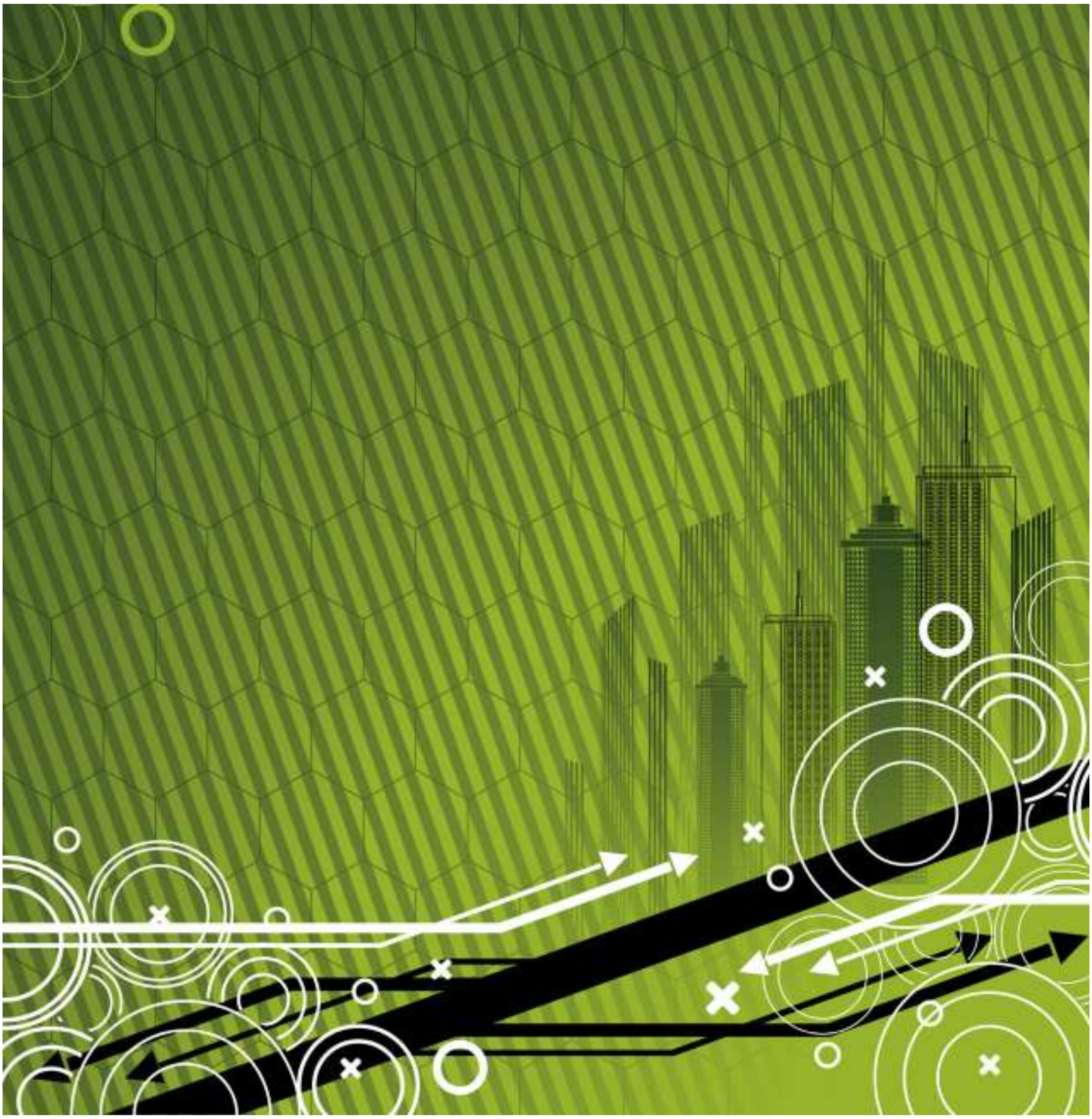
The Green Construction Board

Infrastructure Carbon Review

Technical Report

25 November, 2013



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Preface

In support to the Infrastructure Cost Review, published by Infrastructure UK in 2010, the Green Construction Board commissioned a study to undertake a review of carbon emissions in UK infrastructure, with a view to highlighting the key blockers and enablers for reducing these emissions, and to develop recommendations for promoting carbon reduction at organisational and cross-sector levels.

This Technical Report provides a summary of the information underpinning some key messages highlighted in the Main Report, such as the UK infrastructure's contribution to the UK's carbon emissions and reduction targets as well as the relationship between carbon reduction and cost reduction. It provides an overview of the methodology and the results of analyses supporting the study.

The study has been led by the Infrastructure Working Group of the Green Construction Board as a collaboration between government and industry. Chaired by Chris Newsome of Anglian Water, the Infrastructure Working Group includes representatives from across the public and private sectors. This study was completed between February and July 2013, over which period evidence has been gathered from over 100 interviews from 300 organisations and from the review of 200 documents, as part of a wider literature review. The study has been supported by a joint government and industry Steering Group.

Contents

1 Introduction and approach

Introduction

1.1 In support to the Infrastructure Cost Review, published by Infrastructure UK in 2010, the Green Construction Board and the Department of Business Innovation and Skills commissioned the Infrastructure Carbon Review. The aim of the Infrastructure Carbon Review is to highlight the key enablers for carbon reduction, focusing on those that reduce carbon and cost, in five economic infrastructure sectors in the UK (Communications, Energy, Transport, Waste, and Water) and to develop a recommendations framework for the value chain to reduce carbon.

1.2 This Technical Report has been developed to support the Main Report. Its purpose is to provide a summary of the approach and analyses underpinning the key messages presented in the Main Report. Together with the Main Report, this Technical Report and annexes can be downloaded from the HM Treasury / Green Construction Board websites[1].

Box 1.A: Structure of technical report

Chapter 1 – Introduction and approach: Sets out the context of the Infrastructure Carbon Review and the scope and approach of the Technical Report

Chapter 2 – Carbon reduction in UK infrastructure: Provides further insights into the current and future contribution of UK infrastructure to the national carbon emissions by summarising and discussing the results of the data analysis undertaken as well as a discussion on the relationship between carbon reduction and cost reduction.

Chapter 3 – Carbon data analysis: Summarises the approach and methodology of the carbon data analysis and the key assumptions and sources of information used to analyse current and future carbon emissions in UK infrastructure.

Chapter 4 – Literature review analysis: Provides a snapshot of the reviewed literature sources (including a web reference of the literature review tool developed as part of this study) as well as an overview of the general findings and gives an overview of sector specific messages in relation to carbon reduction.

Context and background

1.3 Carbon reduction has become increasingly important in the global policy arena since the Kyoto Protocol (1997) and more specifically in the UK since the Stern Review (2006) and the Climate Change Act (2008). As part of the latter, the UK Government has made a legally binding commitment to reduce its national carbon emissions by 50% by 2025 and 80% by 2050 (taking 1990 as the baseline year).

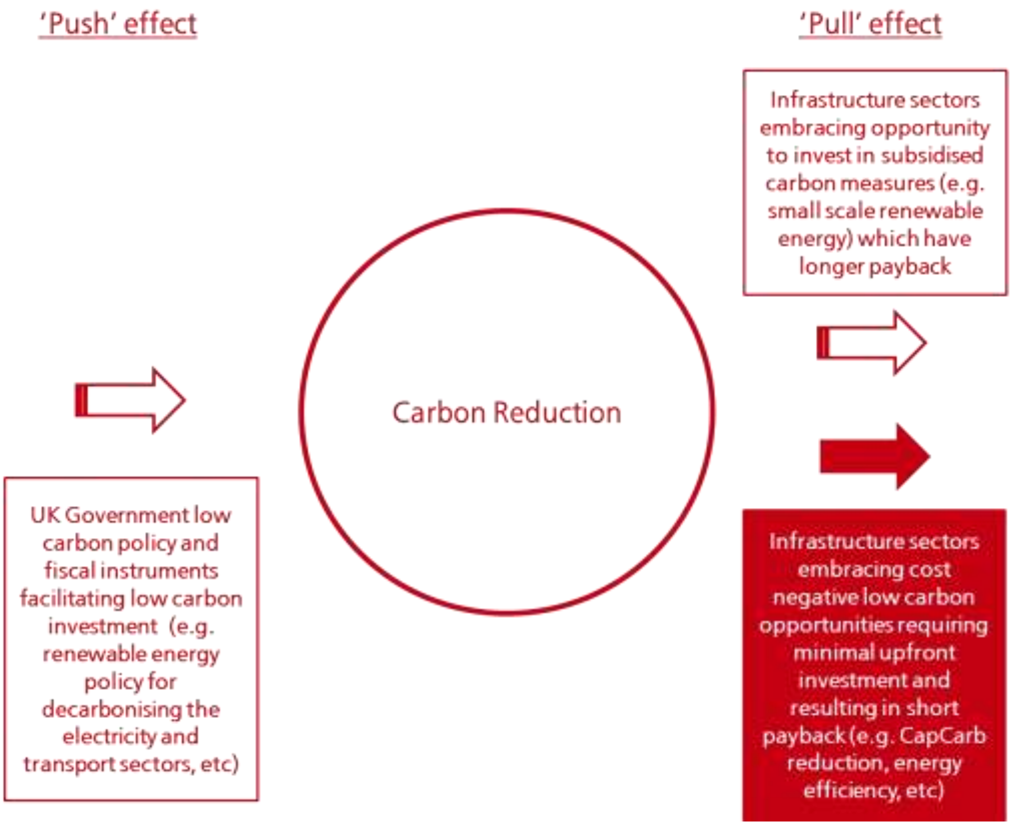
[1] HM Treasury website

1.4 In general, the carbon impact and reduction potential of the UK's national economic infrastructure has not been comprehensively studied to date. The exception is the decarbonisation of the UK electricity supply, which is being extensively addressed by the Department of Energy and Climate Change.

1.5 Results from this study show that UK infrastructure has an important contribution to the national carbon emissions. The carbon impact of the five UK infrastructure sectors is projected to increase from a 53% contribution to the total UK emissions in 2010, to over 80% of the 2025 national carbon reduction target and rising again to 90% in 2050. In short, if carbon reduction is not urgently addressed across the different infrastructure sectors, the UK targets are not likely to be met.

1.6 There are a variety of drivers causing the UK infrastructure sectors to respond by reducing capital (CapCarb) and operational (OpCarb) carbon. Some of these are push related and others are pull related. These "push-pull" drivers are illustrated in Chart 1.A and further explained below.

Chart 1.A: Carbon reduction "push-pull" effect



Source: Green Construction Board

1.7 There is a strong "push" by the UK Government to reduce carbon emissions to meet the legally binding commitments, minimise future costs of climate change to the UK economy and maximise the potential UK benefits from developing a low carbon economy. This "push" effect has incentivised carbon reduction through restructuring of sector-specific policies associated with some infrastructure sectors. Whilst there are policies that impact on all five infrastructure sectors these predominantly focus on energy at the current time. Carbon reduction in this sense involves stimulating investment in cleaner technologies at national scale to reduce the carbon impact of future infrastructure. This approach requires significant public and private sector investment. It is noted that the drive for greater electrification in other infrastructure sectors, such as Transport, will allow many more aspects of infrastructure provision and usage to be decarbonised but increases the challenge faced by the electricity supply industry. **This report does not address the decarbonisation of the UK energy supply, driven by a move to renewable and nuclear energy sources and the capture and storage of emission from fossil fuel combustion, which are being driven by the Department of Energy and Climate Change (DECC). Savings in infrastructure capital and operational carbon emissions and hence costs can be made irrespective of developments in this area and do not need to wait for it.**

1.8 Conversely, there is a strong "pull" by carbon emitters (infrastructure providers, businesses, industry, consumers, and others) to reduce carbon. This "pull" effect is mainly driven by the incentive to reduce capital and operational costs (through avoiding carbon related taxes, reducing fossil fuel electricity use, and others) and by taking advantage of any low carbon financial incentives to deploy low carbon technologies and practices in their operations (for example small-scale renewable energy technologies, energy efficiency measures, low carbon material substitution, and others). There is increasing evidence that some low carbon opportunities require upfront investment but can have reasonably short payback periods(such as in the case of small scale renewable energy technologies benefiting from Feed-in-Tariff support). Nevertheless, others can promote cost-savings in an organisation without the need for such investment. For example reducing capital carbon (CapCarb) can drive or be driven by resource efficiency (e.g. building less) and can eliminate waste in an organisation (e.g. by adopting leaner delivery processes) whereas operational carbon (OpCarb) reduction in the form of reducing fossil fuel energy use reduces operational costs. **It is this "pull" factor that is the main focus of the Infrastructure Carbon Review.**

1.9 Whilst acknowledging that almost 70% of the carbon emissions from UK infrastructure are associated with the end-users of infrastructure and outside the direct control of infrastructure providers who build and operate assets, **the focus of this study is on reducing carbon emissions in the construction and operation of infrastructure assets**.

