UNIVERSITY OF CAMBRIDGE

LAING O'ROURKE CENTRE *for* CONSTRUCTION ENGINEERING *and* TECHNOLOGY

TRANSFORMING CONSTRUCTION

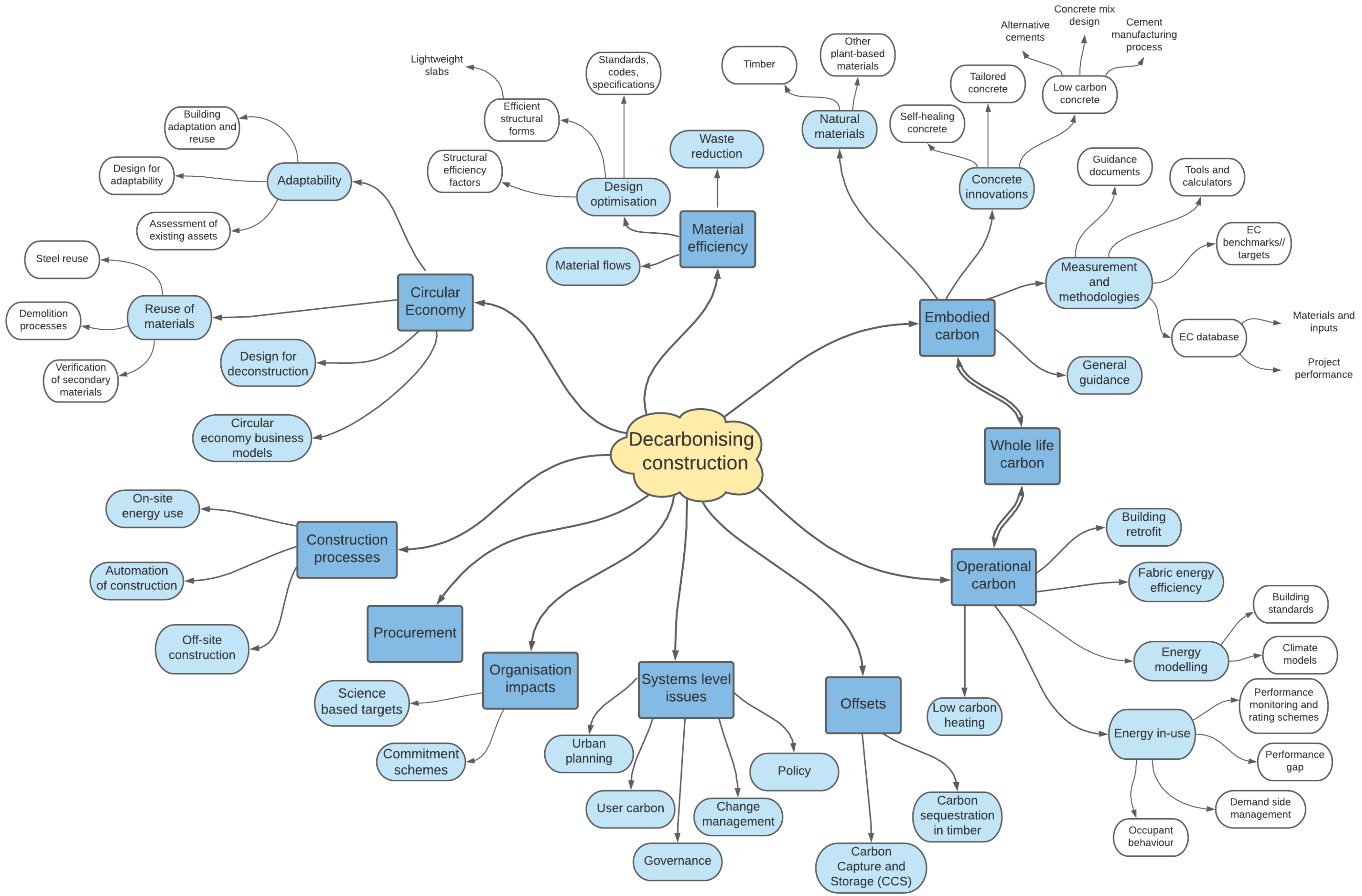
Landscape map of carbon in construction

Tercia Jansen van Vuuren

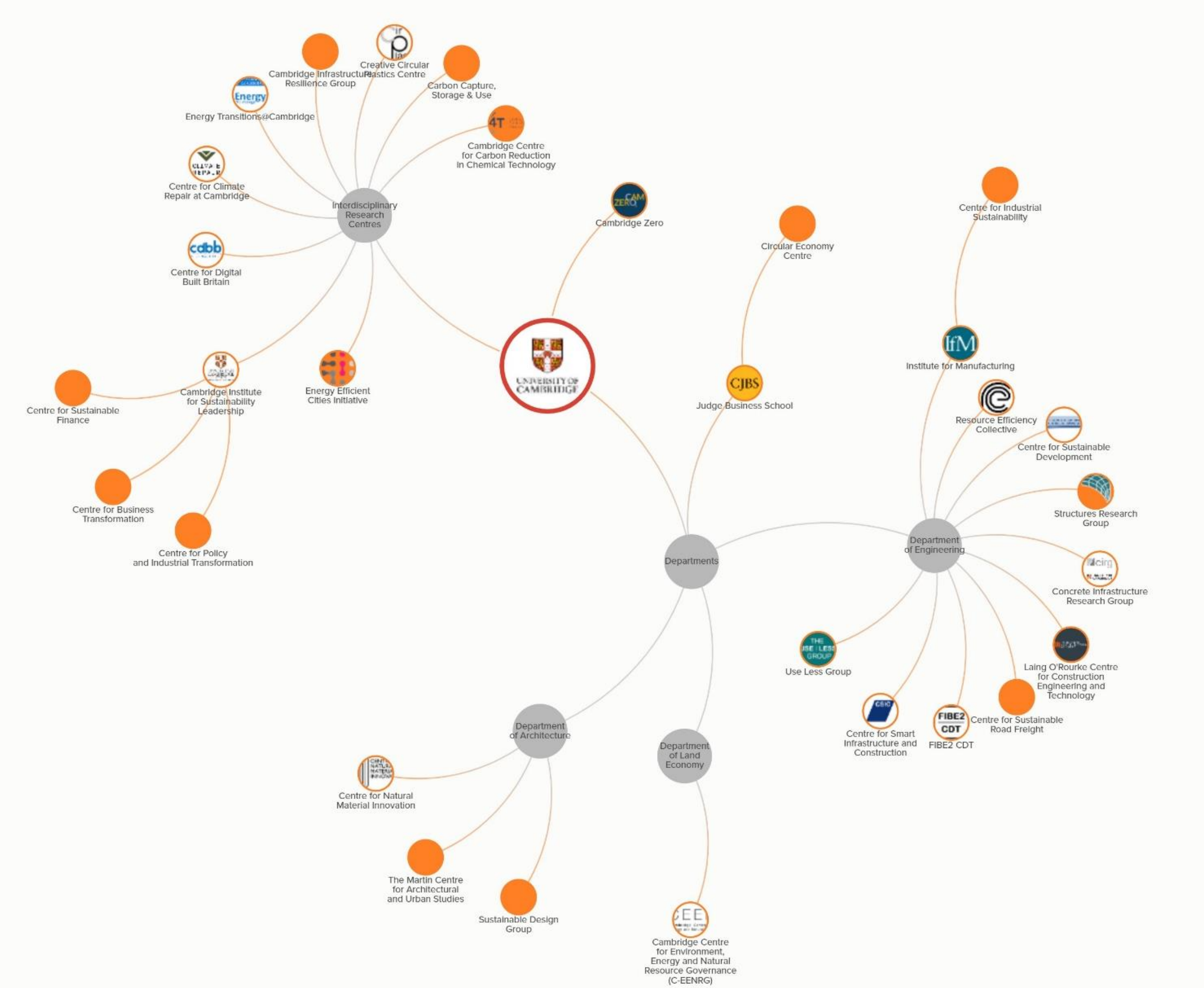
19 Oct 2021

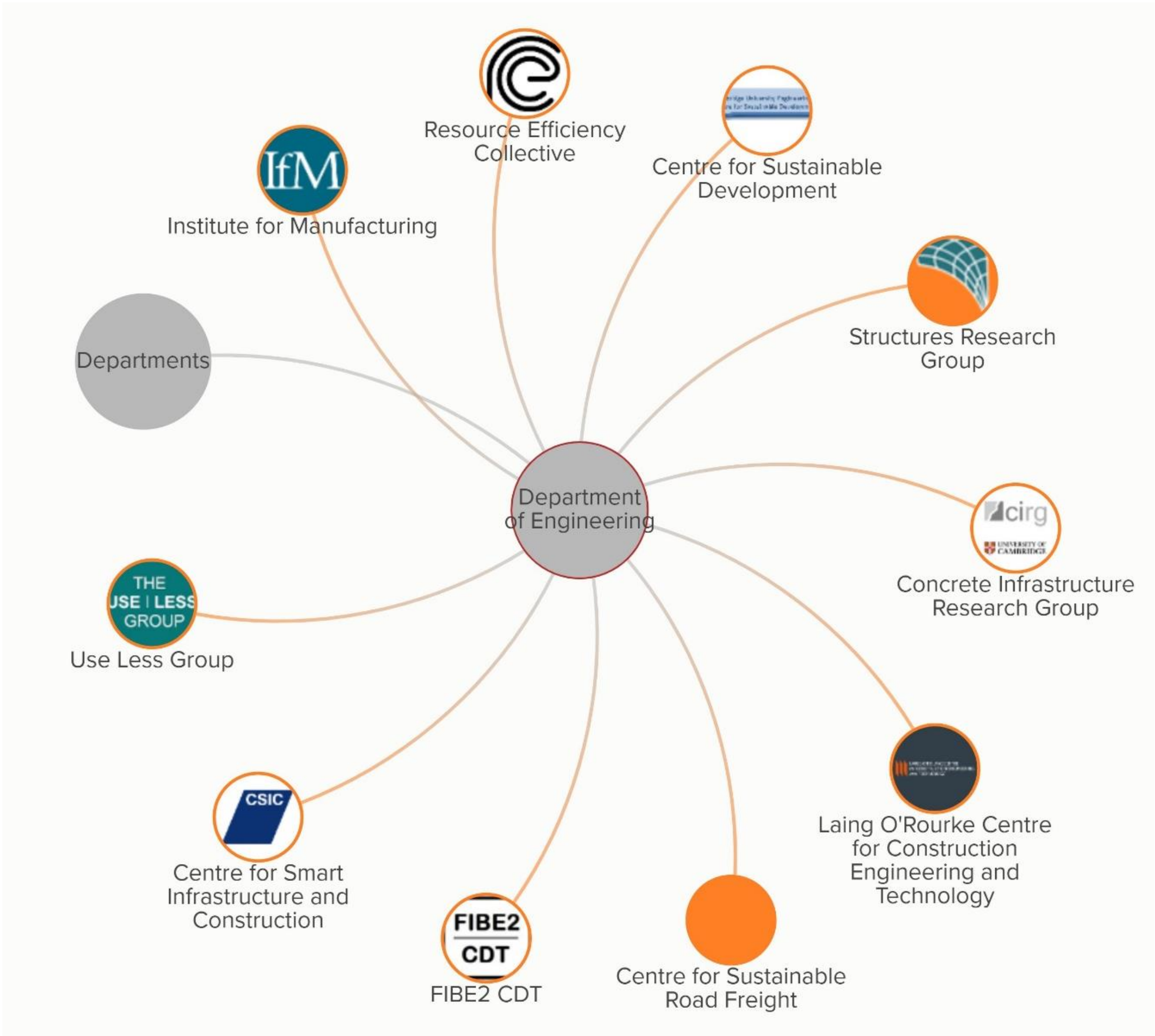
- Themes within decarbonisation
- Research at University of Cambridge
- Wider industry landscape
- Focus on infrastructure initiatives
- Net zero carbon and bridges

