Carbon Reduction in Infrastructure
ICE low carbon lifed panel
2014
Why
What
How
Who
Why reduce carbon?
To avoid dangerous climate change

- Warming of the atmosphere and ocean system is unequivocal
- There is a clear human influence on the climate
- Sea level change since 1950 has occurred at rates unprecedented in the historical record
- It is extremely likely that human influence has been the dominant cause of observed warming since 1950

David J.C. MacKay; *Sustainable Energy – without the hot air.*
Because prevention is better than cure

Climate Change

Mitigation
Don’t let trouble happen

Adaptation
Prepare for the trouble
To conserve scarce resources

Infrastructure is created to meet the requirements of the end users. The real question about sustainable infrastructure is:

how are we going to meet users’ needs in the long-term when everything points towards a resource-constrained future?

Peter Hansford, Chief Construction Adviser
To meet targets and pledges

The Low Carbon Routemap for the Built Environment
The Green Construction Board
Fewer materials / more thoughtful approach

To save money

Lower Carbon

Lower Cost
Strong Correlation Between Cost and Carbon Reduction

Cost and Carbon change from Baseline

Reducing Capital Cost

High Carbon Low Cost

Low Carbon Low Cost

High Carbon High Cost

Low Carbon High Cost

Reducing Capital Carbon
What should we measure / reduce?
What is the whole-life carbon of infrastructure?

Whole life carbon includes all activities associated with the:

- Construction
- Operation
- Use
- End of life of infrastructure assets
What is carbon – capital, operational, use?

Carbon is expended:

- In construction = $\text{CapCarb}$ = embodied carbon
  
  Emissions associated with the creation of an asset

- In operation = $\text{OpCarb}$
  
  Emissions associated with operation and maintenance

- In usage = $\text{UseCarb}$
  
  Emissions from the end-users of infrastructure assets
What processes comprise Cap/Op/UseCarb?

- Construction
- Transport in Supply Chain and to site
- Materials Extraction and Manufacturing
- Demolition
  - Transport and Waste Processing
- Operational and End Use Energy
- Maintenance and Replacements
- Waste
  - OpCarb/Project
  - CapCarb
- Use Carb
  - OpCarb
  - CapCarb
What is the breakdown of infrastructure Carbon?

UseCarb 70%
End Use Energy

OpCarb 29%
Operational

Cap Carb 1%
• Materials Extraction and Manufacturing
• Transport in Supply Chain and to site
• Construction

But varies for different Infrastructure sectors
But Capital Carbon will become a bigger issue in the future.

Note: In certain infrastructures sectors such as water and transport, capital carbon make up as much as 30% of annual emissions.

ICR - 2013
What is “Economic Infrastructure”?

Transport
- Passengers/Freight
  - Road: Cars, Lorries, Buses, Bikes
  - Rail
  - Air Travel
  - Water Travel: Ships Barges Ferries

Energy
- Generation – Power Stations and their Mix
- Transmission/Distribution

Water
- Supply of Clean Water
- Treatment of Waste
- Flood defences

Waste
- Disposal, Transport, Treatment

Comms
- Wireless, Fixed Line, Home Networks
## What is infrastructure carbon – examples by sector?

<table>
<thead>
<tr>
<th>Sector</th>
<th>CapCarb</th>
<th>OpCarb</th>
<th>UseCarb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>Power stations, distribution networks</td>
<td>Losses in conversion, transmission &amp; distribution</td>
<td>Consumer energy use</td>
</tr>
<tr>
<td>Telecoms</td>
<td>Base stations, cables, satellites</td>
<td>Network energy use</td>
<td>Data centres, device energy use</td>
</tr>
<tr>
<td>Highways</td>
<td>Roads, bridges,</td>
<td>Street lighting</td>
<td>Vehicle emissions</td>
</tr>
<tr>
<td>Railways</td>
<td>Track, bridges, tunnels</td>
<td>Signalling</td>
<td>Train emissions</td>
</tr>
<tr>
<td>Aviation</td>
<td>Runways, terminals</td>
<td>Lighting, terminal energy use</td>
<td>Aircraft emissions</td>
</tr>
<tr>
<td>Waste</td>
<td>Waste treatment and recycling facilities</td>
<td>Waste transport, landfill emissions</td>
<td>Minimal</td>
</tr>
<tr>
<td>Water provision</td>
<td>Water/wastewater treatment plants, pipes, pump stations</td>
<td>Treating and pumping water/wastewater</td>
<td>Consumer water heating</td>
</tr>
<tr>
<td>Water management</td>
<td>Flood defences, coastal defences</td>
<td>Minimal</td>
<td>Minimal</td>
</tr>
</tbody>
</table>