Study scope

1.10 The scope of the Infrastructure Carbon Review has been to:

- Provide a better understanding of the direct and indirect contribution UK infrastructure has to the total UK carbon emissions, now and in the future
- Differentiate which of these emissions are under the direct control or influence of the five infrastructure sectors, with a view of informing sector-specific carbon reduction plans
- Focus on carbon reduction measures relevant to the construction, operation and maintenance of all assets necessary for providing and maintaining the required levels of service
- Explore the relationship between carbon reduction and cost reduction keeping the focus on the "pull" drivers for carbon reduction
- Focus on capital carbon (CapCarb) and operational carbon (OpCarb) reductions in UK infrastructure sectors outside the Energy sector where OpCarb reduction and more specifically the decarbonisation of the electricity grid is driven by DECC.

Study approach

1.11 The study has been led by a Research Team on behalf of the Green Construction Board in collaboration with UK Government, industry, academia and professional institutions. It was completed between February and July 2013, over which period the Research Team has gathered evidence on carbon reduction in UK infrastructure from from over 100 interviews from 300 organisations and from the review of 200 documents, as part of a wider literature review. The review has been led by Mott MacDonald and has been supported by a Steering Group formed of representatives from industry-leading organisations representing different players in the UK infrastructure value chain.

1.12 The data gathering process has included consulting with representatives of the UK infrastructure's key stakeholder groups, undertaking a comprehensive literature review, collating relevant case study material from industry leaders and undertaking a comprehensive carbon data analysis for the five economic infrastructure sectors. The carbon analysis has been used to better understand each sector's contribution to the national carbon emissions, as well as to support the analysis of each sector's ability to control or influence the reduction of such emissions. An indicative carbon valuation assessment has also been completed to provide a very high-level estimation of the potential additional value that carbon reduction in UK infrastructure could bring to the UK economy.

Confidentiality

1.13 The information and opinions provided as evidence to this study have been provided on a confidential basis and used anonymously unless prior permission was obtained.

2 Carbon reduction in UK infrastructure

Introduction

2.1 This section provides insights into the current and future contribution of UK infrastructure to the national carbon emissions, as well a discussion on the relationship between carbon reduction and cost reduction. The findings presented in this section support the core messages presented in Chapter 1 of the Infrastructure Carbon Review Main Report.

Definitions

2.2 The Infrastructure Carbon Review considered the following infrastructure sectors, following the UK Government's definition of economic infrastructure as set out in the Strategy for National Infrastructure (also summarised in Table 2.A:)

- Communications
- Energy
- Transport
- Waste
- Water

2.3 Whilst acknowledging that the infrastructure sector provides fundamental services to UK residents, the carbon reduction focus of this study is the construction, operation and maintenance of all assets necessary for providing and maintaining the required levels of service.

Table 2.A: Economic infrastructure sector definitions as stated in the Strategy for National Infrastructure

Infrastructure Sector	Significant Assets
Energy	Gas storage, transmission and distribution, electricity generation (renewable and non-renewable) transmission and distribution
Water	Water resources (rivers, reservoirs and dams), drinking water distribution (pipes and pumping stations), waste water treatment, sewerage systems, flood and coastal defences.
Transport	Roads (strategic and local), heavy rail, light rail, airports, ports, metro systems
Waste	Landfill, recycling facilities, waste collection and processing, hazardous waste treatment, energy recovery

Communications	Fixed voice and data networks, mobile voice and data networks, satellite networks, television and radio broadcast networks and radio spectrum.
Source: Strategy for National Infrastructure, HM Treasury and IUK, March 2010	

2.4 This study categorises carbon emissions into Capital Carbon Emissions (or CapCarb), Operational Carbon Emissions (or OpCarb), End-user Carbon Emissions (UseCarb) and Whole Life Carbon Emissions. These terms have been used throughout the study and their respective definitions are included in Box 2.A:.

Box 2.A: Key definitions for carbon emissions

Carbon is used throughout this report as shorthand for the carbon dioxide equivalent of all greenhouse gases (GHGs). It is quantified as 'tonnes of carbon dioxide equivalent' (tCO2e).

CapCarb (or Capital Carbon): refers to greenhouse gas (or carbon) emissions associated with the construction of an asset. Previously known as embodied or embedded carbon, capital carbon is being adopted within the infrastructure sectors because it accords with the concept of capital cost. It is quantified in tCO2e/year.

OpCarb (or Operational Carbon): describes greenhouse gas (or carbon) emissions associated with the operation of an asset. It is quantified in tCO2e/year.

Whole life carbon: describes greenhouse gas (or carbon) emissions associated with the whole life of an asset. Whole life carbon includes CapCarb and OpCarb. CapCarb relates to the emissions for constructing and maintaining an asset. It is quantified in tCO2e/year.

UseCarb (or End User Carbon): describes greenhouse gas (or carbon) emissions from the end users of infrastructure assets. Although not directly controlled by infrastructure asset owners, UseCarb can be influenced. It is quantified in tCO2e/year.

2.5 Table 2.B: summarises the types of assets that have been included in the overall data analysis for analysing current and future carbon emissions. These emissions have been split into CapCarb, OpCarb and UseCarb). Futher details can be found in Chapter 3.

Table 2.B: Types of infrastructure assets and emissions included in the carbon data analysis

Infrastructure Sector	Inclusions	Types of operational emissions (OpCarb)	Types of end-user emissions (UseCarb)
Energy[1]	• Generation from: - Coal - Oil - Gas - Nuclear - Other thermal sources[2] - Thermal renewables[3] - Non-thermal renewables • Electricity Transmission and Distribution • Gas storage, transmission and distribution.	Scope 1, 2 and upstream Scope 3 emissions[4] from all energy sector energy consumption, and all energy sector conversion, transmission and distribution losses.	Scope 1, 2 and upstream Scope 3 emissions[4] from all energy use not accounted for in other infrastructure sectors (such as energy in buildings, homes, and others).
Water	• Water resources: - Rivers, reservoirs and dams • Distribution of drinking water - Pipelines and pumping stations • Collection and treatment of sewage - Sewers and treatment works • Flood and coastal defences	Direct process emissions. Scope 1, 2 and upstream Scope 3 emissions[4] from Water sector energy consumption.	Scope 1, 2 and upstream Scope 3 emissions[4] from end-user water-related energy consumption (i.e. water heating).
Transport	• Roads • Heavy & light rail • Airports • Ports • Metro systems • Direct vehicle emissions associated with different transport infrastructure.	Scope 2 and upstream Scope 3 emissions from public lighting electricity consumption.	Scope 1 and 2 emissions from all vehicle energy consumption (road, rail, aviation, navigation). This includes electrification of rail infrastructure. Scope 3 emissions excluded (controlled by Fuel Industry, unaccounted for here).
Waste	• Waste collection and treatment • Recycling facilities • Landfill • Energy from waste centres • Hazardous waste treatment	Direct process emissions. Scope 1, 2 and upstream Scope 3 emissions[4] from Waste sector energy consumption. No reallocated energy-sector conversion and distribution losses.	None identified
Communications	• Voice & data networks (fixed and mobile) • Satellite networks • TV and Radio broadcast networks	Network electricity consumption	Data centre and end-user device electricity consumption

[1](For the purposes of the UK strategy for National Infrastructure, the definition of energy infrastructure includes facilities to store gas and generate electricity. Facilities to explore and extract gas (or fossil fuels used to generate electricity) are not included in this definition.)

[2] Includes coke oven gas, blast furnace gas and waste products from chemical processes. From 2007, non-biodegradable wastes are also included.

[3] Includes:

- Landfill gas
- Sewage sludge digestion
- Domestic wood combustion
- Non-domestic wood combustion
- Energy crops and forestry residues
- Straw combustion
- Waste combustion
- Municipal solid waste (MSW) combustion
- General industrial waste (GIW) combustion
- Specialised waste combustion
- Specialist non-biodegradable waste
- Hospital waste
- Animal biomass
- Anaerobic digestion (AD)
- Co-firing of biomass with fossil fuels
- Biodiesel and bioethanol (Liquid Biofuels for Transport)
- Prior to 2007, non-biodegradable wastes are also included

* No reallocated energy sector conversion, transmission and distribution losses to any sectors (refer to Chapter 3 for further explanation)

[4] The Greenhouse Gas (GHG) Protocol defines three scopes of GHG (or carbon equivalent) emissions (http://www.ghgprotocol.org/):

Scope 1 - Direct GHG emissions are emissions from sources that are owned or controlled by an organisation. For example, emissions from combustion in owned or controlled boilers, furnaces and vehicles.

Scope 2 - Accounts for GHG emissions from the generation of purchased electricity by the organisation.

Scope 3 - Optional reporting category that allows for the treatment of all other indirect emissions. They are a consequence of the activities of the company, but occur from sources not owned or controlled by the company. Examples include emissions from the supply chain (for example, the manufacturing of materials for constructing new assets, and others)

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2.6 Whilst the focus of this study is on economic infrastructure assets, it is recognised that there are strong inter-dependencies between infrastructure assets and the behaviour of the end-users of infrastructure. This study therefore categorises carbon emissions associated with infrastructure into emissions which the industry has a direct control of and emissions which the industry has a direct or indirect influence on. The “control” and “influence” differentiation is an important one and has been used extensively throughout this report. For clarity, the definition of these terms is included in Box 2.B:.

2.7 It is also important to note that for the purposes of the study, the carbon emissions of each infrastructure sector has been analysed separately. It is recognised that there are strong links between the operation of the different sectors and a set of assumptions has been made to allow differentiation; these are further explained in Chapter 3.

Box 2.B: Definition of Control and Influence

Control: Emissions related to the construction and operation of infrastructure assets (CapCarb and OpCarb), that infrastructure sectors have direct control of

Influence: Emissions attributed to the use of infrastructure services by the end-users (UseCarb). Although not directly controlled by infrastructure providers, such emissions can be influenced (for example, promoting demand management measures to reduce water and energy consumption in buildings and others)

Industry context – insights

Introduction

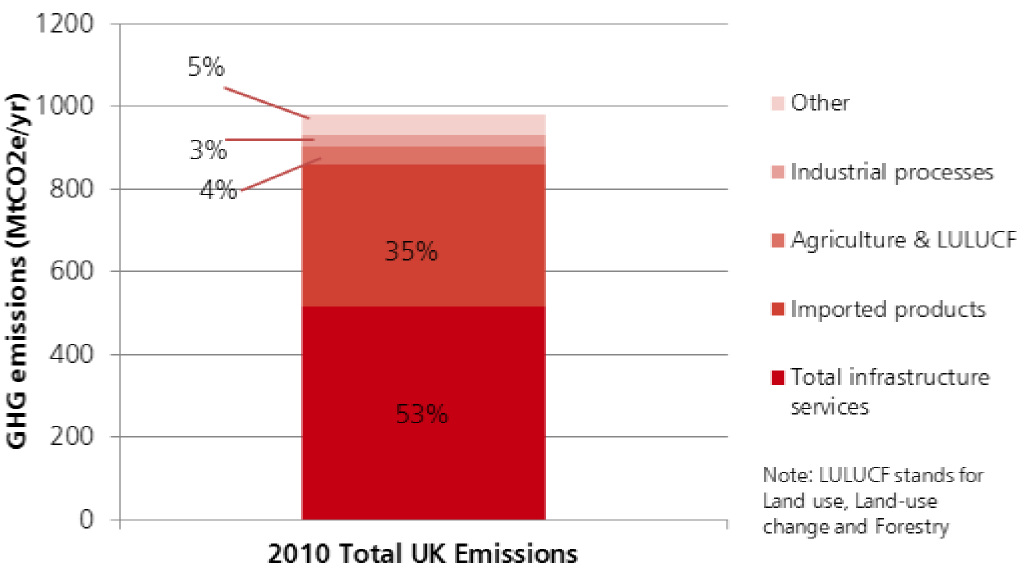
2.8 This section includes a summary of the carbon emissions associated with the UK infrastructure industry. It is used to illustrate the infrastructure industry's contribution to the current and future national emissions and the urgent need for action. Information on the main carbon emission hotspots and reduction potential, together with selective sector insights from the stakeholder interviews, has also been provided. Further details on the methodology, assumptions, sources of information used and any sensitivity analyses undertaken are summarised in Chapter 3.

2.9 This section also includes a general discussion on the carbon reduction potential in UK infrastructure, the likely cost reductions as shown by industry leaders and how such reductions could be applied in new and refurbished infrastructure. Finally a discussion on the potential additional value carbon reduction in infrastructure could bring to the UK economy is explored.

UK Carbon emissions

2.10 The baseline emissions year used for this study is 2010. The UK's national carbon emissions amounted to 981 $MtCO_2e$/yr in 2010. A breakdown of these emissions is shown in Chart 2.A. In 2010, over 53% (or 515 $MtCO_2e$/yr) of the national emissions are associated with the provision of infrastructure services with the next highest contributor, with 35% (or 346 $MtCO_2e$/yr), being imported products (outside the infrastructure sectors) to run our economy.