Understanding themes in decarbonising construction



Overview of research at University of Cambridge


Cambridge Infrastructure Resilience Group
Creative Circular Plastics Centre
Carbon Capture, Storage & Use
Energy Transitions@Cambridge
Cambridge Centre for Carbon Reduction in Chemical Technology
Centre for Climate Repair at Cambridge
Interdisciplinary Research Centres
Cambridge Zero
Centre for Industrial Sustainability
Circular Economy Centre
Centre for Digital Built Britain
Institute for Manufacturing
Judge Business School
Centre for Sustainable Finance
Cambridge Institute for Sustainability Leadership
Energy Efficient Cities Initiative
Resource Efficiency Collective
Centre for Sustainable Development
Centre for Business Transformation
Structures Research Group
Centre for Policy and Industrial Transformation
Departments
Department of Engineering
Concrete Infrastructure Research Group
Use Less Group
Laing O'Rourke Centre for Construction Engineering and Technology
Centre for Sustainable Road Freight
Centre for Smart Infrastructure and Construction
FIBE2 CDT
Department of Architecture
Department of Land Economy
Centre for Natural Material Innovation
The Martin Centre for Architectural and Urban Studies
Sustainable Design Group
Cambridge Centre for Environment, Energy and Natural Resource Governance (C-EENRG)


Resource Efficiency Collective
Centre for Sustainable Development
Institute for Manufacturing
Structures Research Group
Departments
Department of Engineering
Concrete Infrastructure Research Group
Use Less Group
Laing O'Rourke Centre for Construction Engineering and Technology
Centre for Smart Infrastructure and Construction
FIBE2 CDT
Centre for Sustainable Road Freight

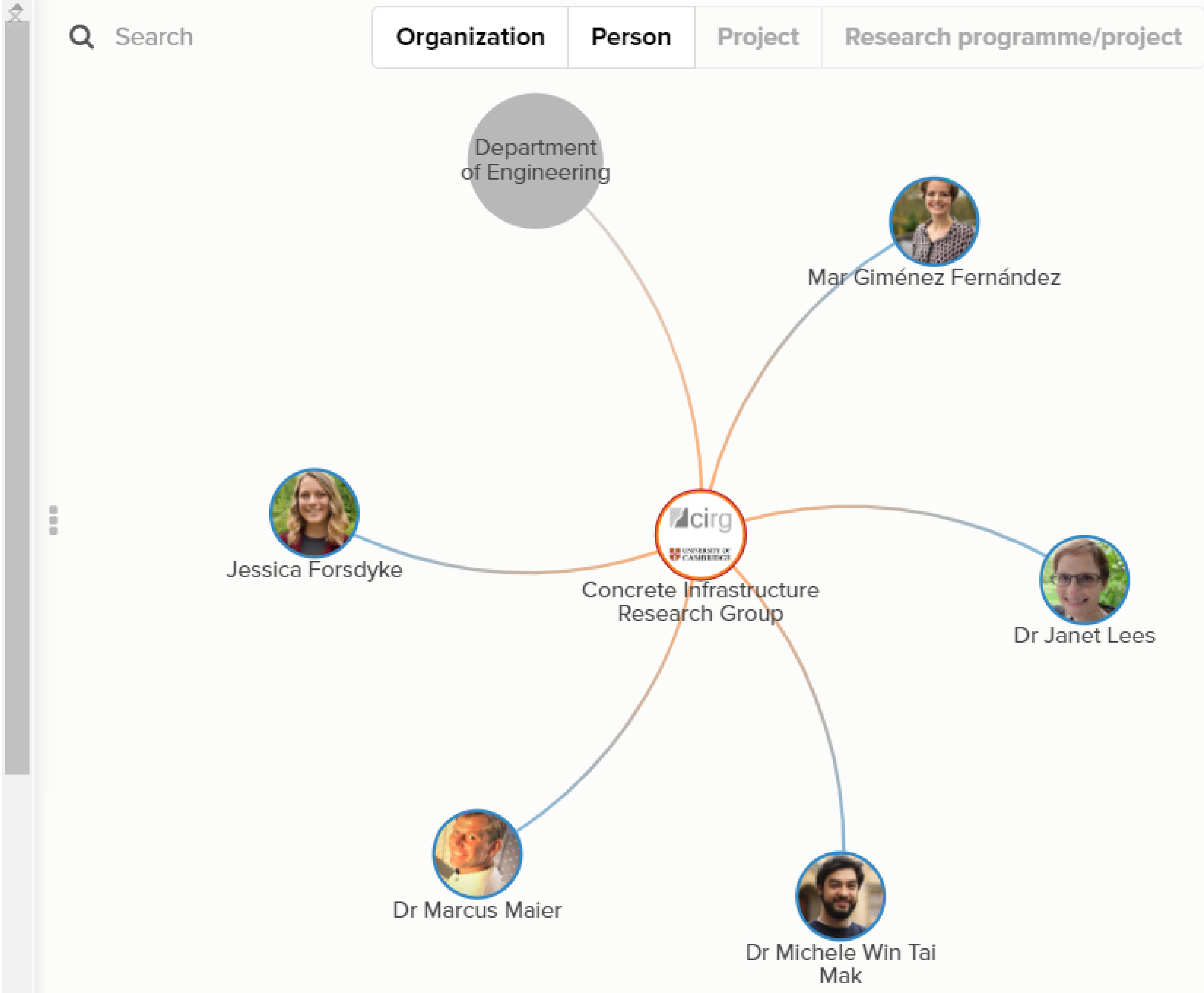
Concrete Infrastructure Research Group

ORGANIZATION

The overarching aim of CIRG research is to provide more sustainable infrastructure. This is achieved through an improved understanding of existing infrastructure assets, the use of new materials and the creation of innovative structural solutions (such as using tailored, or functionally graded, concrete so that high performance concrete is only used where it contributes signficantly to structural performance). Our priority is to investigate novel ways to combine these systems for further advantage.