**Direct control of asset owner / operator**

**Indirect influence of asset owner / operator**
Where is the carbon expended—examples by sector?

<table>
<thead>
<tr>
<th>Sector</th>
<th>CapCarb</th>
<th>OpCarb</th>
<th>UseCarb</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>1.5</td>
<td>125.2 (20.0T+D)</td>
<td>176.7</td>
<td>303.4</td>
</tr>
<tr>
<td>Telecoms</td>
<td>0.9</td>
<td>0.9</td>
<td>6.3</td>
<td>8.1</td>
</tr>
<tr>
<td>Transport</td>
<td>2.5</td>
<td>0.4</td>
<td>156.1</td>
<td>159</td>
</tr>
<tr>
<td>Waste</td>
<td>0.1</td>
<td>19.3</td>
<td>0</td>
<td>19.4</td>
</tr>
<tr>
<td>Water</td>
<td>0.9</td>
<td>4.9</td>
<td>19.2</td>
<td>25</td>
</tr>
<tr>
<td>TOTAL</td>
<td>5.9</td>
<td>150.7</td>
<td>358.3</td>
<td>514.9</td>
</tr>
</tbody>
</table>

Data: ICR 2013 Technical Report
Figures in MtCO2e/yr
Challenge: The decarbonisation of infrastructure

- By infrastructure, we mean **Economic Infrastructure**
- Neglected until recently
- Legislation on buildings’ energy consumption “Conservation of fuel and power”:  
  - 1972 - Part F of Building Regs – scarcity rather than CO₂  
  - 1985 - Part L of Building Regs  
  - 2002 - Part L has renewed focus on savings of CO₂  
- In contrast minimal guidance exists for infrastructure  
- Generally very different characteristics to Buildings and other “Social Infrastructure”  
- 25 million dwellings – standardised interventions
What is different about infrastructure?

Decisions taken in isolation can have unintended consequences

Macro level
All networks are interconnected
- Water pumps need power and telecomms
- Power stations need water and create waste

Micro level
Each “project” is one link in a complex system
- Increasing road capacity can increase congestion
- Improving flood defences can worsen downstream impacts

Usually to serve a function at least cost
• Seldom a vanity project – although sometimes
• Usually as small as it can be – with some fixed allowance for growth
• Often upgraded continuously, over decades, centuries, millennia
How to measure Carbon in order to reduce?
Consider whole life carbon emissions of projects

Example demonstrates that, although Option 2 has the lowest CapCarb, its whole life carbon emissions (CapCarb + OpCarb) are the highest. Option 3 is actually the lowest carbon. Decisions should be made on basis of whole life carbon.

INVEST to SAVE!!
Consider from the start to maximise reduction

Build Nothing – Challenge the root cause of the need explore alternative approaches to achieve the desired outcome

Build Less – Maximise the use of existing assets; optimise asset operation and management to reduce the extent of new construction required

Build Clever – design in the use of low carbon materials; streamline delivery processes; minimise resource consumption

Build Efficiently – embrace new construction technologies, eliminate waste
# Carbon Reduction in Infrastructure

Measure the right thing at the right time to influence low carbon outcomes

<table>
<thead>
<tr>
<th>Question</th>
<th>Goal</th>
<th>Scope</th>
<th>Planning</th>
<th>Design</th>
<th>Construction</th>
<th>Commissioning &amp; Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Should we be doing this?</td>
<td>Inform policy and scope</td>
<td>Whole-life emissions (existing + new)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What is the right approach?</td>
<td>Compare alternatives</td>
<td>Compare whole-life emissions of alternatives</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What is the most carbon-efficient design?</td>
<td>Manage performance</td>
<td>Cradle-to-‘as built’ emissions of implemented schemes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What form of construction suppliers, plant, logistics?</td>
<td>Inform future plans</td>
<td>Operation, use, maintenance emissions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Can it be used and run more efficiently?</td>
<td>Reduce emissions over time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Goals**
- Reduce carbon emissions compared to “as is”
- Develop and deliver lowest whole life’ carbon solutions
- Minimise carbon emissions of construction
- Reduce emissions over time

**Scopes**
- Whole-life emissions (existing + new)
- Compare whole-life emissions of alternatives
- Cradle-to-‘as built’ emissions of implemented schemes
- Operation, use, maintenance emissions
### Choose the right level of carbon accounting to maximise influence on decision making