Chart 2.A: 2010 (baseline) UK Carbon Emissions



Source: Green Construction Board

2.11 The UK Government has a legally binding commitment to reduce the national carbon emissions by 80% by 2050[1]. In order to monitor progress, a system of five-yearly carbon budgets has been established currently as far as 2023-2027. The current national target for 2025 is a 50% reduction.[2]

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[1] taking 1990 as the baseline year

[2] The Committee on Climate Change, "Carbon Budgets and Targets": http://www.theccc.org.uk/tackling-climate-change/reducing-carbon-emissions/carbon-budgets-and-targets/ (last accessed on 19 July 2013)

2.12 The UK Government's official figures for carbon emissions (published by DECC) including the 1990 baseline and 2025 and 2050 targets, are based on a production-based (or territorial-based) reporting methodology. This means that only the emissions occurring within the UK's territorial border are accounted for – for example, emissions from imported goods to the UK or from international aviation and shipping are currently being excluded from the national carbon budgets and the 2050 legally binding carbon cap[3]. The Department for the Environment Food and Rural Affairs (DEFRA) has undertaken research to report the national emissions following a consumption-based reporting methodology, which includes all emissions activity (national or international) linked to the UK economy. The baseline (2010) total UK emissions using a production-based methodology are 635 $MtCO_2e$/yr as compared to 981MtCO2e/yr which are the national emissions using a consumption-based reporting methodology. This represents a 35% difference.

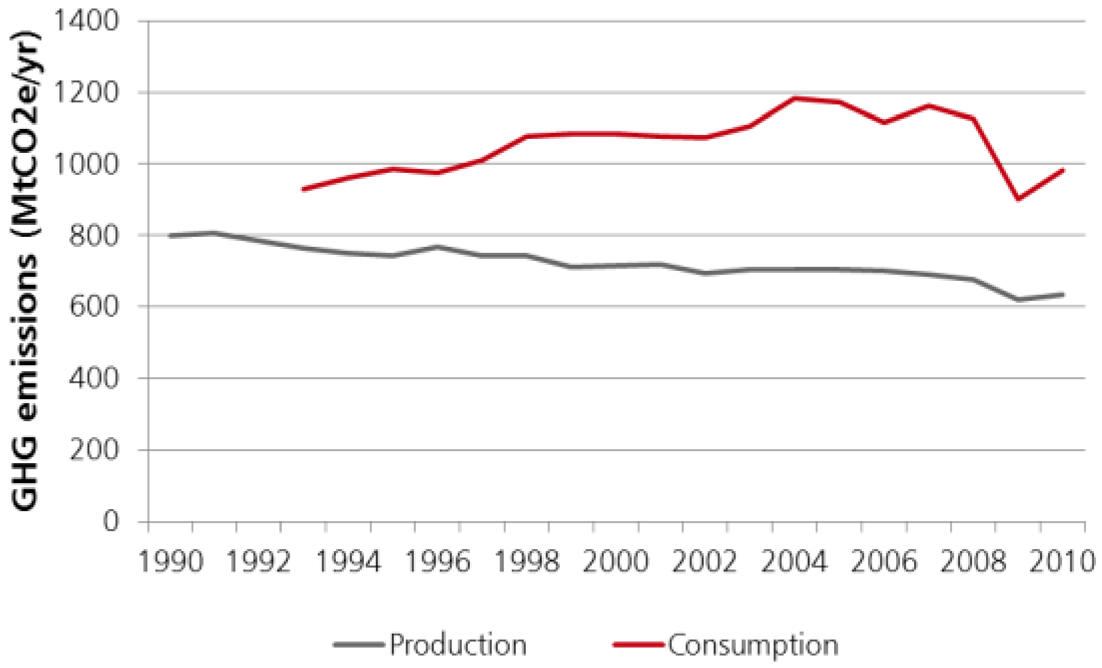
2.13 A historic trend of the UK emissions since 1990 using both reporting methodology approaches is included in Chart 2.B. It can be observed that the UK emissions using the territorial reporting based methodology have decreased by a total of 165 $MtCO_2e$/yr (or 20%) between 1990 and 2010, whereas when imported goods and international aviation and shipping emissions are taken into account in the consumption-based methodology, UK emissions show an increase of 50 $MtCO_2e$/yr (or 5%) with a peak increase of 174 $MtCO_2e$/yr (or 19%) in 2004[4]. This difference in historical emissions trends between the two reporting methodologies is likely to be partially explained by the shifting of manufacturing industries away from the UK[5].

[3] Although DECC stated in December 2012 in a presentation to Parliament that international aviation and shipping emissions will be taken into account in the national carbon budgets going forward and included in the 2050 legal cap. Source: "International aviation and shipping emissions and the UK's carbon budgets and 2050 target. Presented to Parliament pursuant to section 30(3) of the Climate Change Act 2008", December 2012. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65686/7334-int-aviation-shipping-emissions-carb-budg.pdf (last accessed on 19 July 2013)

[4] DEFRA have started the reporting of consumption-based emissions from 1993. This is the year that is used to calculate any increases. Further details can be found in Chapter 3 of this report.

[5] Source: Parliament UK. http://www.parliament.uk/business/committees/committees-a-z/commons-select/energy-and-climate-change-committee/news/consumption-published/. (last accessed on 19 July 2013)

Chart 2.B: UK historical carbon emissions: 1990 - 2010



Source: Green Construction Board

2.14 For the purposes of this study, all national emissions follow a consumption-based methodology, as it is more realistic to include emissions from international aviation and shipping and particularly imported goods when analysing UK infrastructure assets. This is because a lot of products and materials required for the development of new infrastructure originate from the global marketplace. As a result, the UK legal targets for 2025 and 2050 have been re-calculated, for the purposes of this report only, using a consumption-based methodology and the equivalent "targets"[6] are shown in Chart 2.C:.

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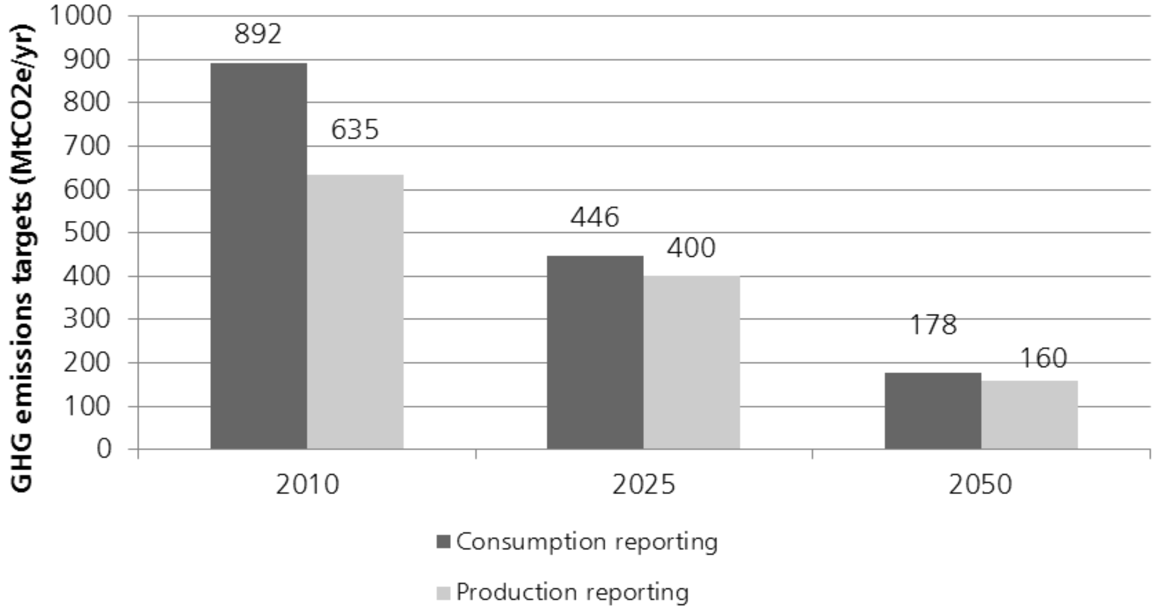
[6] In this investigation, where a consumption-based reporting methodology is used for the 2025 and 2050 targeted UK emissions, these are referred to as UK targets. Where a territorial-based reporting methodology is used for 2025 and 2050, these are referred to as UK legal targets or UK legal cap.

Chart 2.C: UK Carbon Reduction Targets



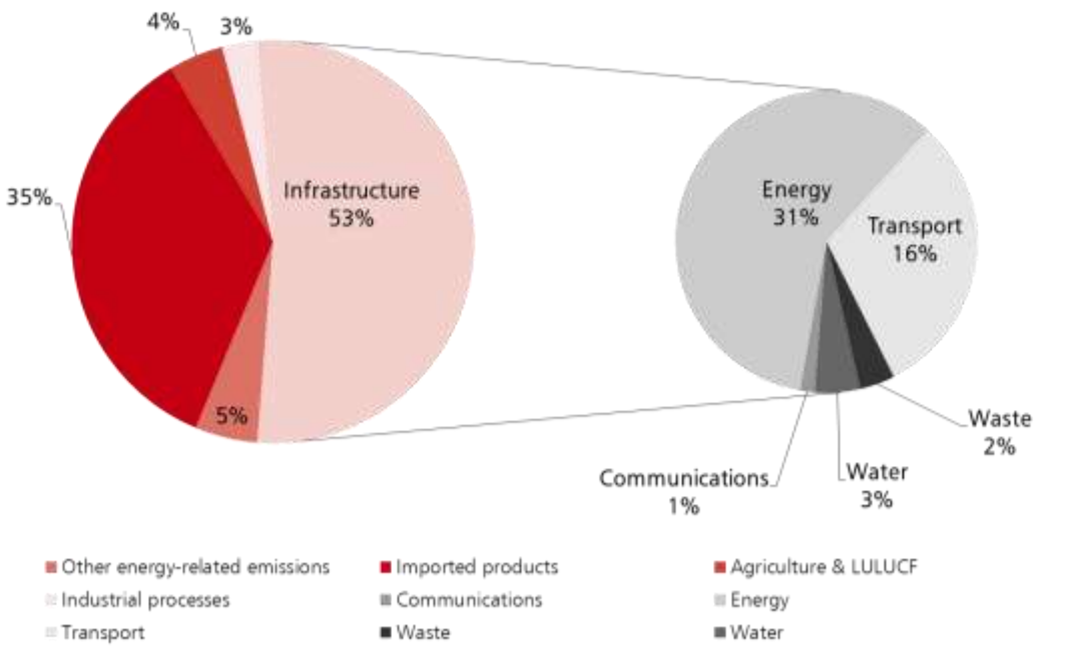
Source: Green Construction Board

2.15 It is important to note that when carbon emissions are reported at national or industry level, irrespectively of the methodology used, there is the risk of "carbon leakage" which implies that some emissions may not be accounted for.

The influence of the infrastructure industry – cross-sector overview

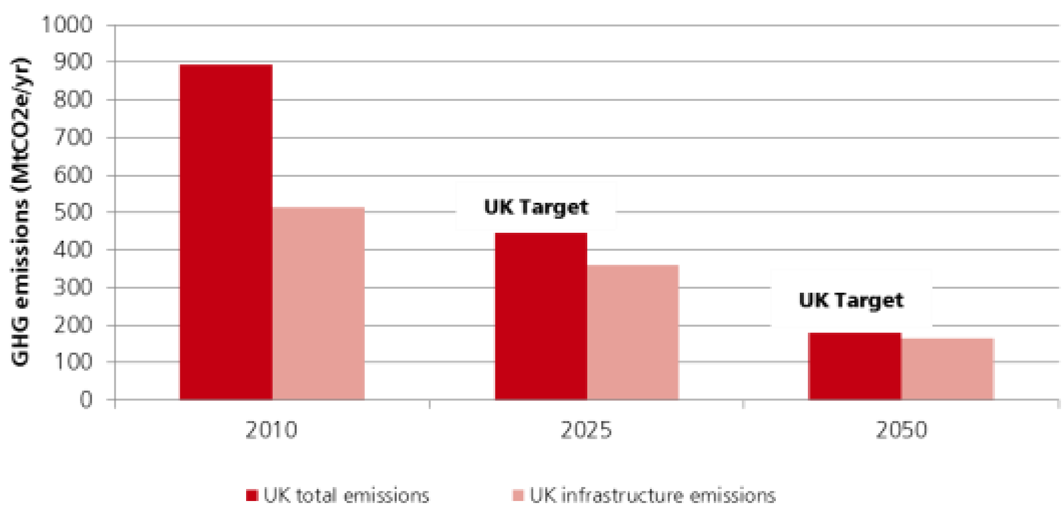
2.16 The infrastructure industry is one of the biggest contributors of UK CO_2e emissions, currently associated with 53% (516MtCO_2e/yr) of the current total UK emissions (981MtCO_2e/yr) – Chart 2.D:. The percentage contribution of infrastructure emissions to the total national emissions is projected to increase in the future, as shown in Chart 2.E:. By 2025 the industry's contribution is estimated to be over 80% (362 MtCO_2e/yr) of the UK target and then rising to 90% (165 MtCO_2e/yr) by 2050. This poses a great challenge for UK infrastructure due to the greater proportion of the total UK emissions, when compared to other areas of the UK economy and indicates the urgent need to reduce carbon.

