical stability, weatherability, and surface energy	Seats and plugs, bearings, non-stick surfaces, coatings for pipes, fittings, valve and pump parts, and gears
Medical	Surface energy, biological stability, mechanical property, chemical resistance	Cardiovascular grafts, ligament replacement, and heart patches

ICRL 1|2022

1

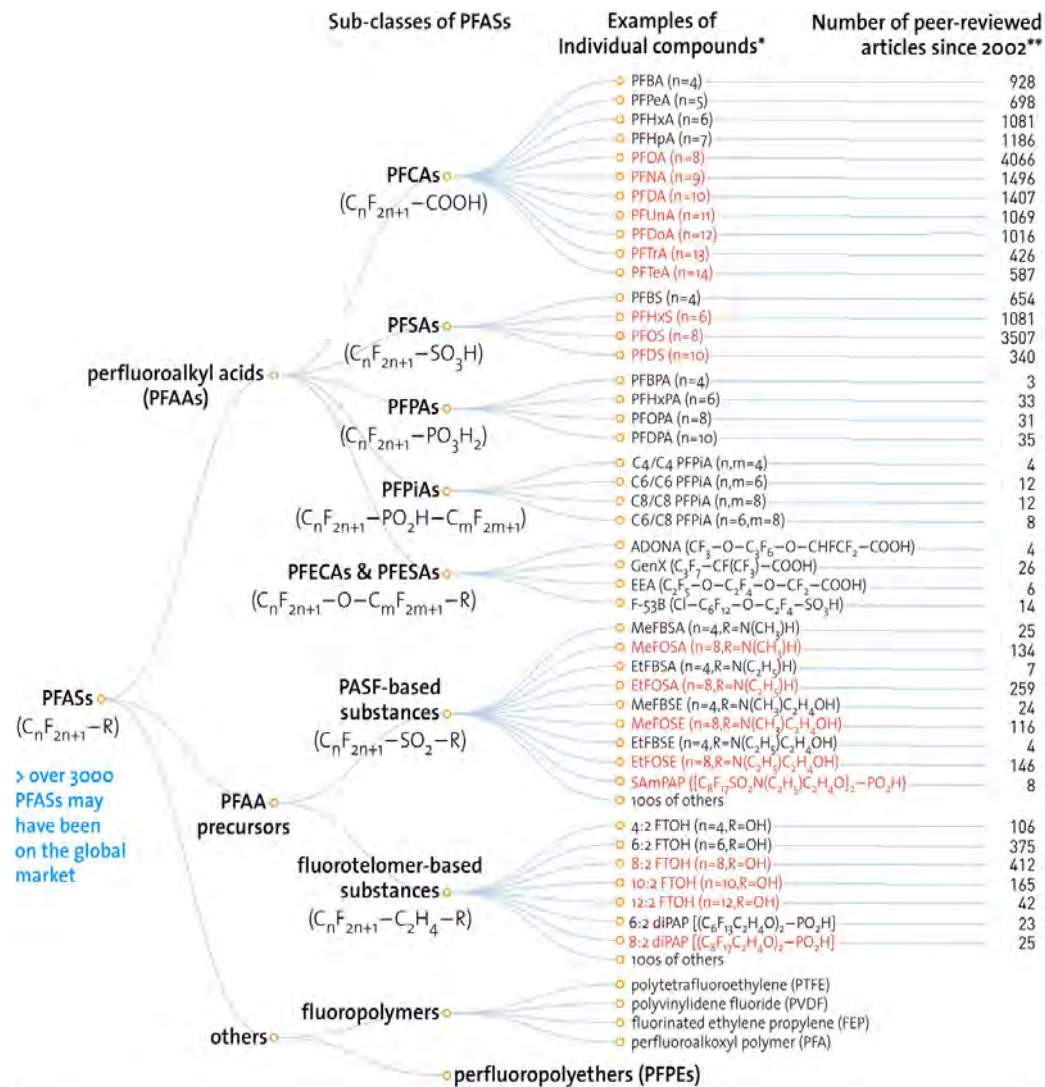
Fluoropolymers: The Safe Science That Society Needs

Jaime Sales, Francisco Hernández, Deepak Kapoor and Marcel van den Noort*

Table A.57. Identified PFAS uses, technical function and examples of PFAS in building material/construction products based on literature and stakeholder input.

Use category	Sub-use(s)	Technical functions	Examples of PFASs
Roofing	Architectural membranes including fluoropolymer films (ETFE) and fabrics or fiber glass coated/laminated with fluoropolymers in e.g. stadium roofs, greenhouses, flexible solar panels	Durability, chemical and UV resistance, light weight, low maintenance, wetting during application of film	Fluorinated polymers e.g. PTFE, ETFE, FEP, PVDF Non-polymeric PFASs e.g. PBSF, HCFO-1233zd ¹
	Weatherproofing Membranes made of materials such as synthetic rubber, polyvinyl chloride (PVC), polyolefin, or other heavy-duty thermoplastics, and coated with a fluoropolymer layer. Used for e.g. flat-type roofs	Durability and stain resistance, moisture control and solar reflectivity	Fluoropolymers
Wires and cables	Electrical cable and wire insulation (in e.g. air conditioner units, computers, light fixtures and heated flooring), PTFE-impregnated plastic or a fiberglass-based tapes for electrical	Flexible, durable, temperature resistance	PTFE, PCTFE, ETFE, FEP, PVDF

PVC, PTFE, ETFE, etc.



* PFASs in RED are those that have been restricted under national/regional/global regulatory or voluntary frameworks, with or without specific exemptions (for details, see OECD (2015), Risk reduction approaches for PFASs. <http://oe.cd/1AN>)
 ** The numbers of articles (related to all aspects of research) were retrieved from SciFinder® on Nov. 1, 2016.



The Fight Against PFAS Contamination Across the Country

'They all knew': textile company misled regulators about use of toxic PFAS, documents show

Thousands more residents outside the original contamination zone may be drinking tainted water



Saint-Gobain claims it did not hide its use of PFOA because the information was included among 90,000 documents it released. Photograph: Charles Platiau/Reuters

Environmental Product Declaration (EPD)

MATRIX GWP [CO2eq/kg] BY TYPE OF MEMBRANE Excluding C & D

	PES/PVC	FiberGlass/ PTFE	ETFE System
[1]			
[2]	5.34		
[3]		241.55	
[4]			38.43
[5]			53.20
[6]			63.40
[7]	4.83		
Av.	5.09	241.55	51.68

Sources:

[1] EPD - Serge Ferrari Tensile composite membranes.

Declare unit: 1m² Weight 1.144 kg (Average total).

[2] EPD - Low & Bonar GmbH Mehgies VALMEX® FR 1000.

Declare unit: 1m² Weight: 1.05 kg

[3] EPD - SHEERFILL II Saint-Gobain Performance Plastics

Declare unit: 1 m² Weight: 1.31 Kg

[4] EPD - Texlon® Vector Foiltec GmbH, Nowofol, Dyneon GmbH.