<table>
<thead>
<tr>
<th>Level of carbon accounting</th>
<th>Project</th>
<th>Asset or process</th>
<th>Component</th>
<th>Work item</th>
<th>Material or product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example</td>
<td>Water supply</td>
<td>Carriageway</td>
<td>Tank</td>
<td>Reinforced concrete</td>
<td>Aggregate</td>
</tr>
<tr>
<td>Typical unit of measurement</td>
<td>kgCO₂e/ Ml</td>
<td>kgCO₂e/km of carriageway</td>
<td>kgCO₂e/m³ of capacity</td>
<td>kgCO₂e/m³ cast</td>
<td>kgCO₂e/kg</td>
</tr>
<tr>
<td>Comprises</td>
<td>Multiple assets</td>
<td>Multiple components</td>
<td>Multiple work items</td>
<td>Materials, transport &amp; site construction</td>
<td>Material only</td>
</tr>
<tr>
<td>Typical data source</td>
<td>Benchmarks from previous projects</td>
<td>Derived benchmarks</td>
<td>Supplier or derived by contractor</td>
<td>Contractor, supplier or generic database</td>
<td>Generic database</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Amount of calculation</th>
<th>Sector specific data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less</td>
<td>More</td>
</tr>
<tr>
<td>More</td>
<td>Less</td>
</tr>
</tbody>
</table>

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**Carbon Reduction in Infrastructure**

Institution of Civil Engineers  @ICE_engineers
Set accounting **boundary** according to what can be controlled and influenced by the project

Typical carbon accounting boundary for infrastructure projects

- Planning and design
- On site asset construction
- Asset operation
- Asset maintenance
- Asset use
- Decommission & Demolition
- Fuel and electricity use
- Transport to/from site

- Extraction and processing of raw materials
- Offsite manufacture of components
- Production of consumables
- Recycling & disposal of waste
- Staff when off-site
- Construction of depots and factories
- Manufacture of construction plant
- Labour when off-site

Adapted from Jowitt et al (2012)
Combine CapCarb, OpCarb and UseCarb to estimate whole life carbon emissions

Construction quantities \times \text{Emissions per unit} = \text{Construction emissions}

Operation quantities/yr \times \text{Emissions per unit} = \text{Annual operation emissions (OpCarb)}

End user quantities/yr \times \text{Emissions per unit} = \text{Annual use emissions (UseCarb)}

\text{Total capital carbon emissions (CapCarb)} = \text{Construction emissions} + \text{Annual operation emissions (OpCarb)} + \text{Annual use emissions (UseCarb)}

\text{Cumulative operation emissions (OpCarb)} \times \text{Years of operation} = \text{Cumulative use emissions (UseCarb)} \times \text{Years of use}

\text{Whole life carbon emissions} = \text{Total capital carbon emissions (CapCarb)} + \text{Cumulative operation emissions (OpCarb)} + \text{Cumulative use emissions (UseCarb)}

* tonnes CO₂e = GHG emissions in equivalent tonnes of carbon dioxide

Depends on the level of carbon accounting applied
Calculate capital carbon (CapCarb) from its significant components

Life cycle analysis approach - Cradle to ‘as built’

Materials and Products × Emission Factor* × Emission Factor × Emission Factor = Total capital carbon emissions (CapCarb)

* Emission factors should take into account the emissions associated with processing raw materials and fabricating products off site.
Calculate operational carbon (OpCarb) from its significant components

\[ \text{Total operational carbon emissions (OpCarb)} = \text{Process emissions (e.g. methane)} \times \text{Emission Factor kgCO}_2\text{e/unit} + \text{Fuel combustion (e.g. diesel)} \times \text{Emission Factor kgCO}_2\text{e/unit} + \text{Electricity use} \times \text{Emission Factor kgCO}_2\text{e/unit} + \text{Transport} \times \text{Emission Factor kgCO}_2\text{e/unit} \]
Who should act?
All of us have a part to play

Adapted from ICR (2013)
Customers, tax-payers and communities do not trust government and asset owners.

Carbon reduction is legally required but slow progress because policy-makers are distracted by short-term economics.

Regulators know carbon reduction makes sense but don’t direct asset owners to low carbon solutions because the mandate is weak.

Want to demonstrate best practice but perceive carbon reduction is costly and not regulated.

Produce low carbon innovations but need designers to specify and contractors to buy them.

Could do more to reduce project carbon but perceive that decisions on the biggest savings are taken by others.