Chart 2.D: Contribution of UK infrastructure emissions to the UK total emissions (2010)



Source: Green Construction Board

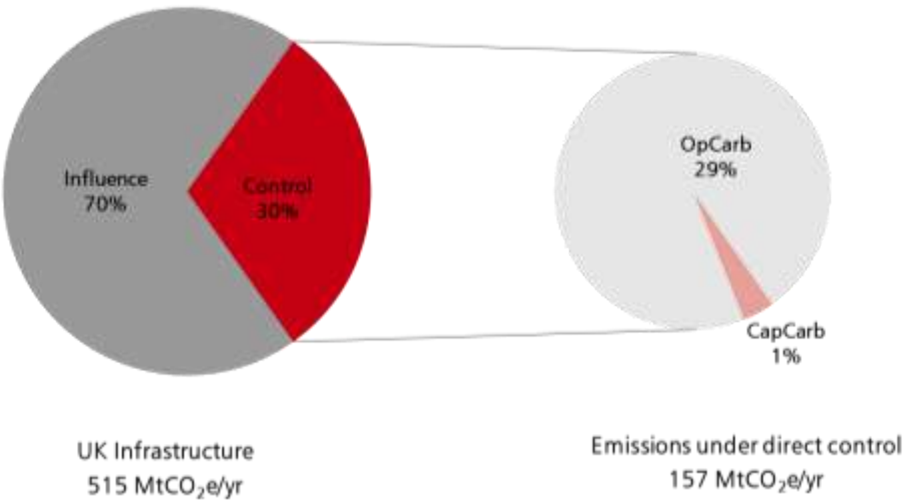
Chart 2.E: Contribution of infrastructure emissions to UK 2025 and 2050 targets



Source: Green Construction Board

2.17 Of the Infrastructure emissions, 30% (157 $MtCO_2e$/yr) is directly controlled by the different infrastructure sectors (i.e. emissions that are associated with the construction and operation of infrastructure assets). Of these, approximately 5.9 $MtCO_2e$/yr (or 4% of the emissions the industry has direct control of) are associated with the construction of new assets (CapCarb) and 151 $MtCO_2e$/yr (or 96%) with the operation of infrastructure. The remaining 70% (358 $MtCO_2e$/yr) is directly controlled by the end-users of infrastructure (UseCarb) but can be influenced by infrastructure assets (refer to Chart 2.F:).

Chart 2.F: Proportion of 2010 UK infrastructure emissions that can be directly controlled or influenced



Source: Green Construction Board

2.18 Going forward, the proportion of the emissions attributed to end-users is forecast to increase from 70% in 2010 to 74% in 2025 and reaching 80% in 2050, although the magnitude of such emissions is forecast to reduce over time. Such increased contribution assumes that infrastructure assets will become more carbon efficient through the adoption of lower carbon construction and operational practices. Despite UseCarb being outside the direct control of infrastructure providers and their supply chain, there are consumer technology and behavioural measures that can be directly influenced by the infrastructure providers.

2.19 The individual infrastructure sector contributions to the current industry and total UK emissions, including the proportion that are directly controlled and influenced, are summarised in Table 2.C:.

Table 2.C: Summary of 2010 UK infrastructure emissions and contribution to UK total emissions

All units MtCO2e/yr	Comms	Energy	Transport	Waste	Water	Total-infra	% infra	% UK total
CapCarb	0.9	1.5	2.5	0.1	0.9	**6**	**1%**	**1%**
OpCarb	0.9	125.2	0.4	19.3	4.9	**151**	**29%**	**15%**
UseCarb	6.3	176.7	156.1	0.0	19.2	**358**	**70%**	**37%**
Control	1.8	126.7	2.9	19.4	5.8	**157**	**30%**	**16%**
Influence	6.3	176.7	156.1	0.0	19.2	**358**	**70%**	**37%**
Total - infra	**8.1**	**303.4**	**158.9**	**19.4**	**25.0**	**515**	**100%**	**53%**

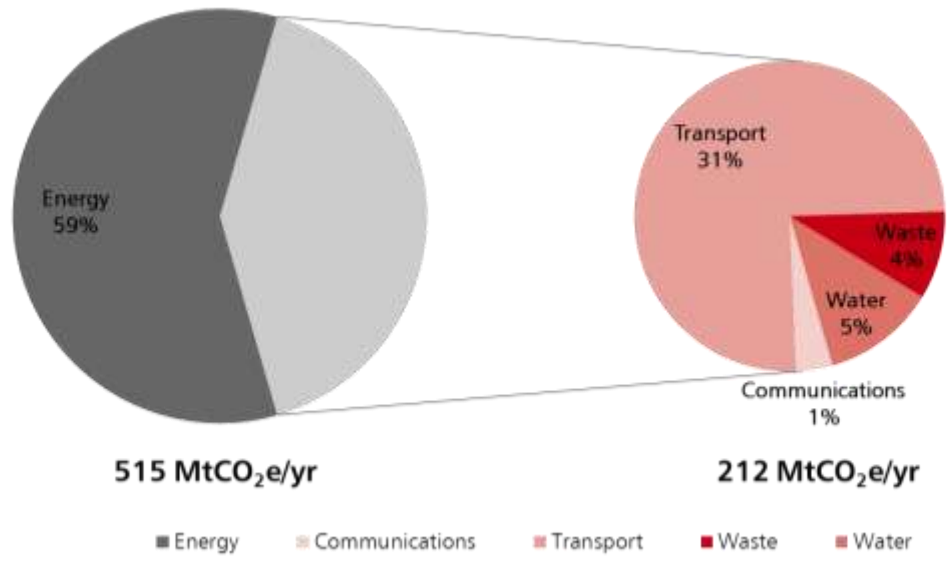
2.20 A key assumption in attributing carbon emissions to the different infrastructure sectors is the allocation of emissions associated with energy use. The proportion of OpCarb from energy use allocated to the Energy sector is mainly related to the conversion and transmission/distribution losses for the production and distribution of electricity and gas. UseCarb emissions in the Energy sector are related to end-user emissions to power and heat buildings. The proportion of emissions from thermal, transmission and distribution losses in electricity and gas systems, have been directly apportioned to the Energy sector on the basis of control. Acknowledging the complexity of the Energy sector market based system, where supply is closely linked to demand and driven by investor confidence in both technology and markets, a simplification it is assumed that the Energy sector is best placed to take measures to reduce those emissions; conversely, end-users may have less control in controlling these emissions and can mainly contribute to reductions through consuming less energy. Energy used by other infrastructure sectors has been allocated to them as OpCarb. This concept is further explained in Chapter 3.

2.21 The major sector emitters (also illustrated in Chart 2.G:) are summarised below

- Energy (303 MtCO_2e/yr total) – energy consumed in homes and buildings is included in its usage total (177 MtCO_2e/yr); generation of electricity and its losses also involves significant losses (125Mt) and measures are taken by DECC to address these through the decarbonisation of the electricity grid.
- Transport (160 MtCO_2e/yr) – most is on vehicle usage under UseCarb (156Mt). There are some plans to address these by the Department for Transport (DfT) in terms of light vehicle electrification and vehicle efficiency, but much is needed in terms of electrifying freight, which needs expansion and electrification of the rail freight network
- Water (25Mt) – water heating in buildings is included in UseCarb (19Mt)
- Waste (19Mt) – the majority of these emissions are OpCarb from the waste degradation in landfill sites and the release of methane (CH_4). The sector is already taking measures to address these, through landfill gas recovery, dedicated waste to energy plants and waste minimisation and recycling.
- Communications (8Mt) has got the smallest contribution with the majority of emissions coming from end-user devices (UseCarb), such as personal computers, mobile phones, and others.

2.22 Chart 2.G illustrates how over 80% of the current emissions in UK infrastructure are from the Energy sector. As stated in the Main Report, DECC is already driving carbon reduction in this sector, particularly OpCarb reduction through the decarbonisation of the electricity grid. OpCarb reduction in the Energy sector is therefore outside the scope of this study.

Chart 2.G: UK Infrastructure emissions by sector (2010)



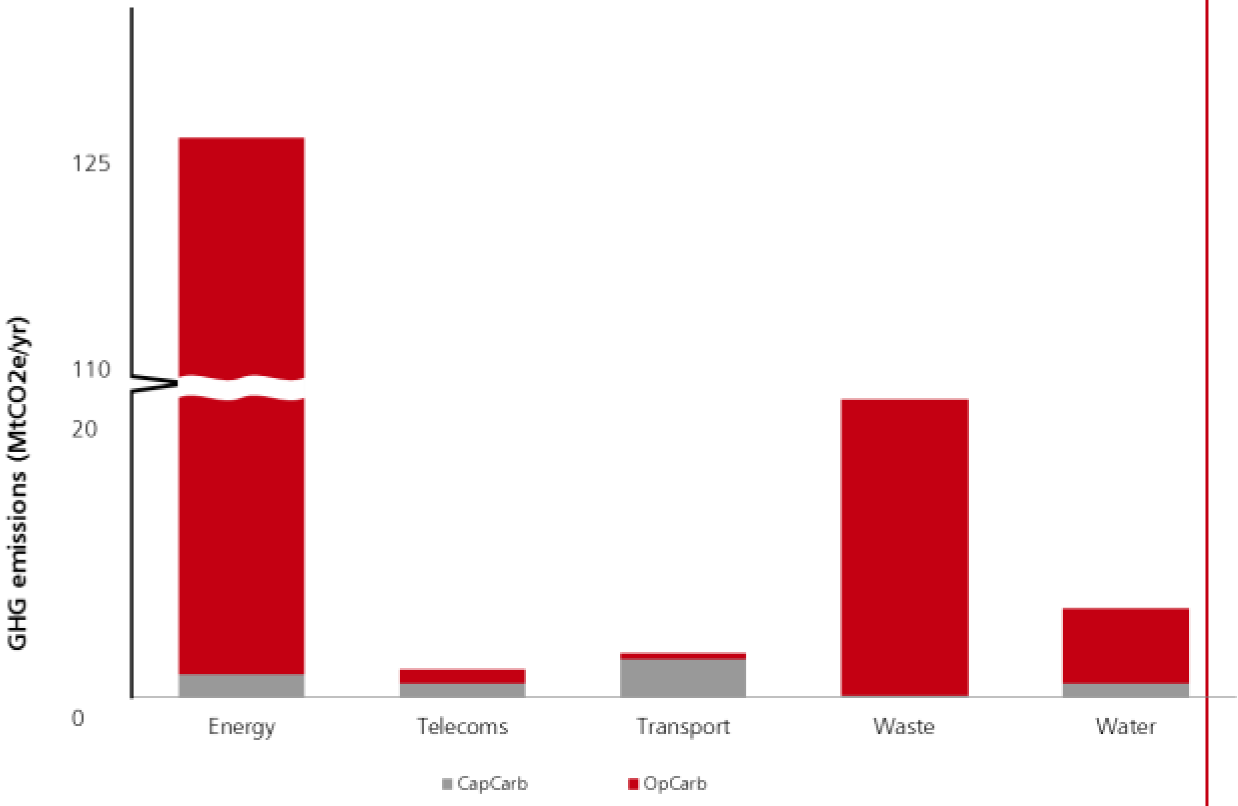
Source: Green Construction Board

2.23 Chart 2.H: illustrates the split of CapCarb and OpCarb in the different infrastructure sectors in 2010. The OpCarb contribution to the emissions that individual sectors can directly control ranges from as little as 14% (in the case of Transport) to as high as 99% (in the case of Waste). In Water, the contribution is over 80% and in Communications approximately 50%. This is due to the nature of the OpCarb emissions in the different sectors and the attribution of operational emissions to end-users (UseCarb). For example, the majority of the OpCarb in the Waste sector is direct methane emissions (CH_4) from landfill sites (with greater global warming potential than CO_2). In addition, the Waste sector is not as asset intensive as other sectors such as Water and Transport hence has a very small CapCarb impact. In contrast, the Transport sector is the most asset intensive of all the other sectors with the highest CapCarb contribution. The Transport Sector OpCarb is quite small as the operational emissions that the sector can directly control only include electricity consumed for public street lighting. The rest of the emissions, such as, fuel or electricity use in vehicles, trains, aeroplanes and other modes of transport is attributed to the end-users. The asset owners, therefore, have less direct control over those.

2.24 It is important to note the assumptions and methodology used for calculating CapCarb and OpCarb (as detailed in Chapter 3) since there may be some inaccuracies in the results presented when compared to available bottom-up sector specific data. For example in the case of the water sector where an industry-wide study[7] indicates that CapCarb emissions in the sector are almost 33% when compared to the 13% contribution from this study. This point is further explored in Chapter 3.