Declare unit 1 m² Weight: 3.89 kg/m²

[5] EPD - TensoSky® - System with Fluon® ETFE-FILM Taiyo Europe GmbH, AGC Inc.

Declare unit: 1 m² Weight: 3.93 kg/m²

[6] EPD - Novum AFP-System Novum Membranes GmbH

Declare unit: 1 m² Weight: 5.20 kg/m²

[7] EPD - Sioen Industries NV

Declare unit: 1m² Weight: 0.9 kg/m²

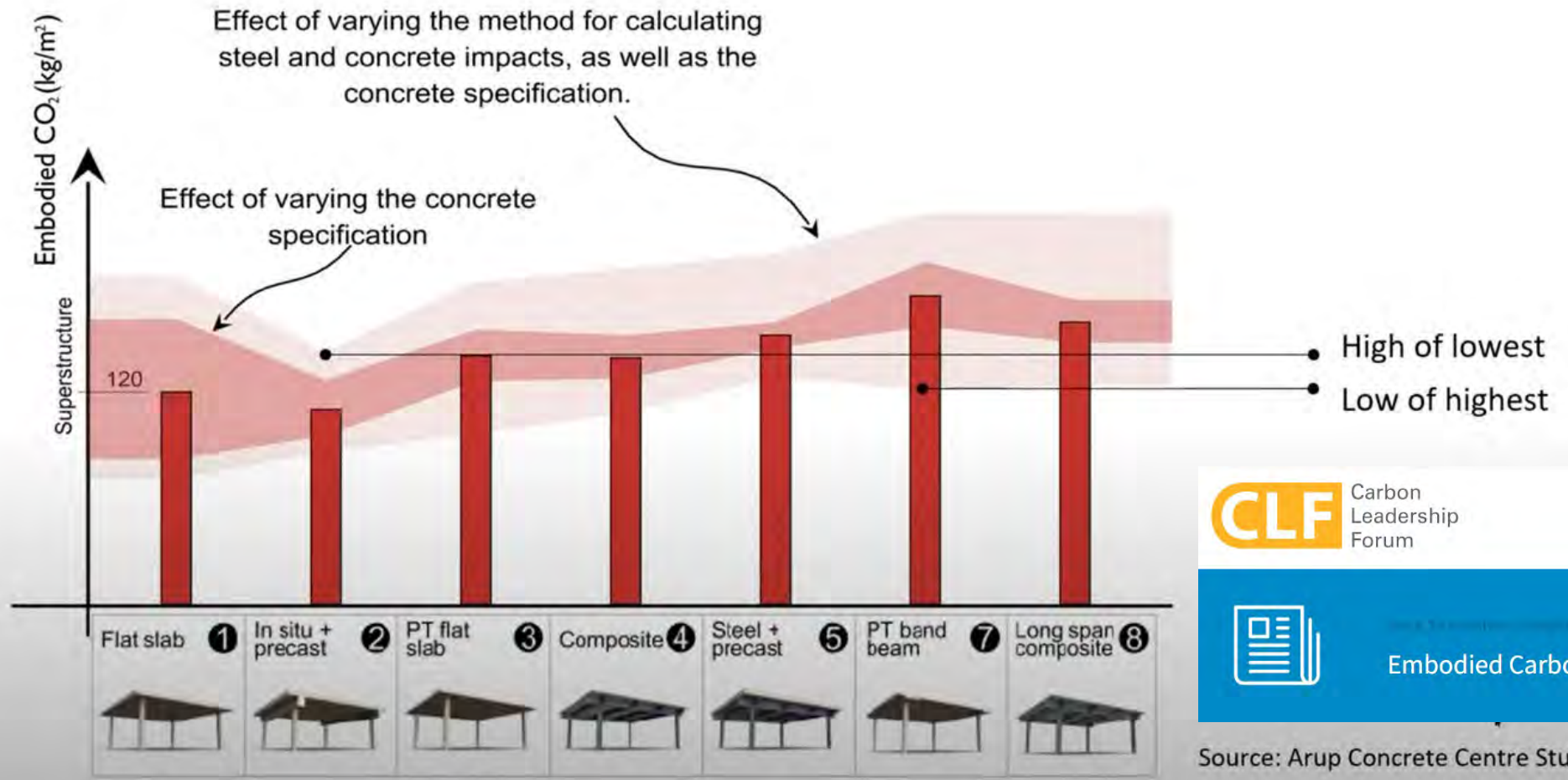


Parameter	Parameter	Unit	Raw Materials	Manufacture	Packaging	Fabrication & Installation	Use	End of Life	Total
Global Warming Potential	GWP	kg CO ₂ -eq	2.29E+02	1.01E+00	7.37E-01	1.08E+01	5.59E-02	2.05E-02	2.42E+02
Ozone Depletion Potential	ODP	kg CFC 11	7.81E-04	3.88E-09	2.37E-08	1.24E-08	1.58E-08	5.58E-09	7.82E-04
Acidification Potential	AP	kg SO ₂ eq	2.05E-01	8.65E-03	5.37E-03	6.86E-02	3.58E-04	1.42E-04	2.88E-01
Eutrophication Potential	EP	kg (PO ₄) ³ eq	2.58E-02	2.28E-04	9.90E-04	2.18E-02	8.42E-05	3.01E-05	4.89E-02
Photochemical Oxidation Potential	POCP	kg C ₂ H ₄ eq	1.90E-02	3.78E-04	4.35E-04	4.55E-03	1.80E-05	6.39E-06	2.44E-02
Abiotic Depletion Potential (non-fossil)	ADPE	kg Sb eq	2.02E-04	3.29E-08	2.34E-08	7.90E-05	6.14E-08	3.91E-08	2.84E-04
Abiotic Depletion Potential (fossil)	ADPF	MJ	3.18E+02	1.59E+01	1.02E+01	1.39E+02	7.85E-01	5.03E-01	4.84E+02





SENSITIVITY ANALYSIS



Embodied Carbon Policy Educational Series

Source: Arup Concrete Centre Study, 2009

Buro Happold's in-house Embodied Carbon Assessment Tool



Building Details

Use: Cultural/Civic
 Floor Area GIA: 82,400 m²
 Approx Construction Value: £50,000,000
 Type: Canopy/Roof

Study Details

Design Stage: Post Completion
 Carbon Data Region: UK

Notes

Calculations carried out in accordance with Istructe How to Calculate Embodied Carbon Guide Rev 1 August 2020.

For carbon factors used refer to page 2. For UK Carbon factors are

Sequestered Carbon has been recorded as Stored Carbon and is not counted in the basic Embodied Carbon Calculation.