CIRG Research Map

Tailored concrete | Assessment of existing assets | Infrastructure

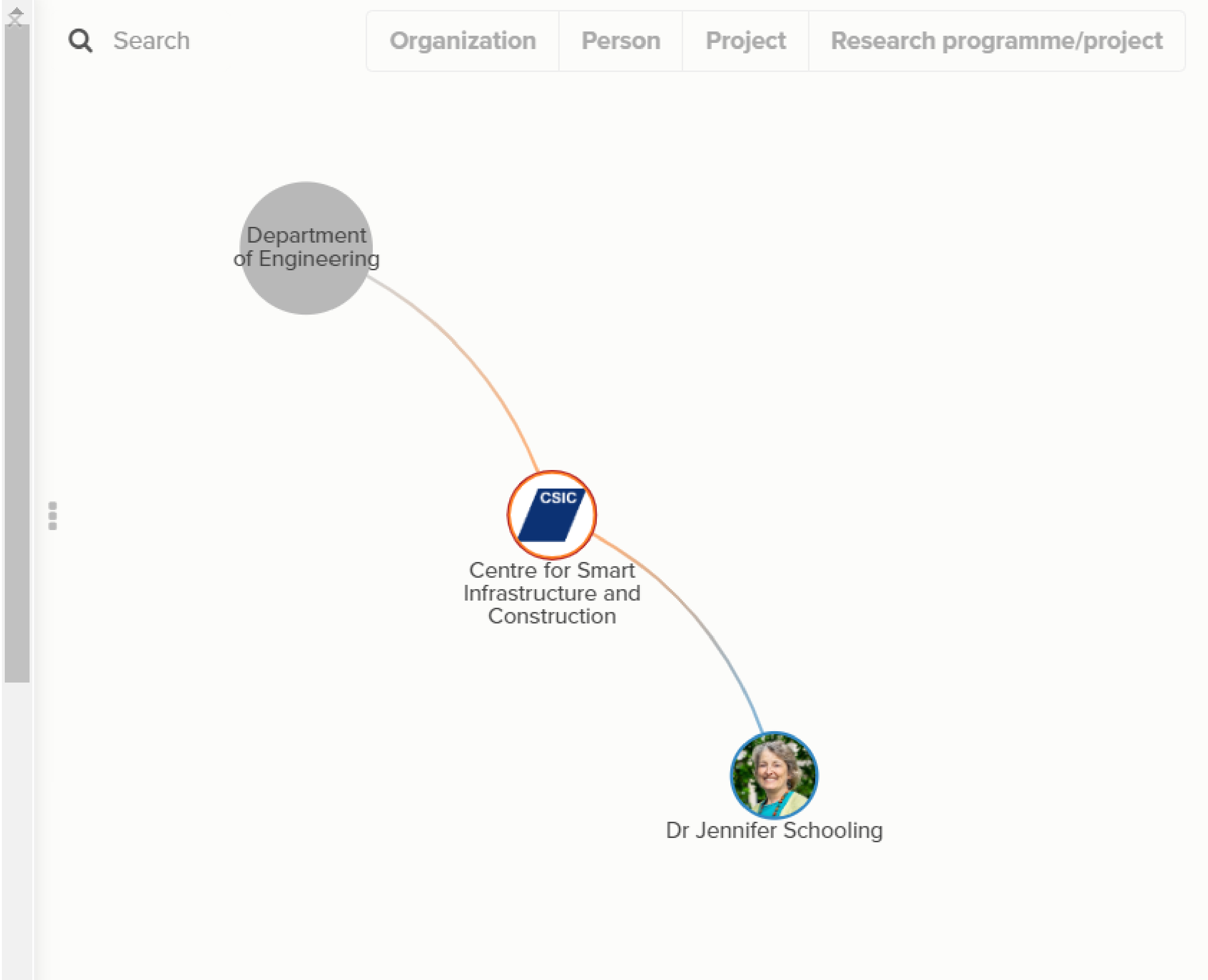


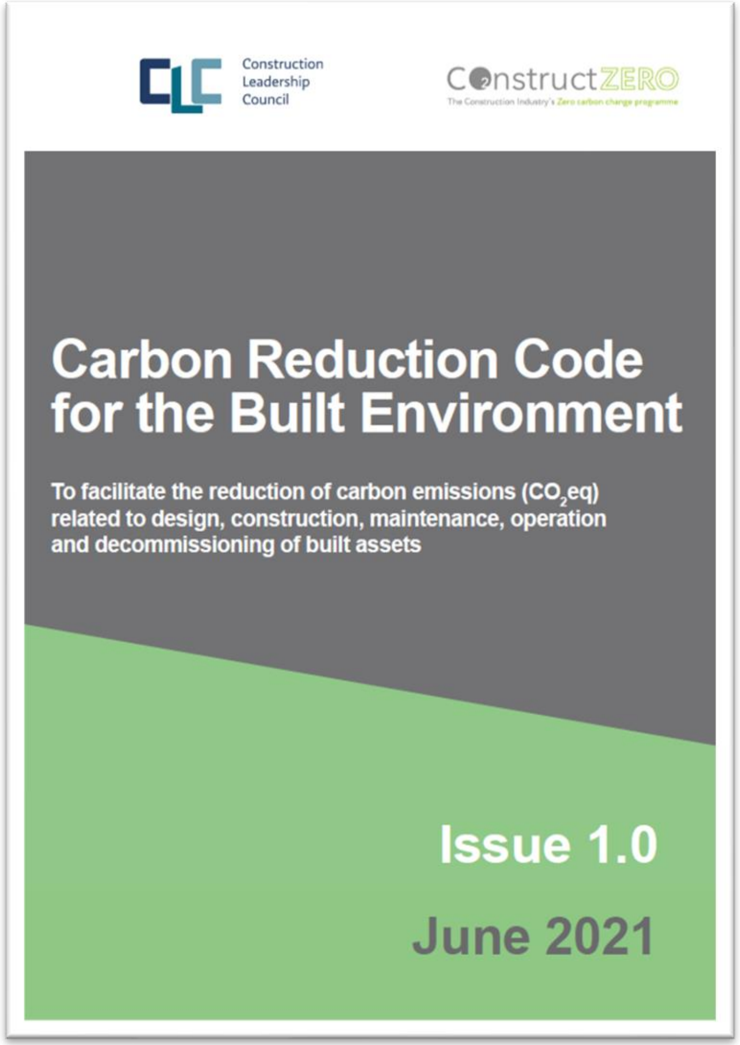
Centre for Smart Infrastructure and Construction

ORGANIZATION

CSIC is a world-leading centre in the development of smart infrastructure and data-driven solutions to enable smarter whole-life asset management decisions, for both new infrastructure and existing assets. CSIC collaborates with partner organisations across policy, standards and industry adoption to effect transformative change.

CSIC works at a number of strategic levels to influence and inform changes required to secure greater efficiency in the design, construction and operation of our infrastructure, providing leadership in exploiting data from monitoring real infrastructure performance to reduce carbon, increase resilience and preserve resources.




Construction Leadership Council

ConstructZERO

The Construction Industry's Zero carbon change programme

Carbon Reduction Code for the Built Environment

To facilitate the reduction of carbon emissions (CO_2eq) related to design, construction, maintenance, operation and decommissioning of built assets