[7] Keil et al. (2013) "Understanding embodied greenhouse gas emissions in the water and sewerage sectors", Water and Environment Journal 27 (2013) 253-260

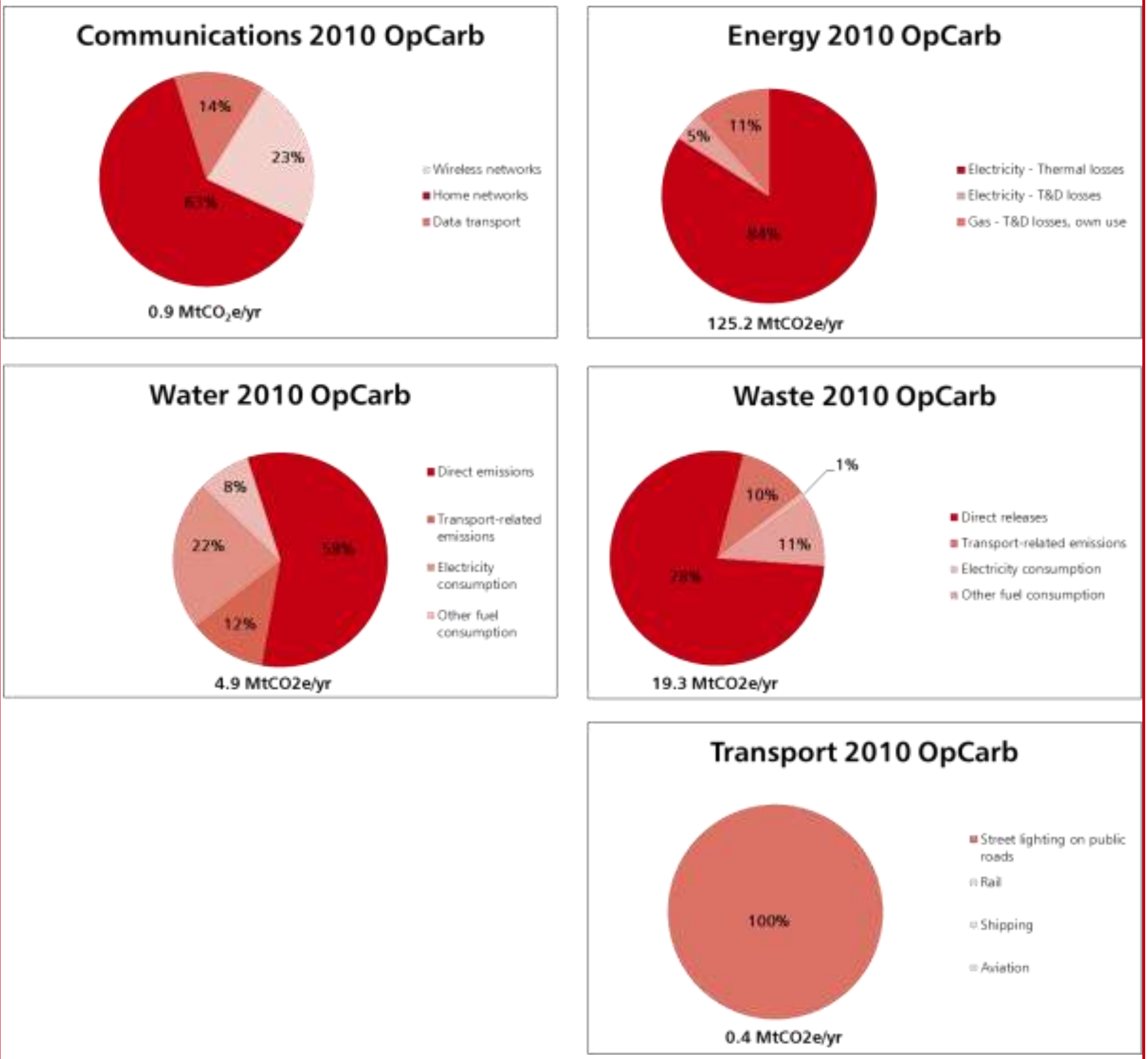
Chart 2.H: CapCarb / OpCarb in Comms, Transport, Waste and Water infrastructure sectors



Source: Green Construction Board

2.25 Chart 2.I shows the types of OpCarb emissions for each infrastructure sector. Although it can be seen that the majority of emissions are associated with electricity use, it is important to note the uniqueness of UK infrastructure as compared to other sectors (e.g. buildings) in that a significant proportion of OpCarb is from direct process emissions (which means emissions released directly as part of a process chemical or thermal reaction not related to energy). If no action is taken, these would remain even after the decarbonisation of the electricity grid.

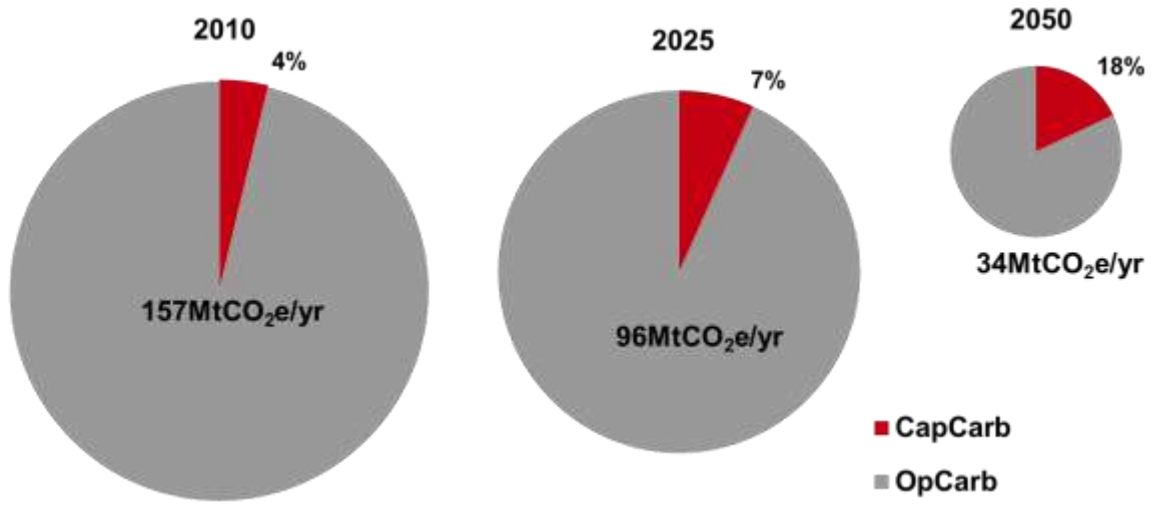
Chart 2.I: OpCarb by sector



Source: Green Construction Board

2.26 The 2010 split of CapCarb and OpCarb could be interpreted as CapCarb appearing relatively insignificant, but this is only because a large part of the OpCarb of UK infrastructure (even if the Energy sector OpCarb is excluded) is associated with power that is currently generated in a carbon intensive way. As the grid is decarbonised, the relative importance of CapCarb will increase, as can be seen in Chart 2.J:. In addition, any future CapCarb intensity reductions are expected to be offset by a greater need to build, so further efficiencies in the delivery of new infrastructure are urgently needed to avoid CapCarb becoming a significant contributer of the UK's emissions target. Therefore, it is equally important for UK infrastructure to equally consider reductions in both the CapCarb and OpCarb that is under its direct control.

Chart 2.J: UK Infrastructure CapCarb and OpCarb split



Source: Green Construction Board

Opportunity for reduction

Carbon reduction potential

2.27 As part of this study, projections on CapCarb, OpCarb and UseCarb reductions have been estimated for the five infrastructure sectors. Table 2.D:and Table 2.E:summarise best case reductions[8] in UK infrastructure emissions for 2025 and 2050 and compared to the respective UK targets – year 2025 has been included as it is a target year in the Government's industrial strategy for construction and respective low carbon messages, whereas year 2050 relates to the national carbon reduction target year as set out in the Climate Change Act (2008).

Table 2.D: Summary of UK infrastructure emissions forecast in 2025 and contribution to UK 2025 target

All units MtCO2e/yr	Comms	Energy	Transport	Waste	Water	Total-infra	% UK infra	% UK total
CapCarb	0.9	2.2	2.2	0.1	1.1	6	2%	1%
OpCarb	1.2	67.9	0.2	15.8	4.1	89	25%	20%
UseCarb	5.0	101.9	139.9	0.0	19.2	266	74%	60%
Control	2.1	70.1	2.4	15.9	5.2	96	26%	20%
Influence	5.0	101.9	139.9	0.0	19.2	266	74%	60%
Total - infra	7.1	172.0	142.3	15.9	24.4	362	100%	80%
Total % reduction from 2010	12%	43%	10%	18%	2%	30%	-	-

[8] The "best case" reduction account for emissions reductions from the decarbonisation of the electricity grid. Refer to Chapter 3 for further explanation on the reduction scenarios considered in the analysis.

Table 2.E: Summary of UK infrastructure emissions forecast in 2050 and contribution to UK 2050 target

All units MtCO2e/yr	Comms	Energy	Transport	Waste	Water	Total-infra	% UK infra	% UK total
CapCarb	0.8	2.0	1.9	0.0	1.4	6.1	4%	3%
OpCarb	0.4	14.2	0.0	10.6	2.7	27.9	17%	16%
UseCarb	0.7	12.6	112.8	0.0	4.8	131.0	79%	74%
Control	1.2	16.2	1.9	10.6	4.1	34.0	21%	19%
Influence	0.7	12.6	112.8	0.0	4.8	131.0	79%	74%
Total - infra	**2.0**	**28.8**	**114.7**	**10.6**	**9.0**	165.0	100%	93%
Total % reduction from 2010	75%	90%	28%	45%	64%	68%	-	-

The above carbon reduction figures have been forecast using national policies, investment and technology forecasts (particularly the Pathways 2050 models developed by DECC), sector-specific published plans as well as insights from industry experts. More detailed sector-specific forecasts are included in the Sector Overview section in Chapter 2. Details on the assumptions and main sources of information used to estimate these forecasts are included in Chapter 3.

- Energy (Total forecast reductions: 172 Mt in 2025 and 28.8 Mt in 2050) – the majority of the total emissions reductions by 2025 and 2050 are directly attributed to progress made for the decarbonisation of the electricity grid. This has a direct impact on reducing OpCarb (67.9 Mt total emissions in 2025 and 14.2 Mt in 2050) through reducing conversion losses in power generation by the adoption of renewable energy technologies. UseCarb is also significantly reduced (101.9 Mt total emissions in 2025 and 12.6 Mt in 2050) mainly through carbon reductions in energy intensity, despite the total energy demand gradually increasing.

- Transport (Total forecast reductions: 142.3 Mt in 2025 and 114.7 Mt in 2050) – the majority of these reductions by 2025 and 2050 are from the electrification of road vehicles and rail and from efficiencies and use of alternative low carbon fuels in domestic and international modes of transport including aviation and shipping (total UseCarb is likely to be 139.9 Mt in 2025 and 112.8 Mt in 2050). OpCarb reduction is mainly associated with efficiencies in public street lighting, the decarbonisation of the electricity grid and small scale renewable energy generation. OpCarb emissions relevant to street lighting are likely to be 0.2Mt in 2025 and to reach less than 1Mt in 2050. CapCarb will also reduce (from 2.5Mt in 2010 to 2.2Mt in 2025 and 1.9Mt in 2050). Such reductions are estimated to be driven by efficiencies in construction practices and the gradual decarbonisation of the supply chain. Investment is still forecast to increase but the overall impact is forecast to be a reduction, if best practice is adopted.

- Water (Total forecast reductions: 24.4Mt in 2025 and 9 Mt in 2050) – reductions in the water sector are forecast to be greater in 2050 than in 2025. The main contribution to emissions is predicted to be from increased energy use in the domestic and industrial sectors (UseCarb) for water heating, and electricity use (OpCarb) by water utilities – the latter being driven by increased water quality and environmental standards. Total OpCarb in 2025 is forecast to reach 4.1Mt and 2.7Mt in 2050. Such reductions are mainly driven from increased energy efficiency measures and reductions in the carbon intensity of electricity use, from the decarbonisation of the grid and the increased deployment of small-scale renewable energy systems in infrastructure. UseCarb projections show 19.2Mt in 2025 and 4.8Mt in 2050. As with other infrastructure sectors, although CapCarb intensity is projected to reduce, total CapCarb is shown to increase due to additional infrastructure requirements.

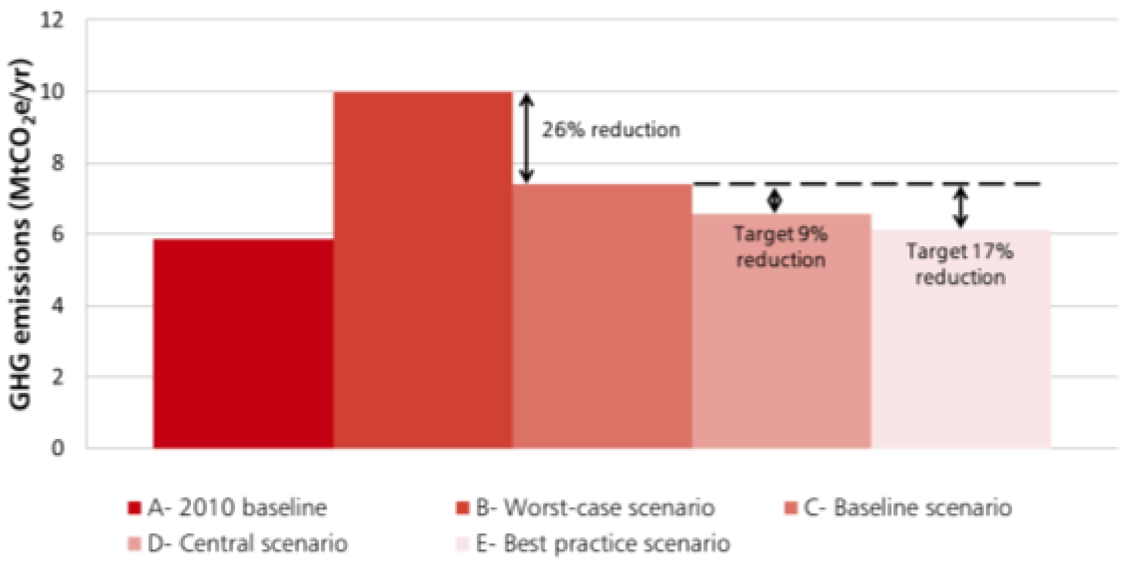
- Waste (Total forecast reductions: 15.9 Mt in 2025 and 10.6 Mt in 2050) – reductions are mainly attributed to OpCarb (15.8Mt in 2025 and 10.6Mt in 2050). These are mainly from reduction in waste volumes , the decarbonisation of the grid and also from the adoption of energy to waste plants generating renewable energy to power the sector's operations. The sector's CapCarb contribution is relatively small as compared to other sectors, nevertheless a 10% reduction is forecasted in 2050 bringing the sector's CapCarb from 0.1Mt in 2010 and 2025 to less than 1Mt in 2050.
- Communications (Total forecast reductions: 7.1 Mt in 2025 and 2 Mt in 2050) - The main reductions can be attributed to efficiencies in end-user communication devices (such as mobile phones, computers, and others, as technology is evolving projecting UseCarb emissions to reach 5Mt in 2025 and 0.7Mt in 2050. OpCarb is projected to be reduced to 1.2Mt in 2025 and 0.4Mt in 2050. Such reduction is mainly related to efficiencies in the operation of data centres and wireless networks but also to the overall effect of the decarbonisation of the electricity grid. It is interesting to note that Communications has the lowest percentage CapCarb reductions with total emissions in 2025 of 0.9Mt (a <1% reduction from 2010) and 0.8Mt in 2050 (a 11% total reduction). This is due to the high projected growth rates in new infrastructure and the embodied emissions from a lot of this infrastructure is independent from efficiencies in the UK grid decarbonisation as the majority of technologies/products used are from the global marketplace. Nevertheless, progress on the decarbonisation of electricity grids overseas have also been considered when forecasting any reductions. It is important to note that Communications is a sector which will have a key role to play in enabling other sectors to reduce their emissions through advanced data handing systems to enable the operation of smart, more efficient infrastructure.