**IASS 2020/21
SURREY 7**
 International Conference on
 Spatial Structures 2020/21

Proceedings of the IASS Annual Symposium 2020/21 and
 the 7th International Conference on Spatial Structures
 Inspiring the Next Generation
 23 - 27 August 2021, Guilford, UK
 S.A. Behnejad, G.A.R. Parke and O.A. Samavati (eds.)

The Carbon Footprint of Long Span Structures: Review of the Millennium Dome and Subsequent Tensile Systems

Corresponding AUTHOR*: Tim C. R. FINLAY*

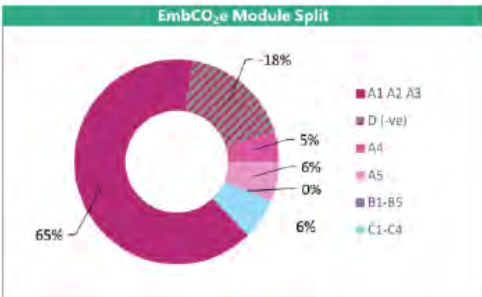
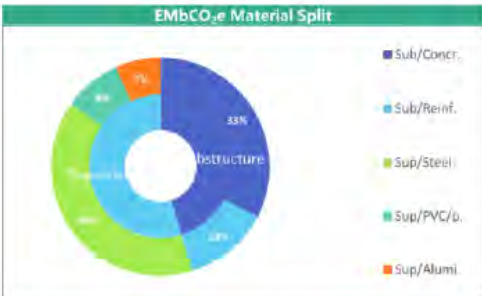
*Buro Happold
 Camden Mill, Lower Bristol Road, Bath, BD2 3DQ
 Tim.finlay@burohappold.com

Embodied Carbon Totals

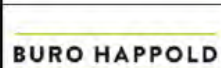
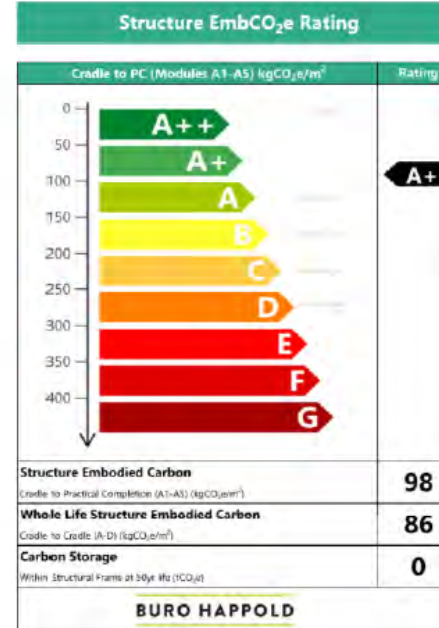
Whole life: **7120** tCO₂e (Modules A1-A3, C1, C3, C4, D) **86** kgCO₂e/m²

To Completion: **8088** tCO₂e (Modules A1-A3) **98** kgCO₂e/m²

Embodied Carbon Rating: **A+**



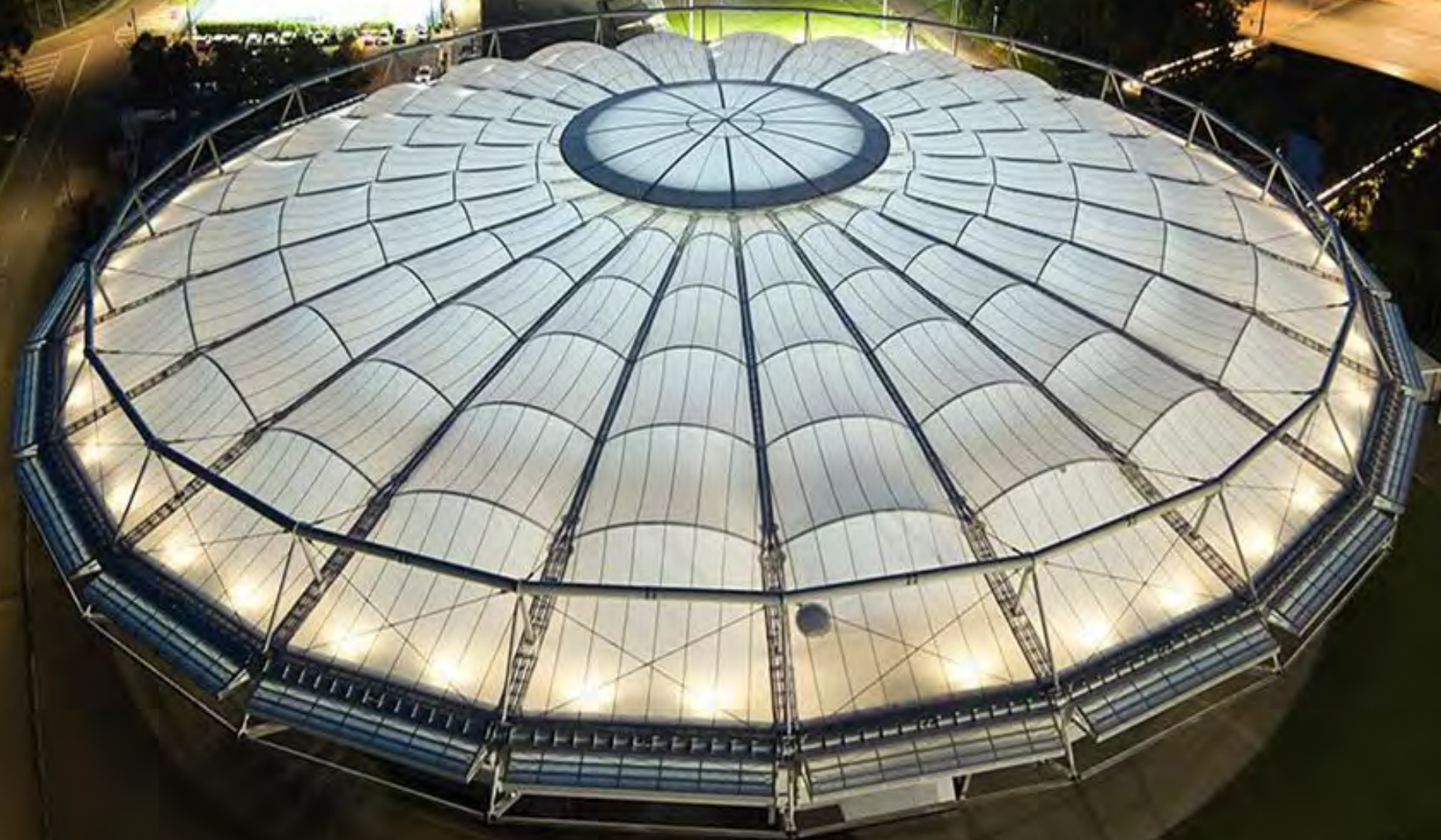
		Embodied Carbon Breakdown tCO ₂ e						
		Construction		Use		End of Life		Total
		A1 - A3	A4	A5	B1-B5	C1 - C4	D	
0. Enabling	Total	0	0	0	0	0	0	0
1. Substruc.		1459	61	358	0	438	0	2317
		554	23	47	0	26	256	908
	Total:	2014	84	405	0	465	256	3224
2. SuperStruc.		4107	303	99	0	87	-1784	2812
		551	8	41	0	5	0	605
		459	11	6	0	2	0	479
	Total:	5117	322	147	0	95	-1784	3896
6. Modular	Total	0	0	0	0	0	0	0
7. Refurb.	Total	0	0	0	0	0	0	0
Other	Total	0	0	0	0	0	0	0
Totals	Total	7130	406	552	0	559	-1527	7120