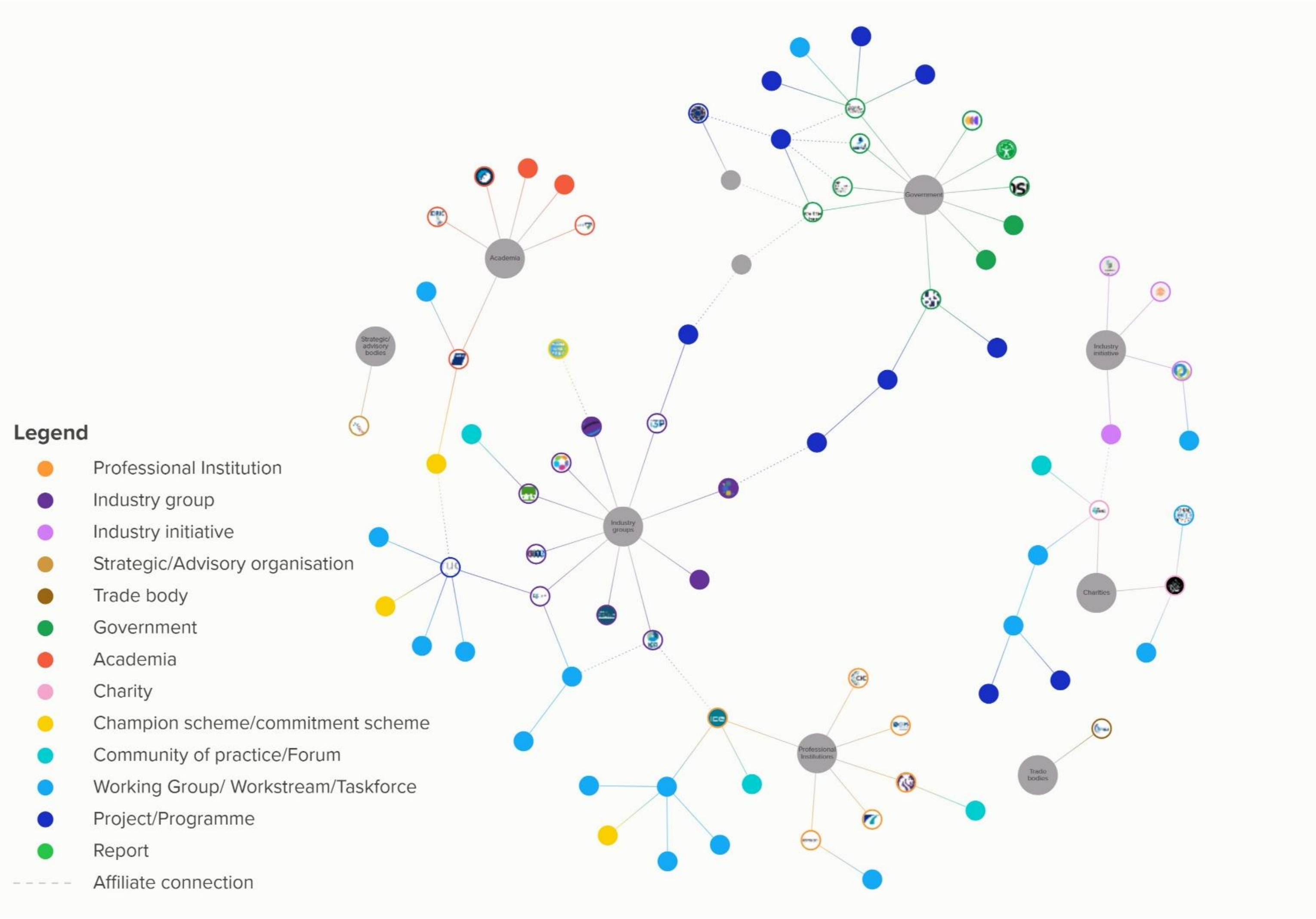
Issue 1.0

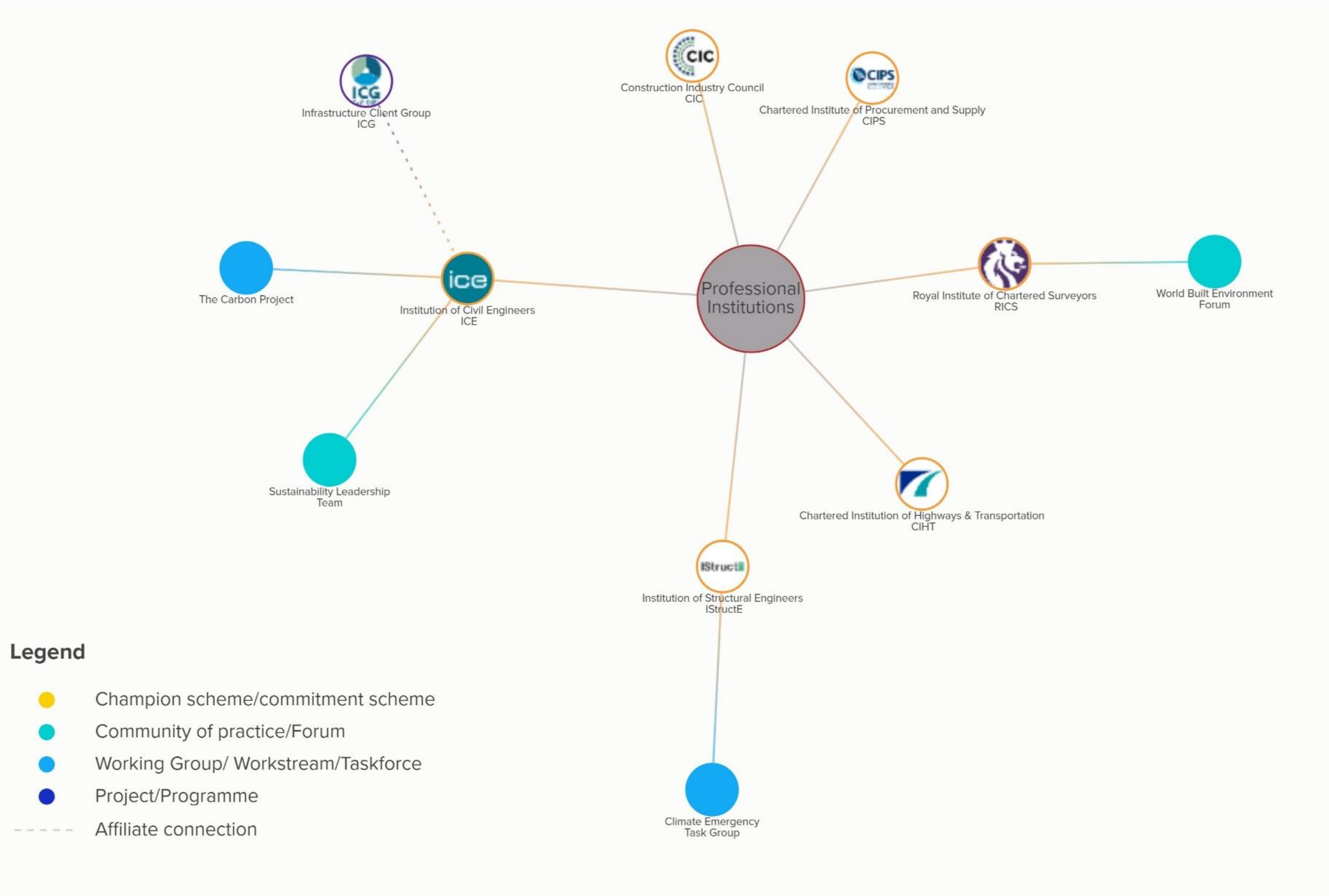
June 2021

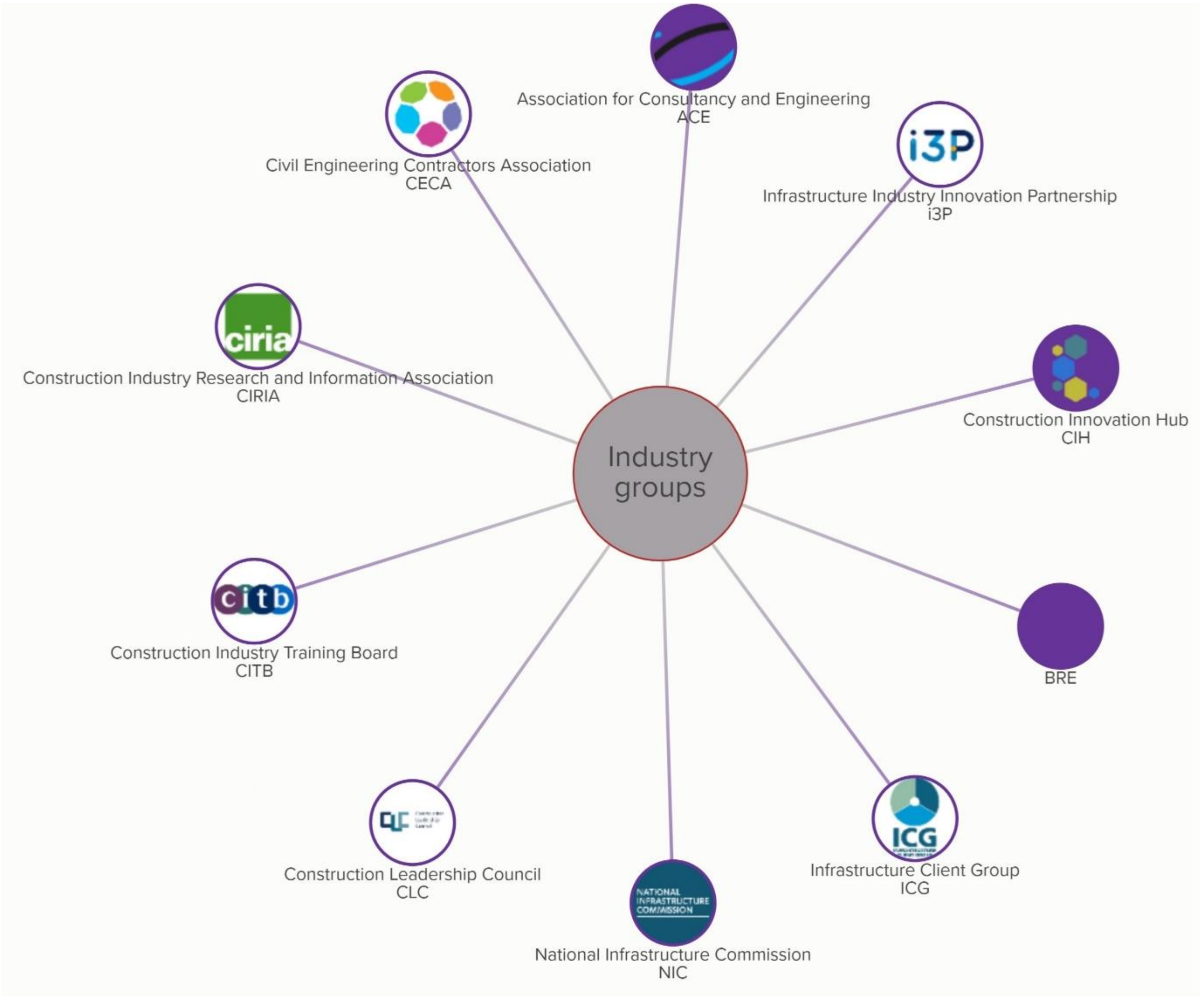
- Framework for organisations to make a public commitment to and report on progress to achieving net zero
- Aim for 75% reduction by 2030
- Commitments around procurement, data & reporting, skills, design philosophy, and knowledge sharing

[Link to Carbon Reduction Code]

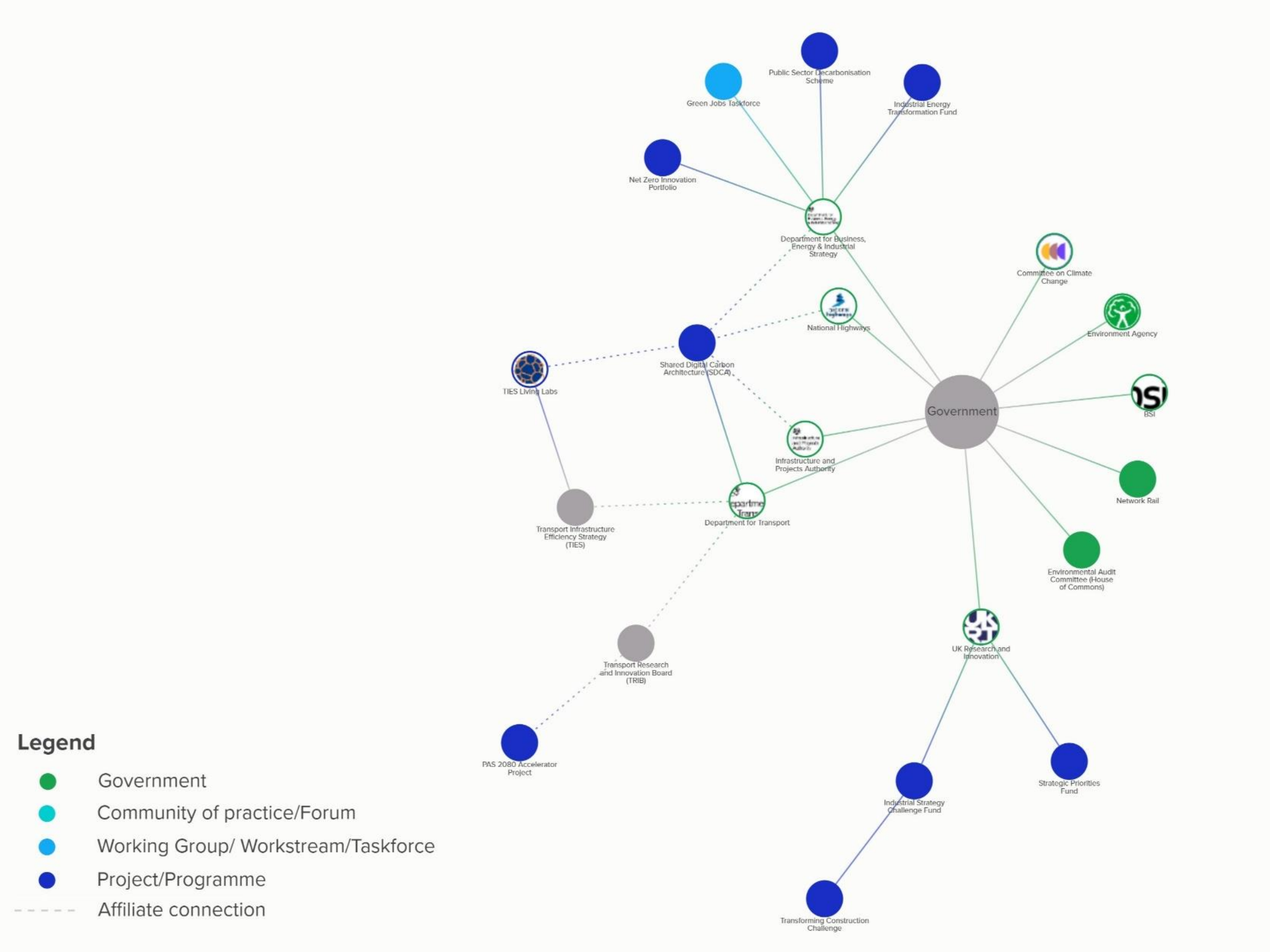
Decarbonising construction – industry landscape