2.28 In summary, UK infrastructure has the potential to reduce emissions by almost 30% by 2025 and over 68% by 2050. The majority of these reductions will come from the Energy Sector and the decarbonisation of the electricity grid. Nevertheless communications, transport, water, waste will still have a significant role to play in achieving the national targets in 2050. Although most of the emissions and reduction potential are attributed to the end-users of infrastructure, future forecasts of the emissions the industry can directly control show that such emissions are still important and should be addressed now.

Capital carbon reduction

2.29 Chart 2.K: illustrates the effect of the different factors affecting CapCarb reduction through projected annual CapCarb reduction scenarios in 2050.

Chart 2.K: Annual CapCarb scenarios in 2050

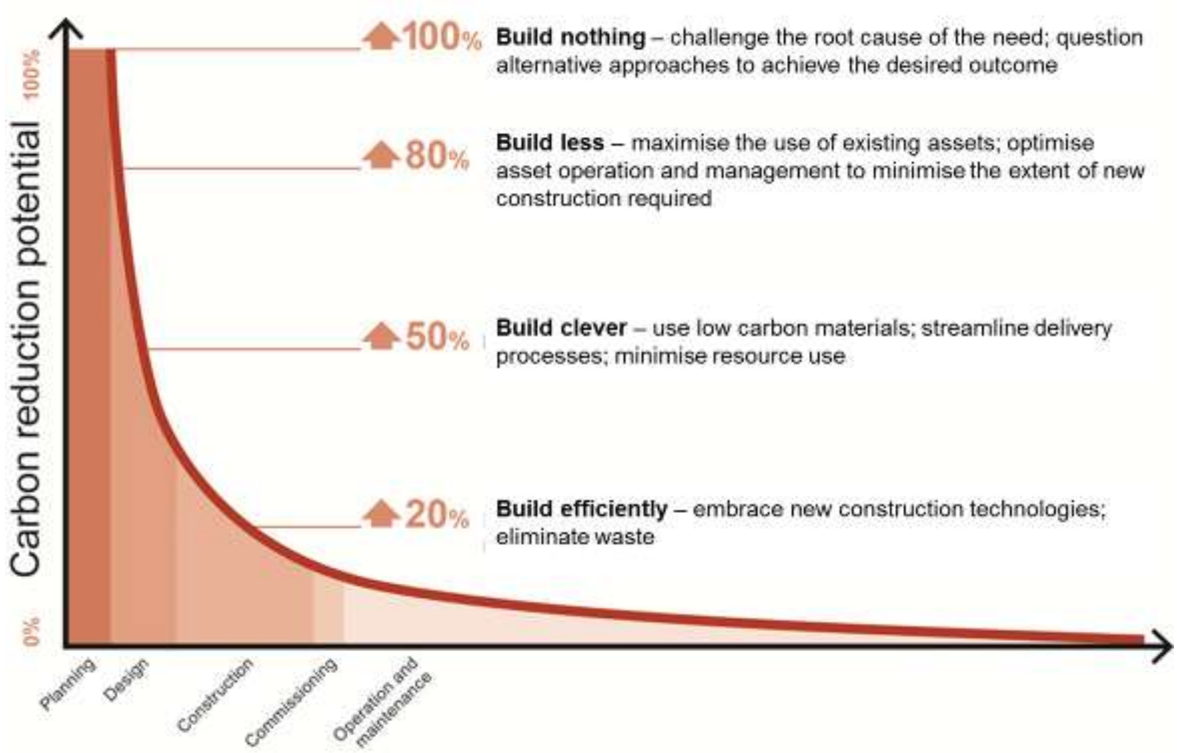


Source: Green Construction Board

2.30 CapCarb is mainly influenced by the fossil energy and fuel used across the supply chain to produce and transport construction materials and mechanical and electrical components for building new and maintaining existing infrastructure. As such, the CapCarb of an asset base could be considered as the OpCarb of the supply chain involved in its construction. The magnitude of CapCarb is also directly related to the quantity of resources used during the construction and maintenance phases in a project's lifecycle. Figure Chart 2.K shows that if no action was taken to reduce resource use and the carbon intensity of the supply chain, then CapCarb would increase by 40% (or 4Mt/yr) by 2050. This increase would reflect an increase in resource use to build new assets to accommodate population growth and end-user levels of service. If no action was taken to reduce the CapCarb of infrastructure assets, external factors such as the decarbonisation of the electricity grid by 2050 and efficiencies in the energy used for the manufacturing and transporting of materials in the global market would still result in a CapCarb reduction of 26% (from a 2050 baseline). This would represent a net increase of 25% from the 2010 baseline (or an additional 1.5Mt/yr). This effect is presented as the "Baseline Scenario". Nevertheless, if UK infrastructure adopted best practice scenarios to deliver infrastructure more efficiently, to use lower carbon materials and other measures then reductions of up to 9% as compared to the Baseline Scenario could be achieved by 2050. If best practice, as followed by early adopters in the industry, was adopted by all infrastructure sectors then CapCarb emissions in 2050 would be 6.1Mt/yr or 17% lower than the 2050 Baseline Scenario. This is presented as the "Best Case Scenario". It is important to note, that total CapCarb projections in the best case 2050 scenario are still estimated to be higher than CapCarb in 2010 (a net increase of (0.25Mt/yr or 4.3%). This is to accommodate growth in the sectors.

2.31 As highlighted in the Main Report, CapCarb reduction can be achieved in different ways. These, together with relevant reduction potentials are illustrated in Chart 2.L:

Chart 2.L: Carbon reduction curve



Source: Green Construction Board

2.32 Since CapCarb reduction is mainly linked to resource efficiency, "asset intensive" infrastructure sectors such as water and transport (and some elements of the power sector) have the opportunity to reduce their CapCarb impact by the "Build nothing" or "Build less" approaches, although these are driven by cost reduction. Particularly in the case of refurbishing or maintaining existing infrastructure assets, where there is greater opportunity to re-use existing assets to achieve the same service outcomes from new infrastructure. Such measures, if adopted at the planning phase of a project could bring reductions of CapCarb up to 50% when comparing more traditional infrastructure delivery practices.

2.33 The "Build clever" and "Build efficiently" approaches, which mainly relate to the selection of lower carbon materials and the adoption of new construction techniques that eliminate waste (such as off-site manufacturing), are applicable to all new infrastructure including the less asset intensive infrastructure sectors (such as Communications). Early adopters in the industry have claimed, as part of the Infrastructure Carbon Review stakeholder consultations, that such approaches can bring reductions in emissions of 20% and above.

2.34 The selection of lower carbon materials is a good way of reducing the CapCarb impact of infrastructure. Such materials could be alternatives to steel or concrete or more traditional materials with recycled content. Selective asset owners from the water and transport sectors, who were consulted as part of this study, have claimed that the use of such materials in new infrastructure assets have brought significant CapCarb and Cost reductions. Before considering alternative or recycled materials for use in new or existing infrastructure, it is important to understand the true functionality of those materials and the effect their use can have in the design life of an asset as well as the carbon impact of the transport of such materials. For example the use of a low carbon material that has a shorter design life than a higher carbon alternative, there is a risk that maintenance or replacement frequencies (and associated future CapCarb and OpCarb) may be increased over the whole life of an asset. Similarly, when selecting a lower carbon material with recycled content (such as recycled aggregates), the location of the material source is key as, if located too far from the construction site, the carbon impact of transporting this material to the site could result in a higher overall CapCarb.

2.35 It is important to note that in some sectors, safety and whole life reliability risks and standards may prevent lower CapCarb practices being mainstreamed more than in other sectors. For example, in the nuclear sector, priorities such as a long asset design life driven by safety and environmental considerations might present additional blockers in the value chain to embrace alternative lower carbon and lower cost materials and practices without prior testing and approval of the materials/practices by the Regulator / International Standards. Nevertheless, such considerations could result in increased opportunities for the supply chain to innovate and deliver lower carbon products/materials that satisfy any sector specific requirements.

2.36 Sectors that involve the use of standard products from the international market place, such as the Communications sector, may find it more challenging to reduce CapCarb to the levels that more asset intensive sectors could achieve. It would be beneficial for these sectors to better understand the overall CapCarb impact of their products, particularly the contribution of transport related emissions.

2.37 Finally, a trade-off between CapCarb and OpCarb reduction may exist in the delivery of infrastructure. When considering alternative solutions for new and existing infrastructure, it is important to consider whole life carbon emissions. For example, using less resources or re-using existing assets in the delivery of new infrastructure (such as selecting a smaller diameter pumped water main or re-using an existing transmission or distribution line to accommodate additional power generation capacity) may have a negative OpCarb effect in that operational emissions over the whole life of an asset might increase. For example, the use of a smaller diameter pumped water main may increase hydraulic headlosses in the infrastructure system hence more power may be consumed or in the transmission/distribution example, losses may be increased. There could be instances where the benefits of reducing CapCarb and Capex may still outweigh any marginal increases in OpCarb and Opex over the whole life. There could be a benefit of adopting such solutions in the maintenance of existing infrastructure in order to defer capital expenditure in future years and this could be a valid solution in a wider asset management strategy with no net effects on the longer-term service outcomes. It is therefore important to consider whole life carbon as part of a wider asset management strategy.

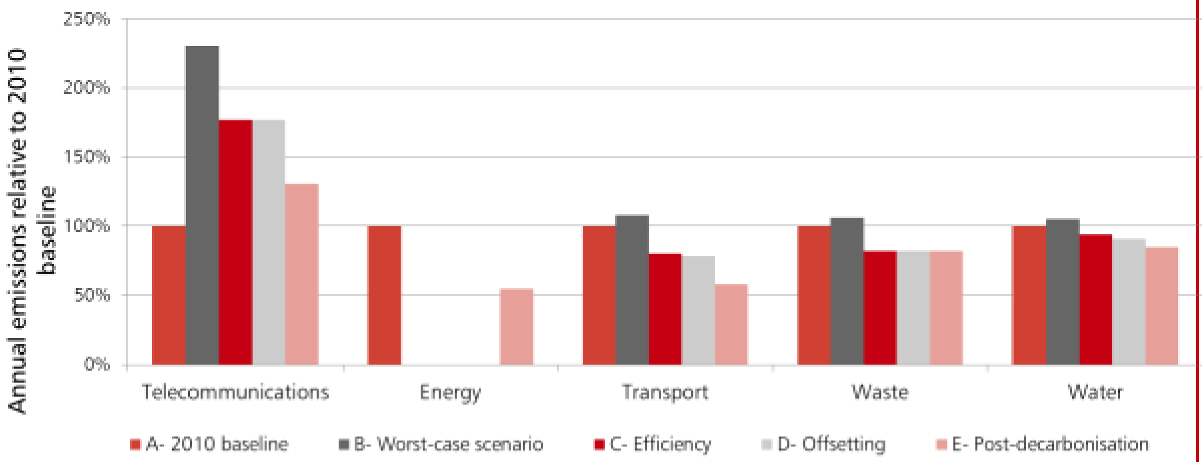
Operational carbon reduction

2.38 For most infrastructure sectors, OpCarb reduction is the most important as it essentially represents a running cost over the whole life of an asset. Decisions on the design of infrastructure will effectively lock in the OpCarb impact of an asset and this OpCarb can be more difficult to reduce during the operation and maintenance phases of an asset. Therfore it is essential to drive down OpCarb during the development phase of infrastructure assets.