Project: Millennium Dome
 Sketch Title: Post Completion Embodied Carbon Assessment () - Summary

Project Number: 3798
 Sketch Number: 0

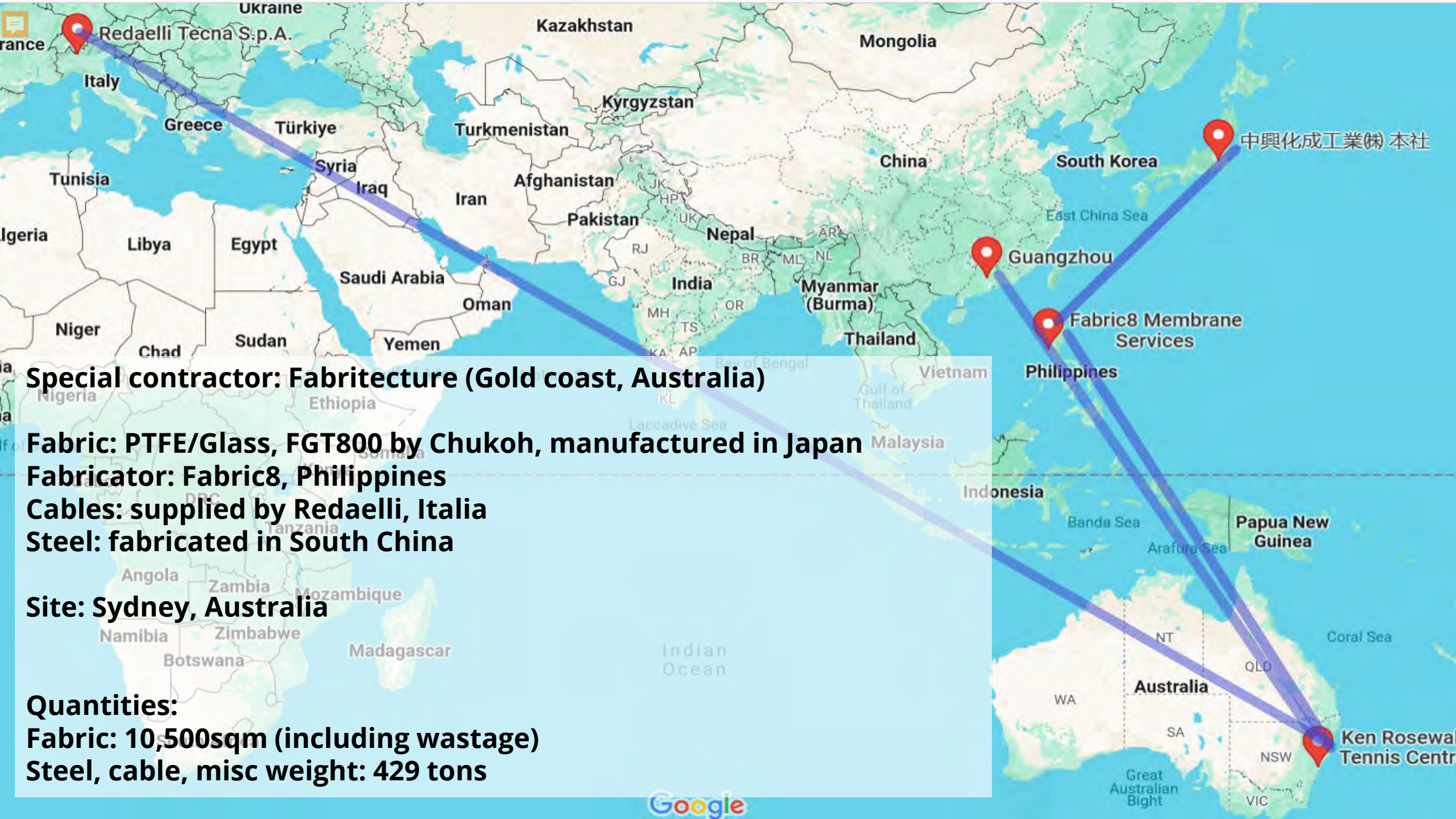
Status: FOR INFORMATION
 Date: 18/06/2021
 Initials: tfinlay
 Revision: 0





TRACKING & REPORTING CASE STUDY; Ken Rosewell Arena





Special contractor: Fabritecture (Gold coast, Australia)

Fabric: PTFE/Glass, FGT800 by Chukoh, manufactured in Japan

Fabricator: Fabric8, Philippines

Cables: supplied by Redaelli, Italia

Steel: fabricated in South China

Site: Sydney, Australia

Quantities:

Fabric: 10,500sqm (including wastage)

Steel, cable, misc weight: 429 tons

Material	Material Type	Material Specification	Structural Element	Description	Volume (m³) or Mass [kg]?	Material Quantity [m³, kg]	Reinforcement [kg/m²]	Element Embodied Carbon [tCO ₂ e]	A1-A3
Custom_EP	Other_EP	Serge Ferrari PVC	2.3 Roof	Membrane	Mass [kg]	12,300		50	49
Other	Aluminium	Extruded profile - European - 31% recycled content	2.1 Frame	Extrusion	Volume [m3]	1		15	14
Steel	Structural_sections	World avg	2.1 Frame	Compression rings & Arches	Mass [kg]	340,000		601	527
Steel	Hot Rolled Galvanised		2.3 Roof	Rods	Mass [kg]	52,700		150	145
Steel	PT_strands	Worldwide: world avg	2.1 Frame	Cables	Mass [kg]	35,219		81	70

A1 - A5: 889 tCO₂e 108 kgCO₂e/m²
 Sequestered carbon: 0 tCO₂e 0 kgCO₂e/m²
 A-C: 925 tCO₂e 112 kgCO₂e/m²

This project scheme releases carbon equivalent to:



1,046 one-way flights from London to New York



523 people's consumption of meat, dairy and beer for 1 year

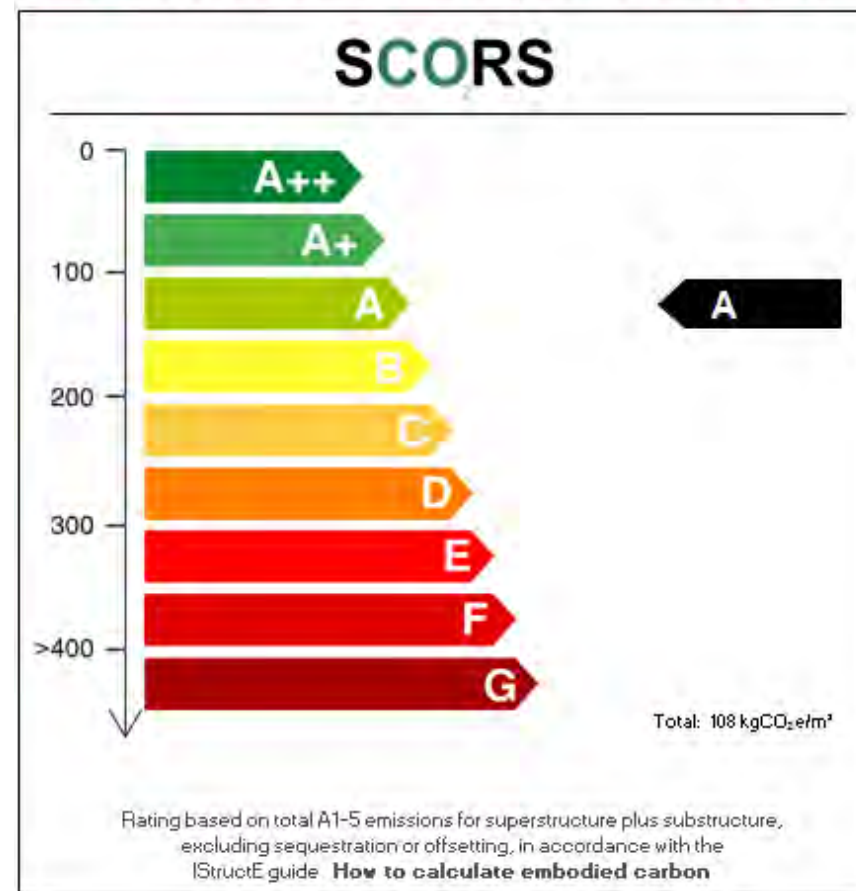


288 average family cars running for 1 year

Scheme performance against targets:

SCORS: 137 kgCO₂e/m² Scheme meets target
 RIBA: 156 kgCO₂e/m² Scheme meets target
 LETI: 0 kgCO₂e/m² Target N/A

This project scheme has a SCORS rating of A



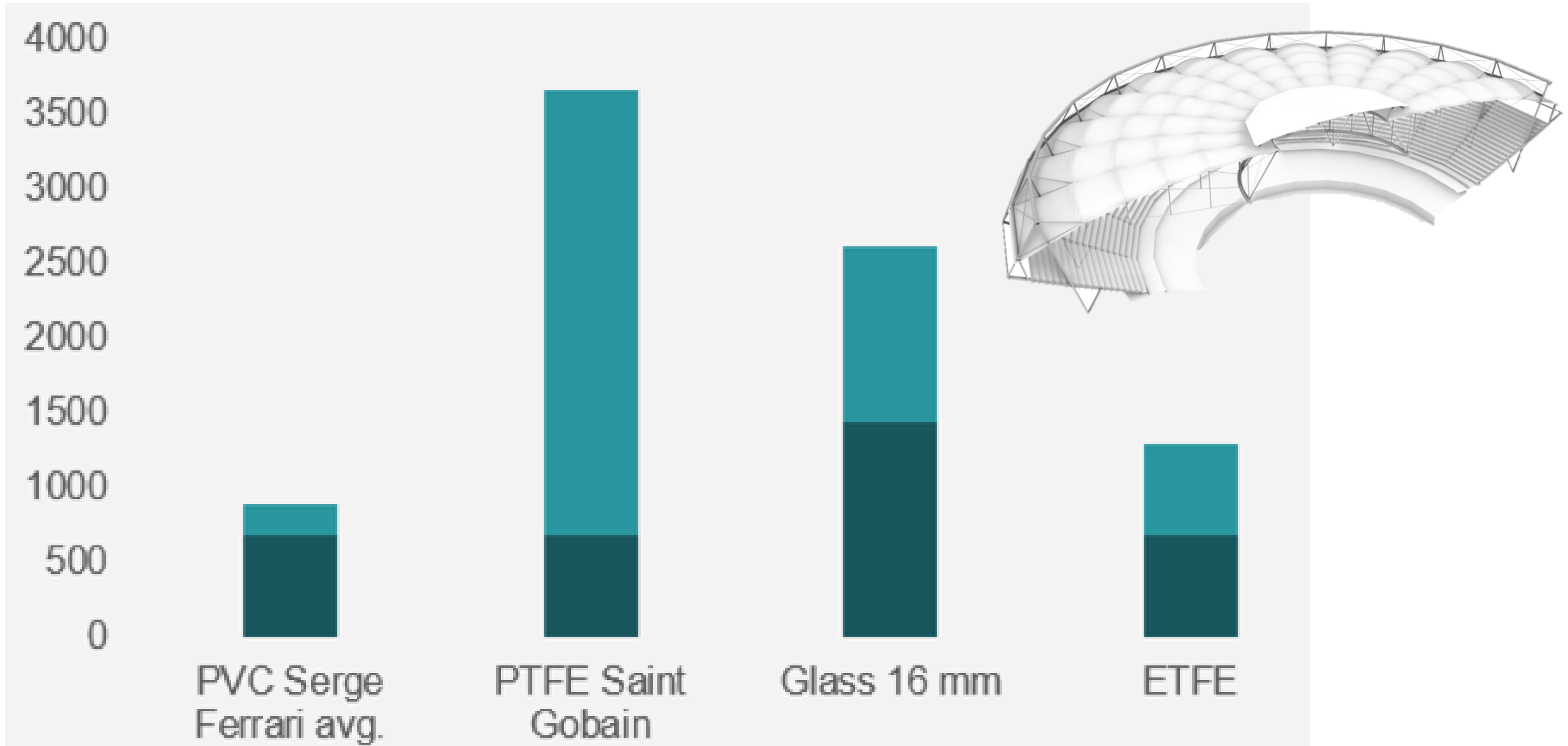


Scheme Rankings

Rank	Scheme	SCORS Rating & A1-A5 Emissions (kgCO ₂ e/m ²)
1st	PVC Serge Ferrari avg.	A (108)
2nd	ETFE	B (158)
3rd	Glass 16 mm	E (319)
4th	PTFE Saint Gobain	G (444)