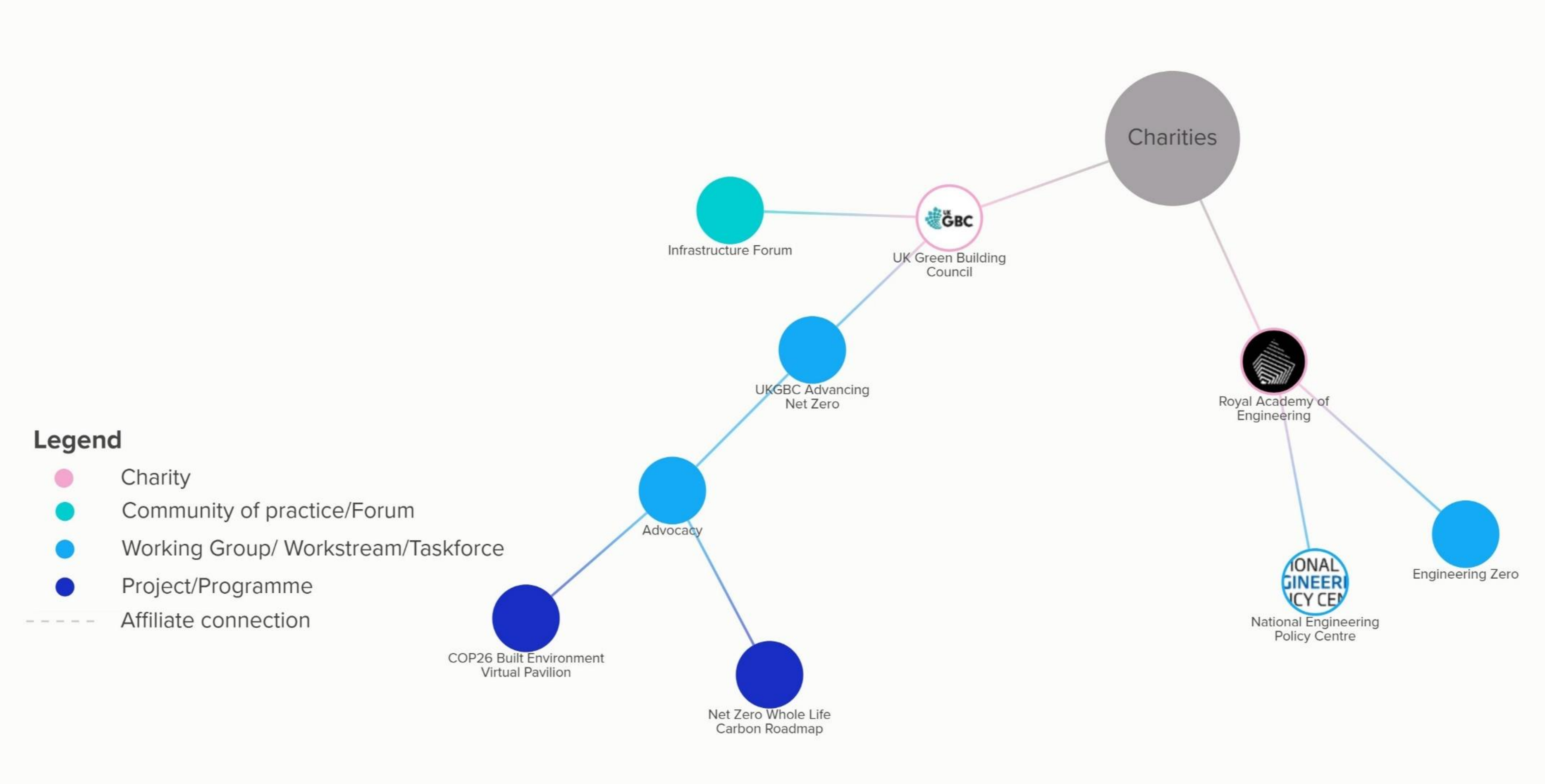

Legend
Professional Institution
Industry group
Industry initiative
Strategic/Advisory organisation
Trade body
Government
Academia
Charity
Champion scheme/commitment scheme
Community of practice/Forum
Working Group/ Workstream/Taskforce
Project/Programme
Report
Affiliate connection


Infrastructure Client Group
ICG
Construction Industry Council
CIC
Chartered Institute of Procurement and Supply
CIPS
The Carbon Project
Institution of Civil Engineers
ICE
Professional Institutions
Royal Institute of Chartered Surveyors
RICS
World Built Environment Forum
Sustainability Leadership Team
Chartered Institution of Highways & Transportation
CIHT
Institution of Structural Engineers
IStructE
Climate Emergency Task Group
Legend
Champion scheme/commitment scheme
Community of practice/Forum
Working Group/ Workstream/Taskforce
Project/Programme
Affiliate connection


Industry groups
Association for Consultancy and Engineering
ACE
Civil Engineering Contractors Association
CECA
Infrastructure Industry Innovation Partnership
i3P
Construction Industry Research and Information Association
CIRIA
Construction Innovation Hub
CIH
Construction Industry Training Board
CITB
BRE
Construction Leadership Council
CLC
National Infrastructure Commission
NIC
Infrastructure Client Group
ICG


Government
Department for Business, Energy & Industrial Strategy
Committee on Climate Change
Environment Agency
National Highways
BSI
Infrastructure and Projects Authority
Department for Transport
Network Rail
UK Research and Innovation
Environmental Audit Committee (House of Commons)


Public Sector Decarbonisation Scheme
Green Jobs Taskforce
Industrial Energy Transformation Fund
Net Zero Innovation Portfolio
Department for Business, Energy & Industrial Strategy
Committee on Climate Change
National Highways
Environment Agency
TIES Living Labs
Shared Digital Carbon Architecture (SDCA)
Government
BSI
Infrastructure and Projects Authority
Network Rail
Transport Infrastructure Efficiency Strategy (TIES)
Department for Transport
Environmental Audit Committee (House of Commons)
UK Research and Innovation
Transport Research and Innovation Board (TRIB)
PAS 2080 Accelerator Project
Strategic Priorities Fund
Industrial Strategy Challenge Fund
Transforming Construction Challenge
Legend
Government
Community of practice/Forum
Working Group/ Workstream/Taskforce
Project/Programme
Affiliate connection


Charities
Infrastructure Forum
UK Green Building Council
UKGBC Advancing Net Zero
Advocacy
COP26 Built Environment Virtual Pavilion
Net Zero Whole Life Carbon Roadmap
Royal Academy of Engineering
National Engineering Policy Centre
Engineering Zero
Legend
Charity
Community of practice/Forum
Working Group/ Workstream/Taskforce
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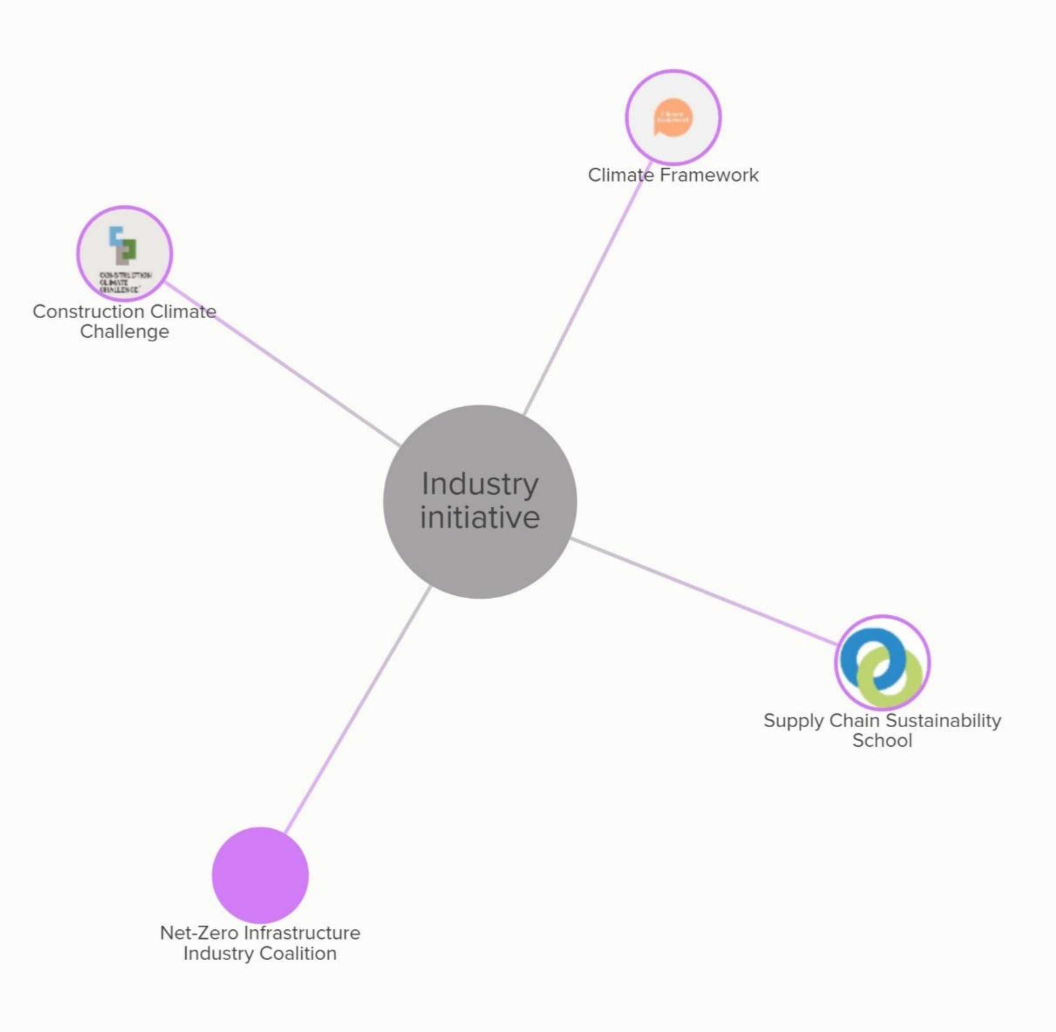
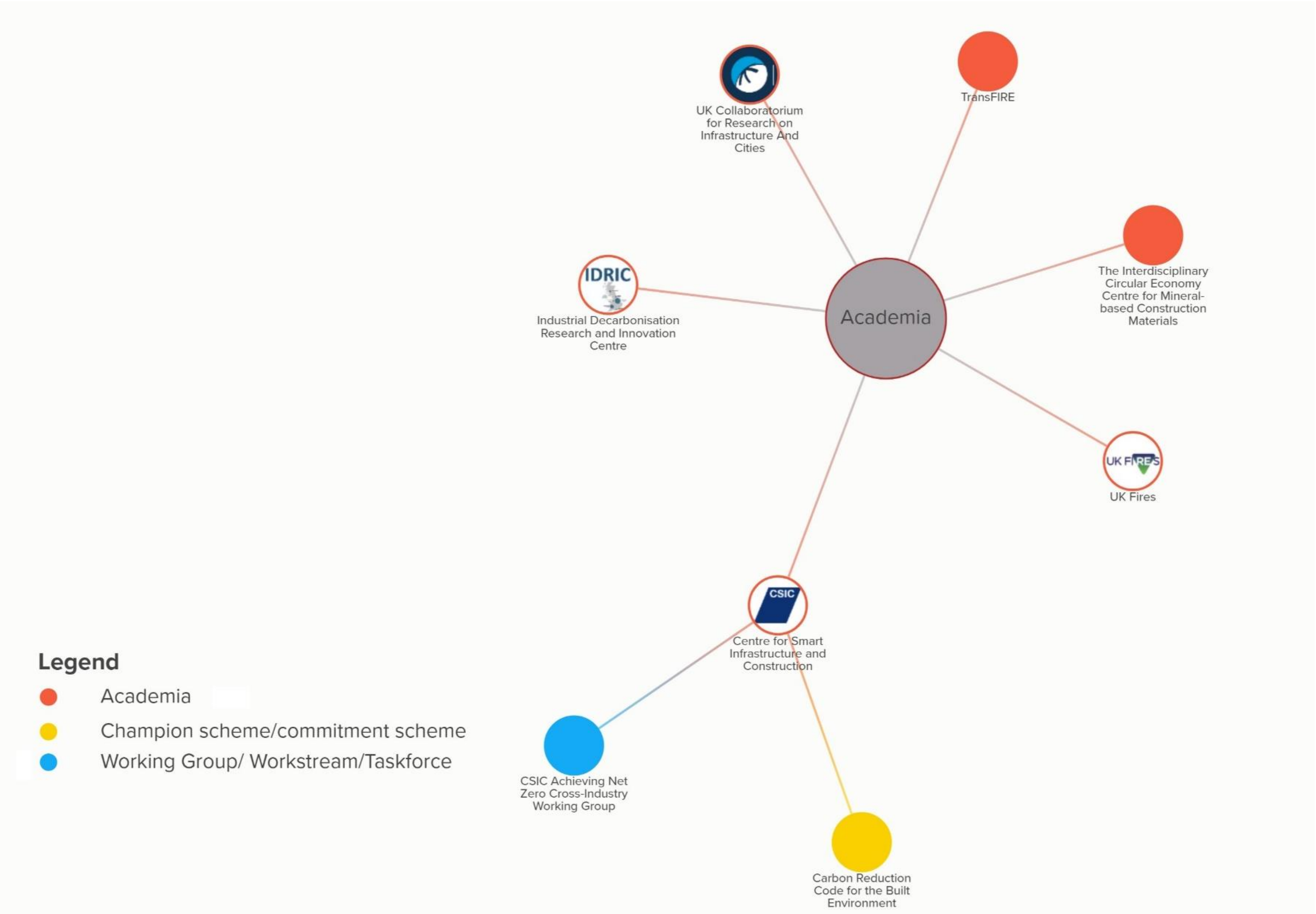
Affiliate connection