We must all overcome our perceived barriers with more innovation, strong leadership and better procurement.
As we overcome barriers, we start to realise opportunities!
Use carbon accounting to ‘oil the wheels’ of low carbon collaboration

Customers, tax-payers and communities

- Involve local communities in low carbon decision-making

Government / Policy Makers

- Strengthen incentives for owners, operators and investors to deliver low carbon infrastructure

Regulators

- Assist asset owners/operators to trial and prove and reward low carbon innovations within a safe, collaborative environment

Asset Owners / Sponsors / Clients

- Apply leadership and better procurement to drive carbon reduction up to policy makers and down to supply chain

- Collaborate with clients to co-create, test and supply innovative low carbon products

Shareholders / Investors

- Bring low carbon innovation at the earliest stages and outperform targets through the project-life cycle

Designers / Contractors

Suppliers / Manufacturers

Collaborate with clients to co-create, test and supply innovative low carbon products
Carbon accounting helps different parties to achieve their low carbon objectives

<table>
<thead>
<tr>
<th>Party</th>
<th>Use carbon accounting to …</th>
</tr>
</thead>
<tbody>
<tr>
<td>Policy makers and regulators</td>
<td>• Inform evidence-based policy and regulation for low carbon infrastructure&lt;br&gt;• Set sector targets and reward strong performers</td>
</tr>
<tr>
<td>Infrastructure owners and operators</td>
<td>• Inform the process of deciding what to do and how best to do it&lt;br&gt;• Set programme and project whole life carbon targets&lt;br&gt;• Measure and report progress in reducing emissions across project lifecycles</td>
</tr>
<tr>
<td>Consultants and designers</td>
<td>• Identify and scope novel low carbon solutions&lt;br&gt;• Promote carbon-efficient solutions in place of conventional alternatives&lt;br&gt;• Ensure solutions are designed for maximum carbon efficiency</td>
</tr>
<tr>
<td>Contractors</td>
<td>• Incentivise the supply chain to construct lowest carbon solutions&lt;br&gt;• Demonstrate outperformance in delivering low carbon solutions</td>
</tr>
<tr>
<td>Supply chain</td>
<td>• Develop, promote and supply low carbon products and services over conventional alternatives</td>
</tr>
<tr>
<td>Professional bodies</td>
<td>• Create and promote industry benchmarks for carbon-efficient infrastructure&lt;br&gt;• Influence future investment models and decision-making</td>
</tr>
</tbody>
</table>
What is the role of the engineer?

- Professional civil engineers work in the whole carbon reduction chain
- The normal education of civil engineers omits some key topics to enable engagement in these topics
  - systems thinking
  - climate change chemistry and physics
- We need to influence university courses
  … but today’s graduates will still be working in 2050
- So we need to rapidly **upskill** the profession for low carbon thinking
- Big picture thinking challenge allows things to be done better
- Other revolutions like BIM support it

- LOW CARBON  ➔  LOW COST
Next Steps for a Low Carbon Future

**Leadership** – this won’t get done if people wait for it to be led by someone else
- Client commitment and vision
- Clarity of client objectives
- Must remember the big picture/fundamental purpose... But also optimise at the project level

**Innovation** – it should drive great innovation in our industry
- Greater thought will have many other spin-offs
- Better overall holistic solutions that optimise other criteria too

**Procurement** - Needs to tie in – align client and suppliers
- Procure by programme not project
- Reward forward thinking and innovation
- Closer partnering – long term incentives for value chain to reduce costs
- Leave time for contemplation – programme needs to allow for innovative input
- Serial clients will save Carbon and Cost and achieve better outcomes
Key references

- Sustainable Energy – Without the Hot Air – MacKay (2009) *the start*
- BIS Construction Innovation and Growth Team (2010) *led to GCB*
- DECC 2050 Pathways (2010)
- ICE Low Carbon Infrastructure Trajectory to 2050 (2011) *set by Peter Hansford*
- DECC Carbon Plan (2011)
- BS EN 15804:2012 Sustainability of construction works (2012)
- Green Construction Board Routemap (2013)
- Infrastructure Transitions Research Consortium National Infrastructure Assessment (2014)
Acknowledgements

ICE is a leading source of professional expertise in transport, water supply and treatment, flood management, waste and energy.

Established in 1818, it has over 80,000 members, 25% of whom are outside the United Kingdom.

The Panel
Tim Chapman – Arup – Panel Chair
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Jamie Radford – Mott Macdonald
David Riley – Anglian Water

Kirsten Henson – KLH
Paul Jowitt – Heriot-Watt University
Tony Parry – University of Nottingham
Bill Thicknes – Skanska
Rob Curd – ICE
Next Steps

Please visit www.ice.org.uk/low-carbon to download this slide pack and start reducing carbon in your projects