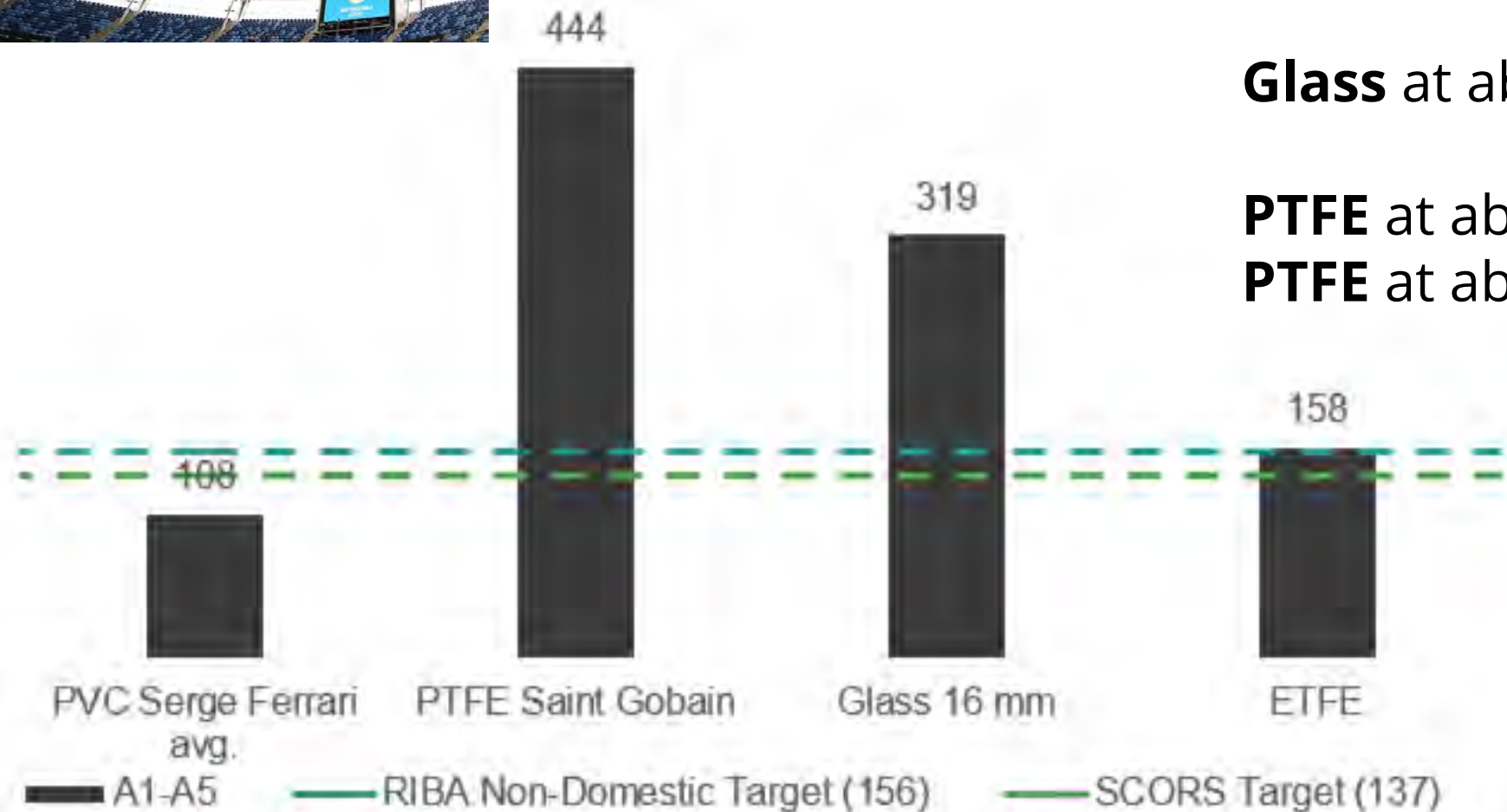
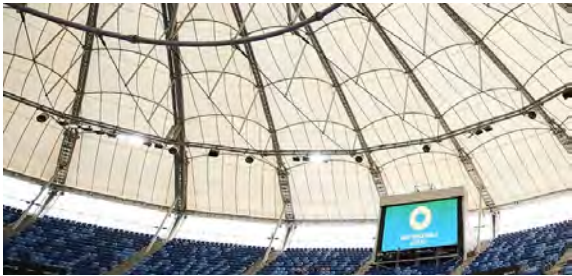
TRACKING & REPORTING CASE STUDY

ESTIMATED EMBODIED CARBON (tCO₂e) Module A1 - A5 by Elements



TRACKING & REPORTING CASE STUDY

Comparison to 2030 Targets (kgCO₂e/m²)



PVC at about 100 kgCO₂eq/m²

ETFE at about 150 kgCO₂eq/m²

Glass at about 300 kgCO₂eq/m²

PTFE at about 450 kgCO₂eq/m²?

PTFE at about 125 kgCO₂eq/m²?

THRESHOLD value of 12kgCO₂e/m²/yr

Carbon emission reductions introduced in Danish building code

DECARBONIZATION NEWS

Denmark leads the way with embodied carbon limits for buildings

From January 1st, 2023, all new buildings in Denmark applying for a building permit must document their environmental impact over 50 years lifespan through **Life Cycle Assessments (LCA)**. New buildings **above 1000 m²** must comply with the limit value of **12 kg CO₂ equivalent /m² /year**. Generic data or EPDs can be used for LCA calculations.