2.39 This study has forecast potential OpCarb reductions for the different infrastructure sectors for 2025 and 2050 using a scenario-based approach. As with CapCarb reduction, the scenarios examined consider the effect the decarbonisation of the electricity grid could have on OpCarb reduction in the different infrastructure sectors. Since the effects of the grid decarbonisation will be most prominent in the long-term, it may be more cost effective for infrastructure providers to take action now to reduce their OpCarb in different ways and irrespectively of the progress made by the Energy Sector. The scenarios are:

- "Current footprint" (total OpCarb emissions in 2010)
- "Worst-case scenario" showing the OpCarb impact of each sector in the future without any action taken now to reduce this OpCarb
- "Efficiency" showing the potential in each sector to reduce OpCarb through energy and resource efficiency measures over the whole life of infrastructure assets
- "Offsetting" showing the potential of each sector to reduce the carbon intensity of their operational energy use and direct emissions through the deployment of low carbon technologies (e.g. renewable energy generation) and
- "Post-decarbonisation" showing the final impact on sector-specific OpCarb taking into account progress from the decarbonisation of the electricity grid. Chart 2.M: and Chart 2.N: and Table 2.F: and Table 2.G: summarise these forecasted reductions in 2025 and 2050.

Chart 2.M: OpCarb reduction potential by infrastructure sector – 2025 forecast in comparison to the 2010 baseline

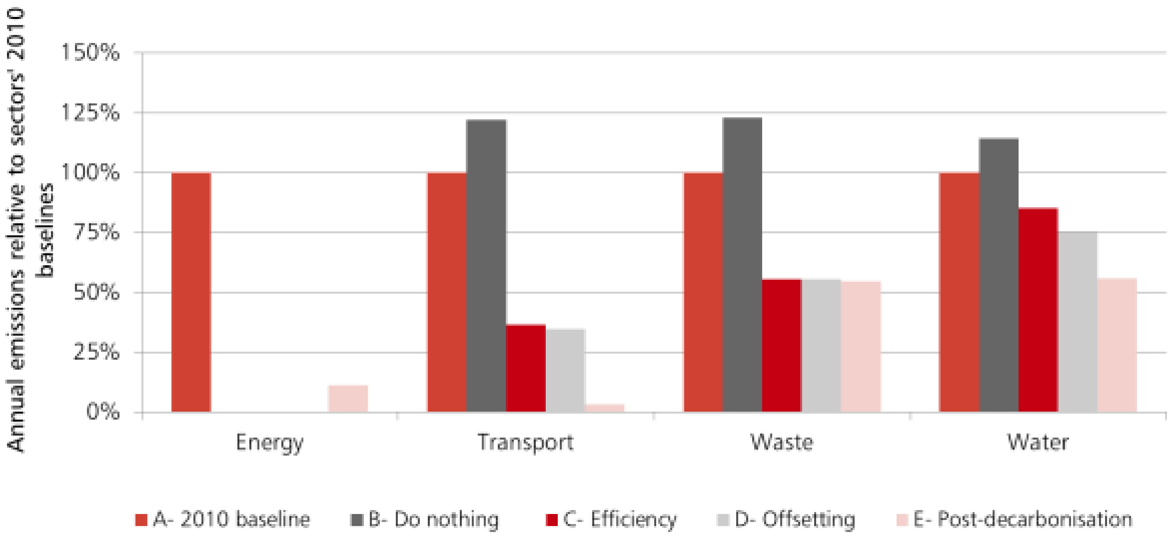


Source: Green Construction Board

Table 2.F: OpCarb reduction potential – 2025 in comparison to the 2010 baseline

	Energy		Comms		Transport		Waste		Water	
	$MtCO_2e/yr$	%	$MtCO_2e/yr$	%	$MtCO_2e/yr$	%	$MtCO_2e/yr$	%	$MtCO_2e/yr$	%
Current (2010)	125.2	100%	0.9	100%	0.4	100%	19.3	100%	4.9	100%
No action	n/a	n/a	2.1	230%	0.4	108%	20.5	106%	5.1	105%
Efficiency	n/a	n/a	1.6	177%	0.3	80%	15.8	82%	4.6	94%
Offsetting	n/a	n/a	1.6	177%	0.3	78%	15.8	82%	4.4	90%
Post - decarbonisation	67.9	54%	1.2	131%	0.2	58%	15.8	82%	4.1	85%

Chart 2.N: OpCarb reduction potential by infrastructure sector – 2050 forecast in comparison to the 2010 baseline



Note: no information available for Comms reduction potential in 2050

Source: Green Construction Board

Table 2.G: OpCarb reduction potential – 2050 in comparison to the 2010 baseline

	Energy		Comms		Transport		Waste		Water	
	$MtCO_2e/yr$	%	$MtCO_2e/yr$	%	$MtCO_2e/yr$	%	$MtCO_2e/yr$	%	$MtCO_2e/yr$	%
Current (2010)	125.2	100%	0.9	100%	0.4	100%	19.3	100%	4.9	100%
No action	n/a	n/a	-	-	0.5	122%	23.7	123%	5.6	114%
Efficiency	n/a	n/a	-	-	0.1	37%	10.7	56%	4.1	85%
Offsetting	n/a	n/a	-	-	0.1	35%	10.7	56%	3.7	75%
Post decarbonisation	14.2	11%	-	-	0.0	3%	10.6	55%	2.7	56%

Note: no information available for Comms reduction potential in 2050

2.40 The results show that in the short-term (2025), total OpCarb may reduce by less than 50% in all sectors, even if grid decarbonisation is taken into account. Most of the reductions are a result of implementing energy and resource efficiency measures as well as deployment of small scale renewable energy generation. The additional impact of the decarbonisation of the grid ranges between <1% and 20% depending on the sector considered. <1% is related mainly to the Waste sector where direct process emissions dominate and are independent of fossil fuel electricity. Such measures can range from replacing inefficient mechanical and electrical assets with newer more efficient technologies (such as opting for more variable speed drives in motors, more efficient motors, switching to LED lighting, opting for lower carbon chemicals, eliminating operational waste in processes and industrial operations, using real-time control systems to optimise operational energy use whilst maintaining levels of service, and others) to investing in small scale renewable energy generation integrated in infrastructure (such as capturing any heat from losses in a high voltage transmission network or a sewer network, capturing energy during the breaking of high-speed trains, generating renewable energy from capturing methane from waste processes or biogas from sewage treatment works, or simply installing small scale solar panels or wind turbines in buildings and other infrastructure assets, and others.

2.41 In 2050, the effect of the decarbonisation of the electricity grid will be greater, accounting for over a 30% contribution in OpCarb reduction, because of the assumed shift to electricity as fuel. Nevertheless, the impact of the “Efficiency” and “Offsetting” scenarios will have in infrastructure can still contribute to reductions between 25% and 65% by 2050 across the sectors. The biggest such contribution will be in the Transport sector where OpCarb reductions (mainly from street lighting) could be offset from the adoption of solar and wind energy and changes to more efficient technologies (such as LED lighting). Although in percentage terms this is relatively high, in real terms it is relatively small. Further information of sector-specific OpCarb is included in the Sector overview section in Chapter 2.

UseCarb reduction

2.42 UseCarb has the largest contribution in UK infrastructure related emissions, but the emissions associated with the end-users of infrastructure and can only be partly influenced by infrastructure asset owners and the wider value chain. These emissions are outside the scope of the Infrastructure Carbon Review, however, they are sufficiently important to address their reduction potential. UseCarb forecast reductions in 2025 and 2050 are sourced and by DECC’s Pathways 2050 model and further analysed as part of this study.

2.43 Reductions in UseCarb mainly relate to end-users becoming more efficient in the way they:

- benefit from infrastructure services (for example becoming less wasteful in the way they consume electricity and water or reducing household waste)
- choose more efficient ways of benefiting from infrastructure services (such as by selecting more energy efficient ways to use electricity, gas and water at home or through the use of more energy efficient communication devices)
- choose lower carbon infrastructure services (for example the selection of the different transport modes – such as using electric vehicles or rail, opting for flights that use less fossil transport fuels or renewable fuels and others). Although these choices are mainly determined by price, the message here is that end-users can have an influence on what services they chose and sometimes, and depending on end-user perceptions, these can be driven by environmental credentials.

UseCarb is forecast to be reduced by 25% (or by 92Mt/yr) by 2025 and 63% (or by 227Mt/yr) by 2050 as compared to the 358Mt/yr UseCarb in 2010. The majority of such reductions will be in the Energy Sector (75Mt/yr reductions by 2025 and 164Mt/yr reductions by 2050), mainly driven by the decarbonisation of the electricity grid and in the Transport Sector (16Mt/yr reductions by 2025 and 43Mt/yr reductions by 2050), mainly driven by the electrification of transport and efficiencies in combustion processes in aviation (as forecasted by DECC). Table 2.H:summarises the reduction potential in UseCarb in the different infrastructure sectors. More sector-specific information is summarised in the Sector Overview section of Chapter 2.

Table 2.H: UseCarb reduction forecast from 2010 – 2025 and 2050

Units in $MtCO_2e/yr$	Comms	Energy	Transport	Waste	Water	Total
2025 reduction forecast	1.3	74.8	16.2	0.0	0.0	92.3
% reduction from 2010 (2025)	20%	42%	10%	0%	0%	26%
2050 reduction forecast	5.5	164.1	43.3	0.0	14.4	227.3
% reduction from 2010 (2050)	88%	93%	28%	0%	75%	63%

2.44 Infrastructure providers can influence UseCarb emissions. The importance of this sector of emissions highlights that this should be taken into account when planning and taking decisions in relation to new infrastructure. Each sector has demonstrated that this can be influenced, through different types of measures.

2.45 In the Energy and Water sectors for example, through the adoption of smart meters to re-profile or manage demand, or through government incentives to incentivise the generation of renewable energy or energy efficiency in the home.

2.46 In transport, examples include modifications in the design of road gradients in motorways to reduce vehicle emissions or the influence of airport owners in reducing aircraft emissions when landed, through innovative fuel filling practices or air side ground based power provision for aircraft, changes in the layout of terminal buildings and landing corridors, and others.

2.47 Advancements in communication systems are the tools that can directly impact on end-user energy use and also support influencing consumer behaviour, through, for example, the development of smart grids and smart cities. A key challenge is how to involve end-users in the key decisions required in creating smart and lower carbon infrastructure to increase the ability/success of behavioural change. A lot of research has been done in this area and needs to be further explored.

The difference between building new infrastructure and maintaining existing infrastructure

2.48 The carbon reduction potential of new and existing infrastructure is likely to be quite different. As illustrated in Chart 2.L: most of the carbon savings are likely to be realised following a "build nothing" or a "build less" approach. In the case of new infrastructure the scope for such approaches may be more limited than in the case of maintaining and/or refurbishing existing infrastructure. In the latter the presence of existing assets may give more opportunity to asset owners for re-using and refurbishing existing older assets in order to extend their life.

2.49 When delivering new infrastructure in greenfield sites, CapCarb and OpCarb reductions may be limited to the "build clever" and "build efficiently" approaches, which mainly involve innovations in technology or materials choices as well as more efficient construction practices. Nevertheless, in asset heavy sectors, such as the Water and Transport sectors, existing assets may be more readily available to be refurbished and re-used to accommodate growth, thus avoiding the need to build new assets to maintain the same level of service. As an example, Anglian Water, amongst others, has shared example case studies demonstrating how the clever refurbishment of existing infrastructure can significantly reduce carbon. These can be seen on the Green Construction Board's website[9].

2.50 Conversely, the CapCarb and OpCarb in existing infrastructure have already been locked into the assets since their construction and carbon reductions may be limited to proactive asset management

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[9] http://www.greenconstructionboard.org/images/stories/FT_Low%20Carbon%20Construction%20in%20the%20UK%20Interactive.pdf, last accessed on 19.07.2013

practices. For example, through the frequent maintenance of existing mechanical and/or electrical components to avoid rapid deterioration and future increases in energy use or through proactive refurbishment of such components by installing more energy technologies (i.e. the "build clever" approach). Considering that approximately 34%[10] of the annual UK infrastructure spend is attributed to the maintenance and refurbishment of existing infrastructure, such reductions can have significant contributions to the overall reduction potential.

2.51 The scope for a "build nothing" or a "build less" approach may be more applicable to the refurbishment of existing infrastructure. For example, by introducing smart instrumentation systems to modify the functionality of existing assets, the latter can continue to provide existing or new services without the need for building new assets.

2.52 Asset management will inevitably become more important in reducing carbon in existing infrastructure and the increasing professionalization and maturity of the discipline of asset management can already be seen in the different infrastructure sectors.

Sector dependencies and unintended consequences

2.53 Although the carbon data analysis undertaken in this study attempts to clearly attribute carbon emissions in each infrastructure sector on the basis of control, in reality, there are strong interdependencies and carbon reduction at national scale would require cross-sector collaborative approaches. Examples of the latter could range from identifying the most cost-effective ways to source low carbon electricity to mainstreaming low carbon sector specific transport practices, creating cross-sector synergies for managing waste products in a low carbon way, or reducing critical water use in infrastructure assets, amongst others.