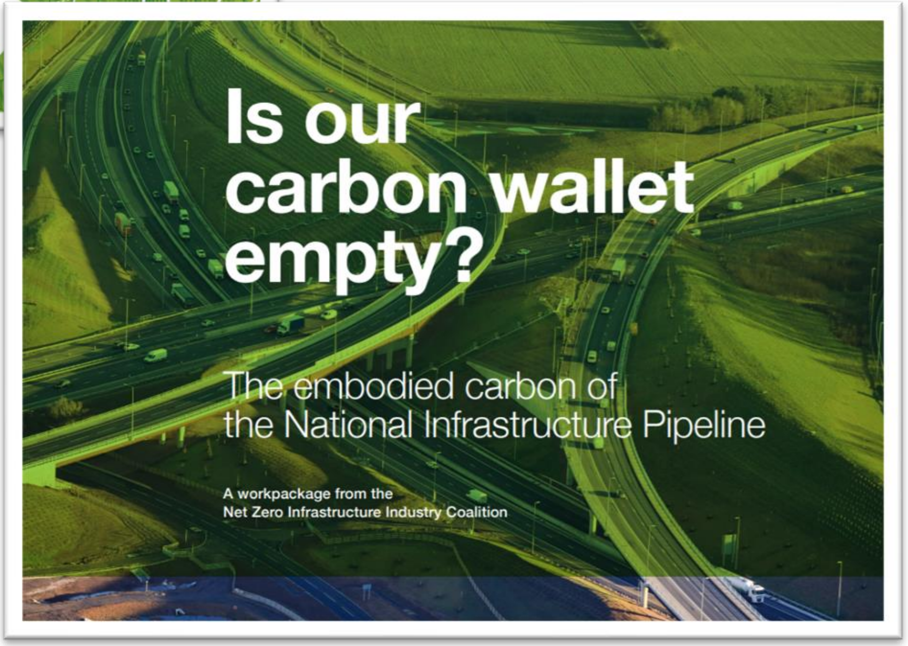

Climate Framework
Construction Climate Challenge
Industry initiative
Supply Chain Sustainability School
Net-Zero Infrastructure Industry Coalition


UK Collaboratorium for Research on Infrastructure And Cities
TransFIRE
IDRIC
Industrial Decarbonisation Research and Innovation Centre
Academia
The Interdisciplinary Circular Economy Centre for Mineral-based Construction Materials
UK FIRES
UK Fires
CSIC
Centre for Smart Infrastructure and Construction
CSIC Achieving Net Zero Cross-Industry Working Group
Carbon Reduction Code for the Built Environment
Legend
Academia
Champion scheme/commitment scheme
Working Group/ Workstream/Taskforce

Mar 2021

Click here for report

Apr 2021



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Apr 2021

Click here for report

Sept 2021

Click here for report

ice Institution of Civil Engineers

ICE
Rachel Skinner
(ICE President 2020/2021)

Annual report

State of the Nation 2020:
Infrastructure and the 2050 net-zero target

State of the Nation 2021:
Six ways for civil engineers to act on climate change

Oct 2021
Click here for report

The Carbon Project: Towards Net Zero Infrastructure

Work Streams

Measuring, Sharing and Benchmarking of Carbon Impacts
Chair: Kat Ibbotson (Environment Agency)

Capability Building in Low Carbon Design and Delivery
Chair: Steve Denton (WSP)

Identifying Systems-Level Reduction in In-Use Carbon
Chair: Tim Chapman (Arup)

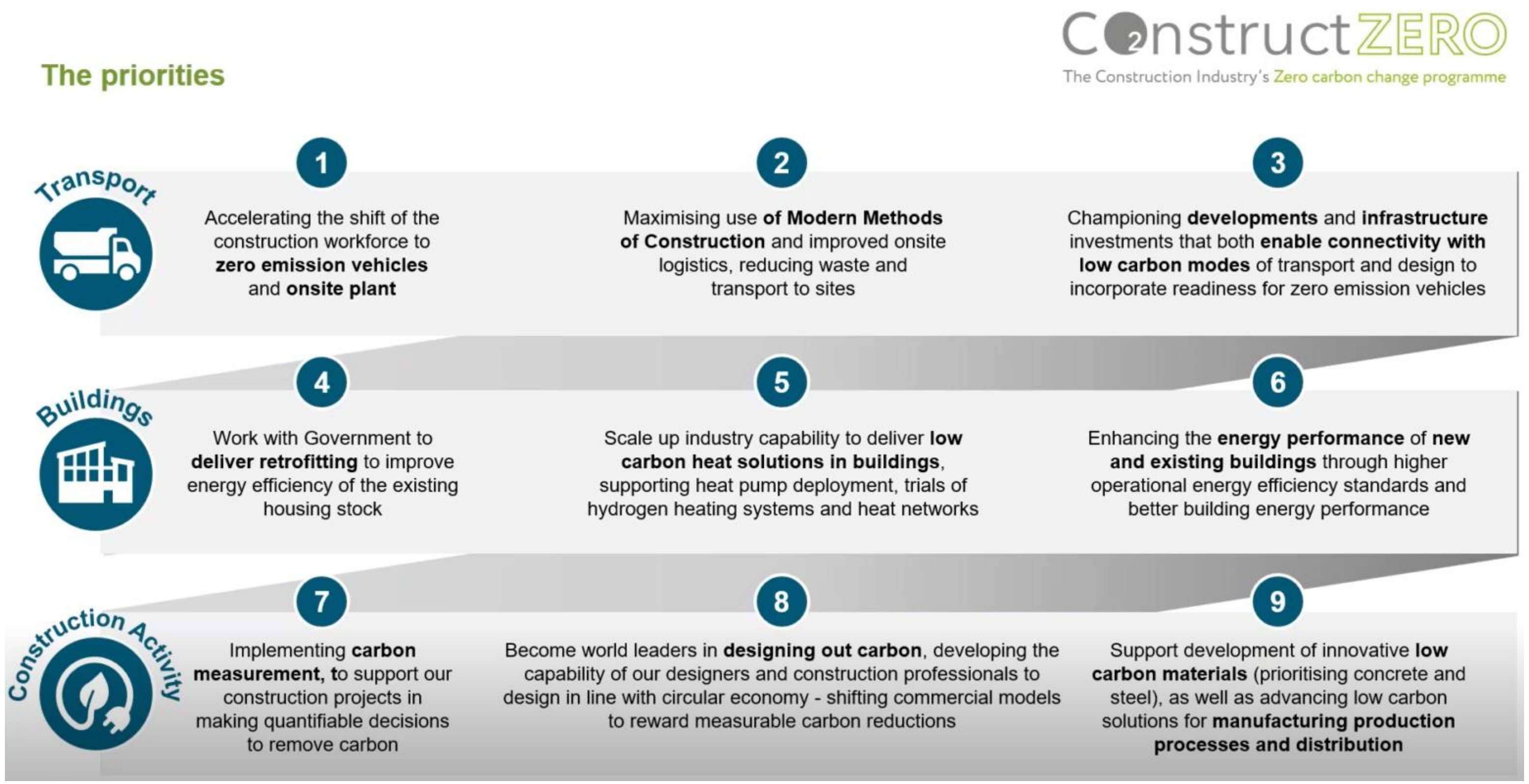
ICE Carbon Champions

Find out more about The Carbon Project

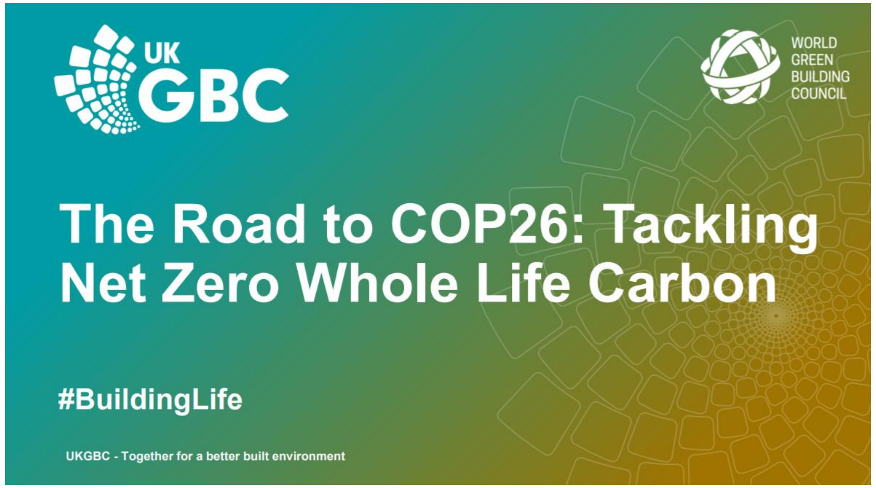
ConstructZERO

The Construction Industry's Zero carbon change programme

- Consolidate actions across sector; not develop new roadmap or pathway
- Driven by priorities set based on 6th carbon budget
- 9 priorities and three work streams:
  - Performance management (milestones, metrics, targets)
  - Signpost & support
  - Communication & Engagement