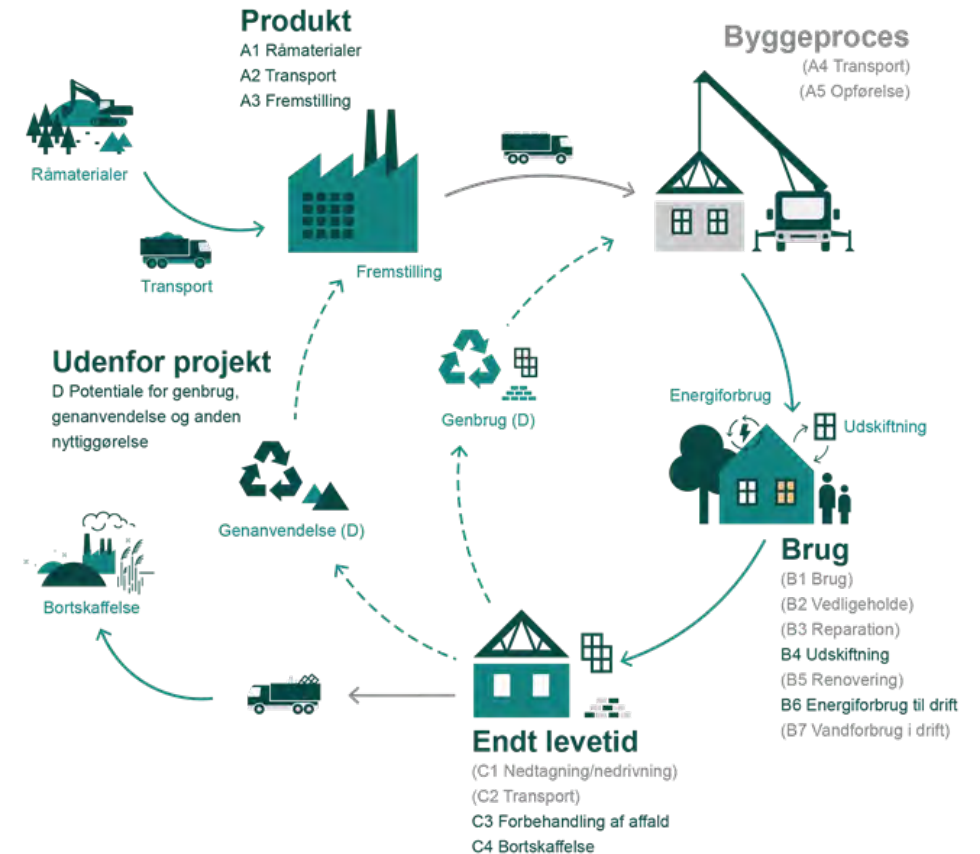


www.oneclicklca.com

$$12 \text{ kgCO}_2\text{eq/m}^2 \times 50 \text{ years} = 600 \text{ kgCO}_2\text{eq/m}^2$$

$$50\% \text{ Embodied Carbon} = 300 \text{ kgCO}_2\text{eq/m}^2 \text{ (other 50\% Operational)}$$

$$50\% \text{ Structure + Substructure} = 150 \text{ kgCO}_2\text{eq/m}^2 \text{ (other 50\% finishes, misc.)}$$



DECLARATION(S)

Implementation

Embodied Carbon
Action Plan
Share Data
Reduction
Strategies
Advocacy

Built
Environment
Declares
Climate and
Biodiversity
Emergency

Australia
Belgium
Canada
Chile
Czech Republic
Denmark
Finland
France
Germany
Hungary
Iceland
Ireland
Italy
Kenya
Latvia
New Zealand
Norway
Poland
Portugal
Singapore
Slovenia
South Africa
Spain
Sweden
Switzerland
Taiwan
United Kingdom
United States

Germany
Architects

United Kingdom
Architects
Building Service
Engineers
Civil Engineers
Contractors
Interior Design
Landscape
Architects
Project Managers
Structural Engineers
Students

#BuiltEnvironmentDeclares

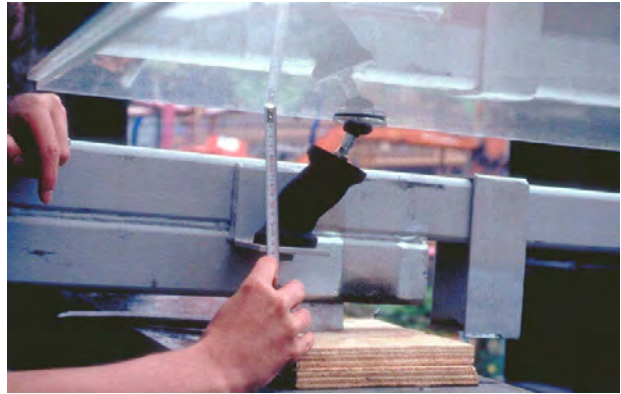
BUILT ENVIRONMENT DECLARES is a global petition uniting all strands of construction and the built environment. It is both a public declaration of our planet's environmental crises and a commitment to take positive action in response to climate breakdown and biodiversity collapse.

Sony Center Forum Roof

materials, specifications, thermal, wind, construction

materials & structures

collaborate to innovate



Bruce Danziger | structural engineer | 24-september-2015



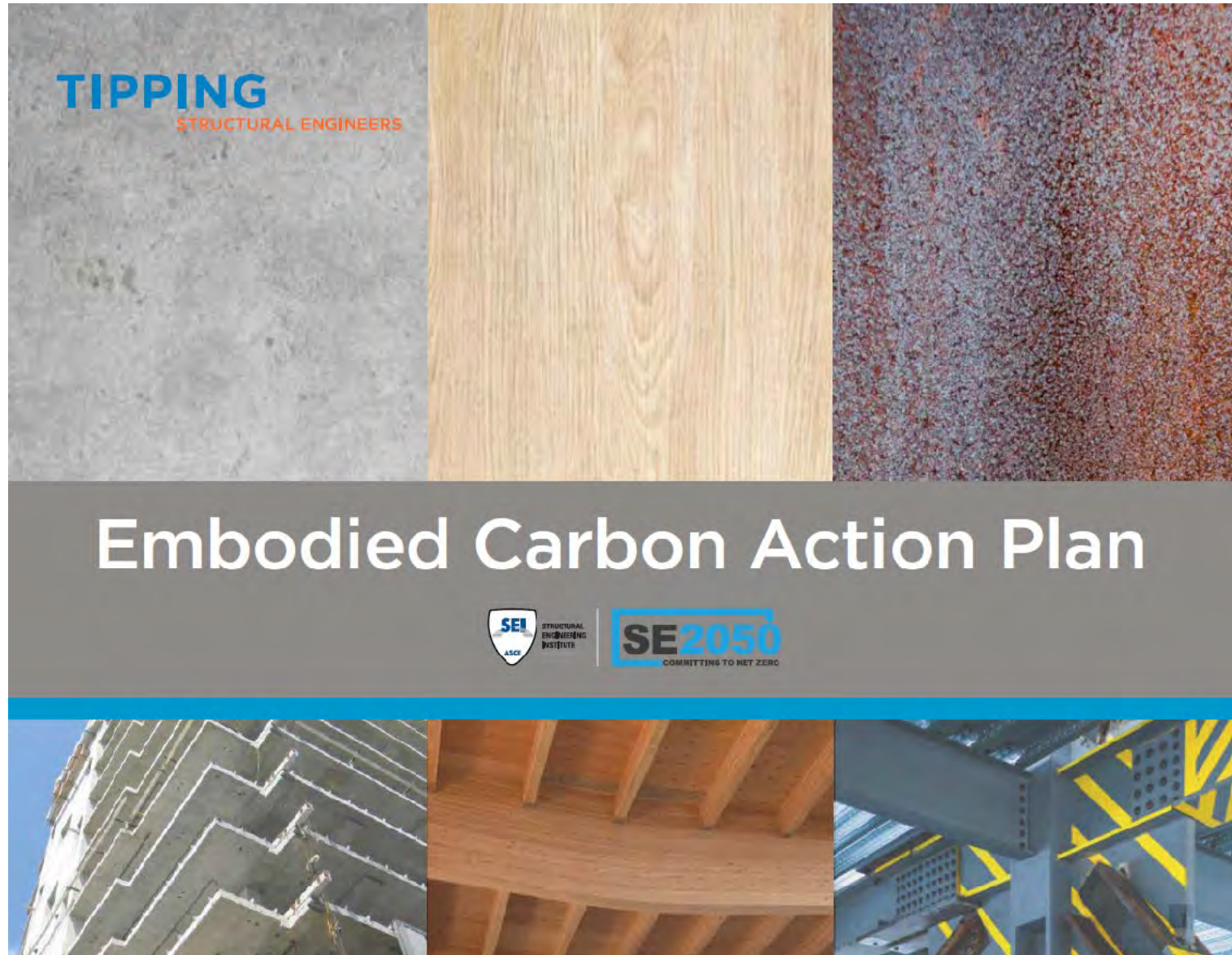


Our Mission

To accelerate progress towards net zero carbon bridges by sharing knowledge and ideas, and shaping best practice.