More information here

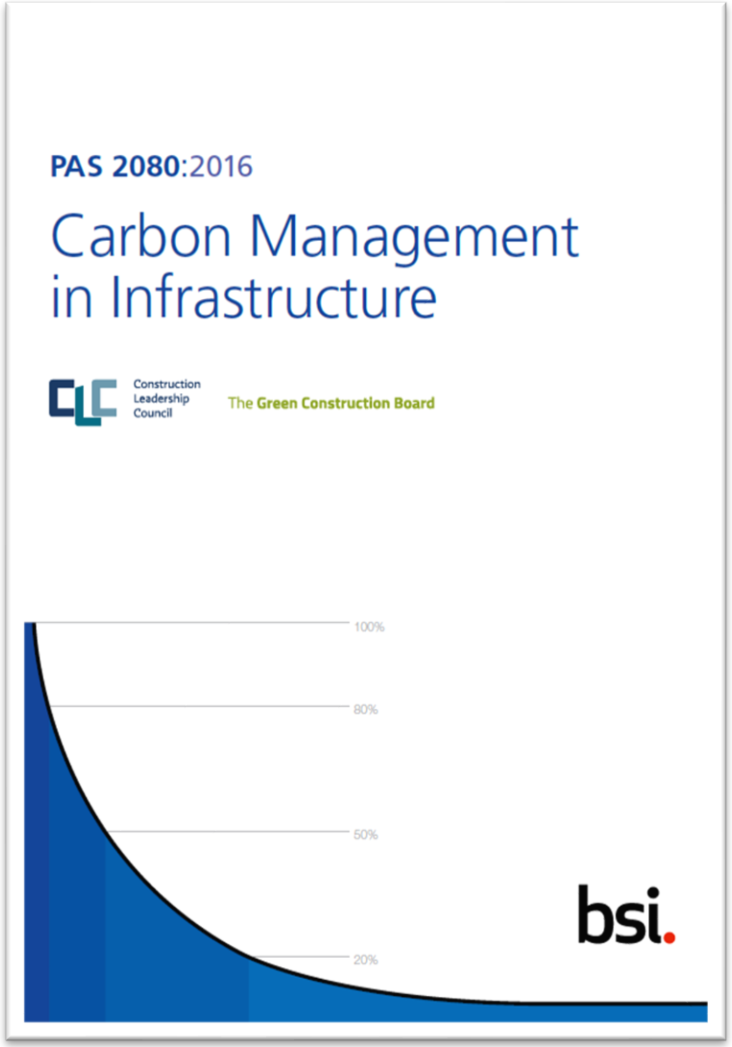


Key outputs

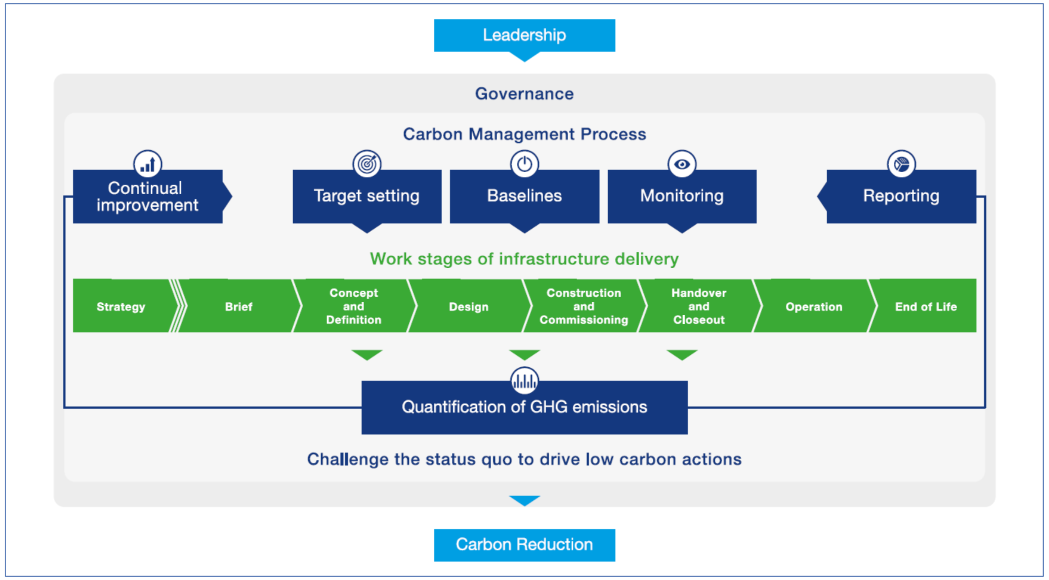
More information here

- Pathway for the UK built environment industry to achieve net zero whole life carbon for all building types and infrastructure.
- Task groups: New build – residential/commercial; Retrofit – Residential/commercial; Infrastructure

- Key points for infrastructure from draft Roadmap released for consultation:
  - Mandatory adoption of PAS 2080
  - Carbon reduction targets & reporting commitments in procurement
  - Contribution to central database for benchmarking & performance improvement



- About the <u>**processes**</u> necessary for managing whole life carbon
- Promotes consistent approach to data, quantification, benchmarking, reporting etc.
- Leadership & governance are key enablers



expedition
part of the Useful Simple Trust

PAS 2080 Accelerator Project

Final Report

June 2021

Certified B Corporation · Social Enterprise UK Certified Member · EOA Employee Ownership Association · INVESTORS IN PEOPLE We invest in people Silver

NetworkRail · HS2 · i3P · Transport Research and Innovation Board (TRIB)

Expedition

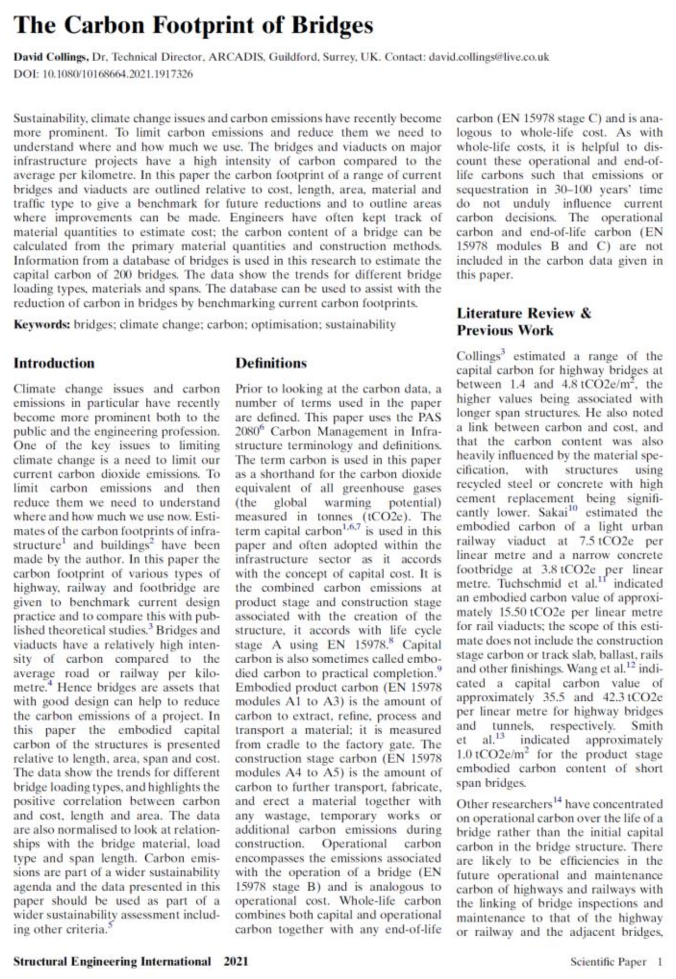
15 July 2021

[Click here for report]

Net Zero carbon and bridges

Dr David Collings (Technical Director) (May 2021) *The Carbon Footprint of Bridges*, Structural Engineering International

[Click here for paper]



The Carbon Footprint of Bridges

David Collings, Dr, Technical Director, ARCADIS, Guildford, Surrey, UK. Contact: david.collings@live.co.uk

DOI: 10.1080/10168664.2021.1917326

Sustainability, climate change issues and carbon emissions have recently become more prominent. To limit carbon emissions and reduce them we need to understand where and how much we use. The bridges and viaducts on major infrastructure projects have a high intensity of carbon compared to the average per kilometre. In this paper the carbon footprint of a range of current bridges and viaducts are outlined relative to cost, length, area, material and traffic type to give a benchmark for future reductions and to outline areas where improvements can be made. Engineers have often kept track of material quantities to estimate cost; the carbon content of a bridge can be calculated from the primary material quantities and construction methods. Information from a database of bridges is used in this research to estimate the capital carbon of 200 bridges. The data show the trends for different bridge loading types, materials and spans. The database can be used to assist with the reduction of carbon in bridges by benchmarking current carbon footprints.