EMBODIED CARBON ACTION PLAN

ECAP



1. Education

2. Tracking & Reporting

3. Reduction Strategies

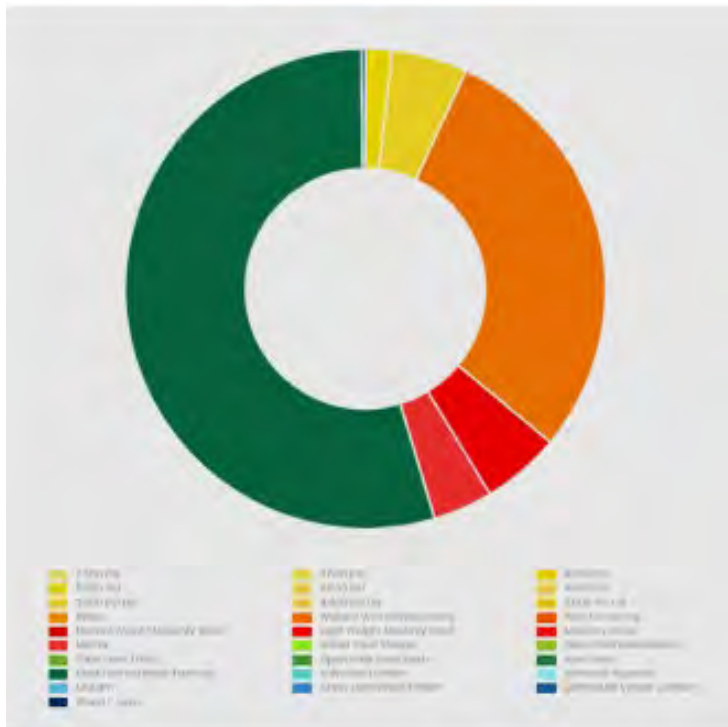
4. Advocacy

5. Implement



REDUCTION STRATEGIES

EMBODIED CARBON INTENSITY: By Primary Building Use Type



ECOM – Embodied Carbon Estimator

Form an internal Team

Collect Data

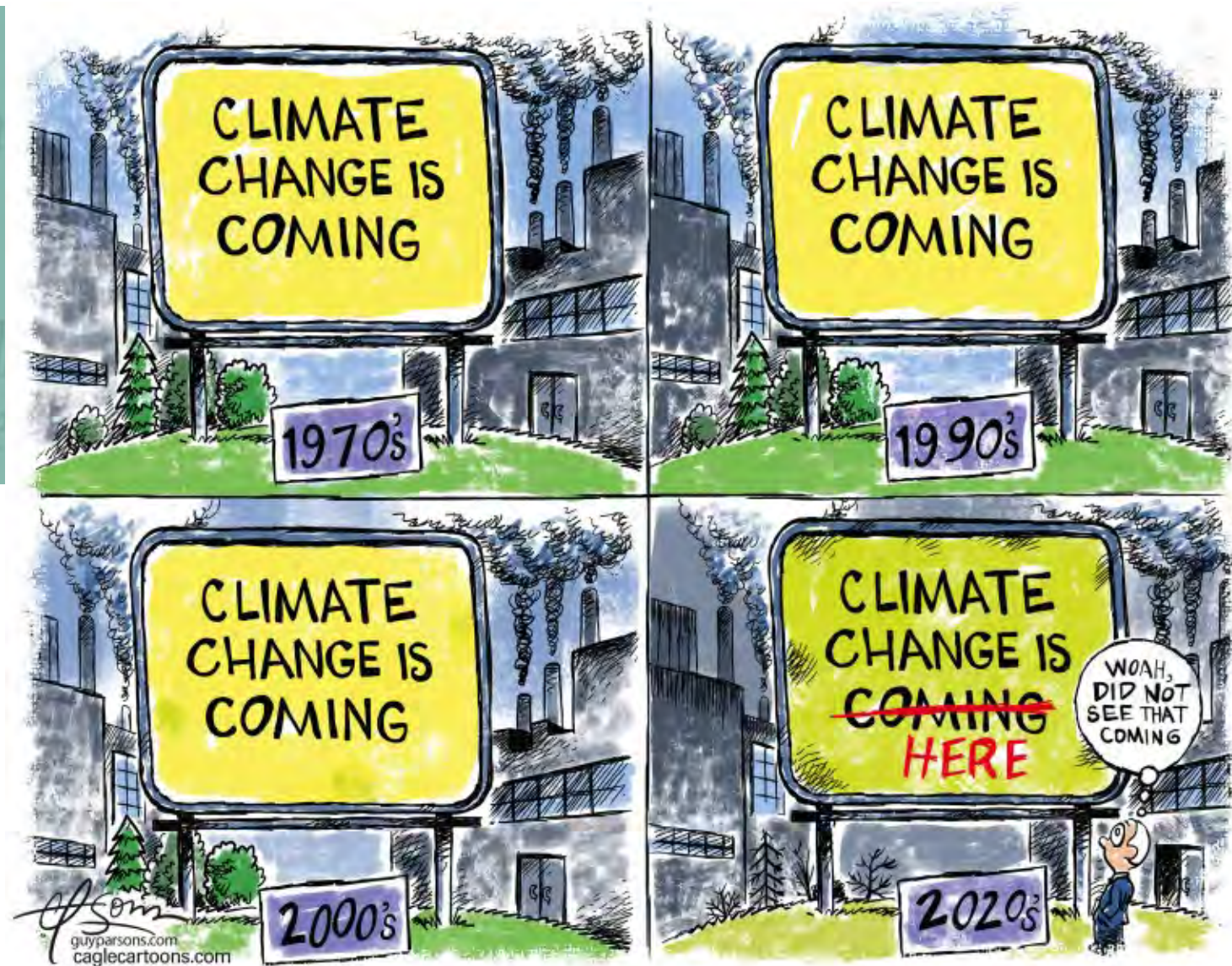
Investigate Carbon Accounting Tools

Establish Baselines

Set Reduction Targets

VOW, PLEDGE, DECLARE, COMMIT, PLAN & THEN IMPLEMENT (Entregable)

Planning to Plan: Green Washing, Green Wishing

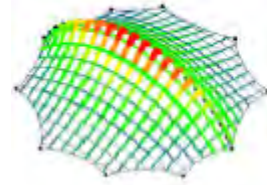




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Mail@LightweightFootprint.org

Thank You



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SUSTAINABLE DEVELOPMENT GOALS