Keywords: bridges; climate change; carbon; optimisation; sustainability

Introduction

Climate change issues and carbon emissions in particular have recently become more prominent both to the public and the engineering profession. One of the key issues to limiting climate change is a need to limit our current carbon dioxide emissions. To limit carbon emissions and then reduce them we need to understand where and how much we use now. Estimates of the carbon footprints of infrastructure[1] and buildings[2] have been made by the author. In this paper the carbon footprint of various types of highway, railway and footbridge are given to benchmark current design practice and to compare this with published theoretical studies.[3] Bridges and viaducts have a relatively high intensity of carbon compared to the average road or railway per kilometre.[4] Hence bridges are assets that with good design can help to reduce the carbon emissions of a project. In this paper the embodied capital carbon of the structures is presented relative to length, area, span and cost. The data show the trends for different bridge loading types, and highlights the positive correlation between carbon and cost, length and area. The data are also normalised to look at relationships with the bridge material, load type and span length. Carbon emissions are part of a wider sustainability agenda and the data presented in this paper should be used as part of a wider sustainability assessment including other criteria.[5]

Definitions

Prior to looking at the carbon data, a number of terms used in the paper are defined. This paper uses the PAS 2080[6] Carbon Management in Infrastructure terminology and definitions. The term carbon is used in this paper as a shorthand for the carbon dioxide equivalent of all greenhouse gases (the global warming potential) measured in tonnes (tCO2e). The term capital carbon[1,6,7] is used in this paper and often adopted within the infrastructure sector as it accords with the concept of capital cost. It is the combined carbon emissions at product stage and construction stage associated with the creation of the structure, it accords with life cycle stage A using EN 15978.[8] Capital carbon is also sometimes called embodied carbon to practical completion.[9] Embodied product carbon (EN 15978 modules A1 to A3) is the amount of carbon to extract, refine, process and transport a material; it is measured from cradle to the factory gate. The construction stage carbon (EN 15978 modules A4 to A5) is the amount of carbon to further transport, fabricate, and erect a material together with any wastage, temporary works or additional carbon emissions during construction. Operational carbon encompasses the emissions associated with the operation of a bridge (EN 15978 stage B) and is analogous to operational cost. Whole-life carbon combines both capital and operational carbon together with any end-of-life carbon (EN 15978 stage C) and is analogous to whole-life cost. As with whole-life costs, it is helpful to discount these operational and end-of-life carbons such that emissions or sequestration in 30–100 years' time do not unduly influence current carbon decisions. The operational carbon and end-of-life carbon (EN 15978 modules B and C) are not included in the carbon data given in this paper.

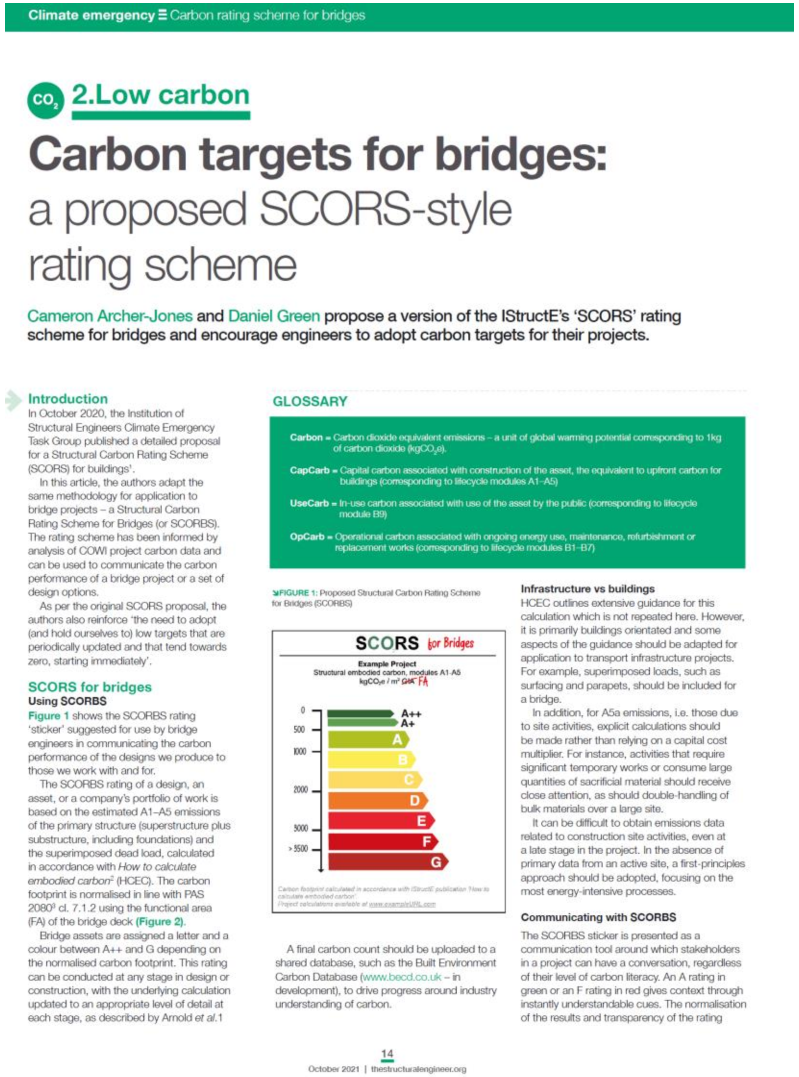
Literature Review & Previous Work

Collings[3] estimated a range of the capital carbon for highway bridges at between 1.4 and 4.8 $tCO2e/m^2$, the higher values being associated with longer span structures. He also noted a link between carbon and cost, and that the carbon content was also heavily influenced by the material specification, with structures using recycled steel or concrete with high cement replacement being significantly lower. Sakai[10] estimated the embodied carbon of a light urban railway viaduct at 7.5 tCO2e per linear metre and a narrow concrete footbridge at 3.8 tCO2e per linear metre. Tuchschmid et al.[11] indicated an embodied carbon value of approximately 15.50 tCO2e per linear metre for rail viaducts; the scope of this estimate does not include the construction stage carbon or track slab, ballast, rails and other finishings. Wang et al.[12] indicated a capital carbon value of approximately 35.5 and 42.3 tCO2e per linear metre for highway bridges and tunnels, respectively. Smith et al.[13] indicated approximately 1.0 $tCO2e/m^2$ for the product stage embodied carbon content of short span bridges.

Other researchers[14] have concentrated on operational carbon over the life of a bridge rather than the initial capital carbon in the bridge structure. There are likely to be efficiencies in the future operational and maintenance carbon of highways and railways with the linking of bridge inspections and maintenance to that of the highway or railway and the adjacent bridges,

- Structural Carbon Rating Scheme for Bridges (SCORBS)
- Cameron Archer Jones and Daniel Green (COWI)
- Oct 2021 IStructE

Click here for paper



CO_2 2.Low carbon

Carbon targets for bridges: a proposed SCORS-style rating scheme

Cameron Archer-Jones and Daniel Green propose a version of the IStructE's 'SCORS' rating scheme for bridges and encourage engineers to adopt carbon targets for their projects.

Introduction

In October 2020, the Institution of Structural Engineers Climate Emergency Task Group published a detailed proposal for a Structural Carbon Rating Scheme (SCORS) for buildings[1].

In this article, the authors adapt the same methodology for application to bridge projects – a Structural Carbon Rating Scheme for Bridges (or SCORBS). The rating scheme has been informed by analysis of COWI project carbon data and can be used to communicate the carbon performance of a bridge project or a set of design options.

As per the original SCORS proposal, the authors also reinforce 'the need to adopt (and hold ourselves to) low targets that are periodically updated and that tend towards zero, starting immediately'.

SCORS for bridges

Using SCORBS

Figure 1 shows the SCORBS rating 'sticker' suggested for use by bridge engineers in communicating the carbon performance of the designs we produce to those we work with and for.

The SCORBS rating of a design, an asset, or a company's portfolio of work is based on the estimated A1–A5 emissions of the primary structure (superstructure plus substructure, including foundations) and the superimposed dead load, calculated in accordance with *How to calculate embodied carbon*[2] (HCEC). The carbon footprint is normalised in line with PAS 2080[3] cl. 7.1.2 using the functional area (FA) of the bridge deck (Figure 2).

Bridge assets are assigned a letter and a colour between A++ and G depending on the normalised carbon footprint. This rating can be conducted at any stage in design or construction, with the underlying calculation updated to an appropriate level of detail at each stage, as described by Arnold *et al.*1

GLOSSARY

Carbon = Carbon dioxide equivalent emissions – a unit of global warming potential corresponding to 1kg of carbon dioxide ($kgCO_2e$).

CapCarb = Capital carbon associated with construction of the asset, the equivalent to upfront carbon for buildings (corresponding to lifecycle modules A1–A5)

UseCarb = In-use carbon associated with use of the asset by the public (corresponding to lifecycle module B9)

OpCarb = Operational carbon associated with ongoing energy use, maintenance, refurbishment or replacement works (corresponding to lifecycle modules B1–B7)

FIGURE 1: Proposed Structural Carbon Rating Scheme for Bridges (SCORBS)

A final carbon count should be uploaded to a shared database, such as the Built Environment Carbon Database (www.becd.co.uk – in development), to drive progress around industry understanding of carbon.

Infrastructure vs buildings

HCEC outlines extensive guidance for this calculation which is not repeated here. However, it is primarily buildings orientated and some aspects of the guidance should be adapted for application to transport infrastructure projects. For example, superimposed loads, such as surfacing and parapets, should be included for a bridge.

In addition, for A5a emissions, i.e. those due to site activities, explicit calculations should be made rather than relying on a capital cost multiplier. For instance, activities that require significant temporary works or consume large quantities of sacrificial material should receive close attention, as should double-handling of bulk materials over a large site.

It can be difficult to obtain emissions data related to construction site activities, even at a late stage in the project. In the absence of primary data from an active site, a first-principles approach should be adopted, focusing on the most energy-intensive processes.

Communicating with SCORBS

The SCORBS sticker is presented as a communication tool around which stakeholders in a project can have a conversation, regardless of their level of carbon literacy. An A rating in green or an F rating in red gives context through instantly understandable cues. The normalisation of the results and transparency of the rating

What needs to be done?

- Shared database for benchmarking (e.g. www.becd.co.uk)
- Agreed framework for carbon measurement
- Understanding (and sticking to) carbon budgets for expenditure on infrastructure

Thank you

Questions?

tadsj2@cam.ac.uk