2.54 Of all the cross-sector dependencies, the most important, in terms of national carbon reductions, are the synergies between the Energy and Communications sectors with all other infrastructure sectors. The decarbonisation of the electricity grid, driven by the Energy sector, as well as the deployment of smarter data communication and control systems, driven by the Communications sector are core in driving OpCarb and UseCarb reductions in all sectors by creating smarter and more efficient infrastructure assets. CapCarb increases in these sectors, particularly when associated with technologies that enable carbon reductions can be justified when the benefits of significant OpCarb and UseCarb reductions outweigh such increases. For example from the increased deployment of renewable energy technologies, telecommunication data centres and instrumentation systems for real time control, amongst others. Nevertheless, CapCarb reductions should always be considered in these enabling sectors or technologies, by considering "build efficiently" or "build clever" approaches.

2.55 CapCarb and OpCarb reduction efforts should not be considered in isolation as there might be unintended consequences affecting a sector's whole life carbon impact or UseCarb. For example, if CapCarb reduction in infrastructure assets is achieved by opting to re-use an existing asset or by opting to use materials that have lower strength (and hence resource requirement) for a particular function, this could result in an increased asset replacement/refurbishment frequency which could increase whole life carbon.

2.56 Although the standardisation and off-site manufacturing of assets have resulted in Capex and CapCarb savings (mainly through the elimination of construction waste and improvements in construction programmes), the wider CapCarb impact of such practices must carefully considered since there might be emissions associated with the transport of such products which are hidden or not correctly reported. In addition, increased standardisation might prevent design teams continuing

[10] Source: ONS 2010 construction output tables

to innovate and as a result the full CapCarb reduction potential in next generation infrastructure assets might not be realised in the long-term.

2.57 CapCarb reduction efforts may also have a negative effect on OpCarb or UseCarb. For example, when a smaller diameter pipeline is selected in a water pumping system (which would have a lower CapCarb), the friction losses in the overall system would be greater hence OpCarb would increase. In the transport sector for example, if lower carbon coatings, which require more frequent maintenance, are selected for the refurbishment of a bridge, future traffic management practices may result in UseCarb increases due to fossil fuelled road vehicles may not be operating at their optimum combustion efficiency, due to lower travel speeds and frequent engine start / stops.

2.58 Unintended consequences affecting UseCarb may also occur when the focus is solely on carbon reduction in infrastructure assets. For example avoiding to include an additional station in a new low carbon public transport system, to avoid the additional resulting CapCarb and OpCarb, might affect end-user mode choice and increase UseCarb (by end-users still having to use their fossil fuelled vehicles to reach an existing station located at a greater distance, or avoiding using the new public transport system altogether). UseCarb should therefore be consider when assessing the overall carbon impact of infrastructure assets.

Sector overview

2.59 This section includes an introduction to how or whether carbon reduction is considered in the decision-making of the different infrastructure sectors as well as a breakdown of 2010 sector-specific emissions (CapCarb, OpCarb and UseCarb) and a summary of carbon reduction forecasts for 2025 and 2050. These are the results of the data analysis undertaken as part of this study. The principal information source for future carbon reduction projections has been DECC's Pathways 2050 Calculator. Chapter 3 details any assumptions for deriving current and future emission data and any other key sources of information used.

Box 2.A: Communications

Carbon reduction in decision-making

During the last few years, the Communications sector has been able to achieve significant energy savings through more efficient data centres and server virtualisation, but these techniques have had less effect in the telecoms sector. Whilst data centres can often be located in places where renewable energy is plentiful or cooling is cheap, telecoms equipment typically has to be located close to where the services are required. Although equipment vendors are constantly improving their products, relentless increases in the demand for bandwidth caused by the dramatic growth in digital content has driven up energy consumption in the telecoms sector. Indeed, it has recently been suggested that ambitious government plans to increase broadband availability could have the unintended effect of forcing public and private sector ICT to consume unsustainable amounts of energy, requiring an exponential growth in power generation.

Carbon emissions baseline -2010

The main inclusions in the estimation of OpCarb and UseCarb are:

- OpCarb: Wireless, home and transport network electricity consumption
- UseCarb: Enterprise network, data centre and user device electricity consumption

(refer to Chapter 3 for CapCarb methodology and further details on inclusions)

Communications 2010 CapCarb

All units MtCO2e/yr	Emissions	% UK Comms emissions	% UK Infra CapCarb
Total - Comms CapCarb	0.9	11%	**15%**

Communications 2010 OpCarb

All units MtCO2e/yr	Emissions	% UK Comms OpCarb	% UK Comms emissions	% UK Infra OpCarb
Wireless networks	0.2	23%	3%	**0%**
Home networks	0.6	63%	7%	**0%**
Data transport	0.1	14%	2%	**0%**
Total - Comms OpCarb	0.9	100%	11%	**1%**

Communications 2010 UseCarb

All units MtCO2e/yr	Emissions	% UK Comms UseCarb	% UK Comms emissions	% UK Infra UseCarb
Data centres	2.0	31%	24%	**1%**
Enterprise networks	0.2	3%	2%	**0%**
End-user devices	4.1	66%	51%	**1%**
Total - Comms UseCarb	6.3	100%	78%	**2%**

Carbon reduction forecast

2025

Communications 2025 CapCarb

All units MtCO2e/yr	Emissions	% UK Comms emissions	% UK Infra CapCarb
Total - Comms CapCarb	0.9	12%	**14%**

Communications 2025 OpCarb

All units MtCO2e/yr	Emissions	% UK Comms OpCarb	% UK Comms emissions	% UK Infra OpCarb
Wireless networks	0.4	34%	6%	**0%**
Home networks	0.3	28%	5%	**0%**
Data transport	0.4	37%	6%	**0%**
Total - Comms OpCarb	1.2	100%	17%	**1%**

Communications 2025 UseCarb

All units MtCO2e/yr	Emissions	% UK Comms UseCarb	% UK Comms emissions	% UK Infra UseCarb
Data centres	2.8	55%	39%	**1%**
Enterprise networks	0.2	4%	3%	**0%**
End-user devices	1.9	39%	28%	**1%**
Total - Comms UseCarb	5.0	100%	71%	**2%**

Box 2.B: Energy

Carbon reduction in decision-making

In the energy sector there has been reporting of operational emissions of the majority of generators due to the EU Emissions Trading Scheme requirements. The EU ETS has gone some way to establishing a market for delivering efficiencies and lower carbon generation. In addition there are UK specific incentives to reduce emissions by promoting renewable technologies, namely the Renewables Obligation and Feed In Tariffs. The Carbon Reduction Commitment also applies to large consumers of energy, under which energy use attracts further financial penalties which aim to increase efficiency. The new Electricity Market Reform package as part of the Energy Bill 2013, will introduce new mechanisms to further reduce emissions including Contract for Difference and an Emissions Performance Standard for new generating plant.

Carbon emissions baseline -2010

The main inclusions in the estimation of OpCarb and UseCarb are:

- OpCarb: All losses from production and supply of electricity and natural gas
- UseCarb: Energy use not accounted for in other infrastructure sectors

(refer to Chapter 3 for CapCarb methodology and further details on inclusions)

Energy 2010 CapCarb

All units MtCO2e/yr	Emissions	% UK Energy CapCarb	% UK Energy emissions	% UK Infra CapCarb
Electricity	1.2	78%	0%	**20%**
Gas	0.3	22%	0%	**6%**
Total - Energy CapCarb	1.5	60%	0%	**25%**

Energy 2010 OpCarb

All units MtCO2e/yr	Emissions	% UK Energy OpCarb	% UK Energy emissions	% UK Infra OpCarb
Electricity - Thermal losses	105.2	84%	35%	**70%**
Electricity - T&D losses	5.6	4%	2%	**4%**
Gas - T&D losses, own use	14.4	11%	5%	**10%**
Total - Energy OpCarb	125.2	100%	41%	**83%**

Energy 2010 UseCarb

All units MtCO2e/yr	Emissions	% UK Energy UseCarb	% UK Energy emissions	% UK Infra UseCarb
Electricity consumption	53.1	30%	17%	**15%**
Gas consumption	123.7	70%	41%	**35%**
Total - Energy UseCarb	176.7	100%	58%	**49%**

Carbon reduction forecast

2025

Energy 2025 CapCarb

All units MtCO2e/yr	Emissions	% UK Energy CapCarb	% UK Energy emissions	% UK Infra CapCarb
Electricity	1.9	85%	1%	**29%**
Gas	0.3	15%	0%	**5%**
Total - Energy CapCarb	2.2	100%	1%	**34%**

Energy 2025 OpCarb

All units MtCO2e/yr	Emissions	% UK Energy OpCarb	% UK Energy emissions	% UK Infra OpCarb
Electricity - Thermal losses	63.2	93%	37%	**71%**
Electricity - T&D losses	4.1	6%	2%	**5%**
Gas - T&D losses, own use	0.6	1%	0%	**1%**
Total - Energy OpCarb	67.9	100%	39%	**76%**

Energy 2025 UseCarb

All units MtCO2e/yr	Emissions	% UK Energy UseCarb	% UK Energy emissions	% UK Infra UseCarb
Electricity consumption	46.3	45%	27%	**17%**
Gas consumption	55.7	55%	32%	**21%**
Total - Energy UseCarb	101.9	100%	59%	**38%**

2050

Energy 2050 CapCarb

All units MtCO2e/yr	Emissions	% UK Energy CapCarb	% UK Energy emissions	% UK Infra CapCarb
Electricity	1.7	85%	6%	**28%**
Gas	0.3	15%	1%	**5%**
Total - Energy CapCarb	2.0	100%	7%	**33%**

Energy 2050 OpCarb

All units MtCO2e/yr	Emissions	% UK Energy OpCarb	% UK Energy emissions	% UK Infra OpCarb
Electricity - Thermal losses	13.5	96%	47%	**49%**
Electricity - T&D losses	0.6	4%	2%	**2%**
Gas - T&D losses, own use	0.0	0%	0%	**0%**
Total - Energy OpCarb	14.2	100%	49%	**51%**

Energy 2050 UseCarb

All units MtCO2e/yr	Emissions	% UK Energy UseCarb	% UK Energy emissions	% UK Infra UseCarb
Electricity consumption	6.3	50%	22%	**5%**
Gas consumption	6.3	50%	22%	**5%**
Total - Energy UseCarb	12.6	100%	44%	**10%**

Box 2.C: Transport

Carbon reduction in decision-making

The government is taking steps to reduce carbon emissions from all forms of transport in the UK. The Department for Transport sets out the following carbon related priorities in relation to the work it undertakes:

- encouraging sustainable local travel
- promoting lower carbon transport, such as walking and cycling as well as introducing more environmentally-friendly buses and trains
- supporting the development of the market for electric and other ultra-low emission vehicles

These priorities are reflected in a number of DfT's actions and initiatives, including the Local Sustainable Transport Fund, a £600m fund made available to fund a number of local authority sustainable transport schemes to be delivered between 2011 and 2015, and their support for the development of ultra low emission vehicles through the Office for Low Emission Vehicles (OLEV). As an operational agency of the Department for Transport, the Highways Agency has developed a carbon calculation methodology for collecting and calculating their carbon emissions and plans to use this data to inform whole life design decisions from a carbon perspective. In addition it is working with Network Rail and supply chain partners to develop a framework that enables the whole life carbon impact of a major infrastructure project to be managed or influenced.

Carbon emissions baseline -2010

The main inclusions in the estimation of OpCarb and UseCarb are:

- OpCarb: Public lighting electricity consumption
- UseCarb: All vehicle energy consumption, including international aviation and shipping.

(refer to Chapter 3 for CapCarb methodology and further details on inclusions)

Transport 2010 CapCarb

All units MtCO2e/yr	Emissions	% UK Transport CapCarb	% UK Transport emissions	% UK Infra CapCarb
Road	1.2	51%	1%	**21%**
Rail	0.9	36%	1%	**15%**
Shipping	0.2	6%	0%	**3%**
Aviation	0.2	7%	0%	**3%**
Total - Transport CapCarb	2.5	100%	1%	**42%**

Transport 2010 OpCarb

All units MtCO2e/yr	Emissions	% UK Transport OpCarb	% UK Transport emissions	% UK Infra OpCarb
Street lighting on public roads	0.4	100%	0%	**0%**
Rail	N/A	N/A	N/A	N/A
Shipping	N/A	N/A	N/A	N/A
Aviation	N/A	N/A	N/A	N/A
Total - Transport OpCarb	0.4	100%	0%	0%

Transport 2010 UseCarb

All units MtCO2e/yr	Emissions	% UK Transport UseCarb	% UK Transport emissions	% UK Infra UseCarb
Road - Cars	80.7	52%	46%	**23%**
Road - Buses	5.7	4%	3%	**2%**
Road - Freight	17.2	11%	10%	**5%**
Road - Total	103.7	66%	59%	**29%**
Rail - Diesel	2.3	1%	1%	**1%**
Rail - Electric	0.8	0%	0%	**0%**
Rail - Total	3.1	2%	2%	**1%**
Shipping - Domestic	6.4	4%	4%	**2%**
Shipping - International	8.9	6%	5%	**2%**
Shipping - Total	15.3	10%	9%	**4%**
Aviation - Domestic	2.2	1%	1%	**1%**
Aviation - International	31.9	20%	18%	**9%**
Aviation - Total	34.1	22%	20%	**10%**
Total - Transport UseCarb	156.1	100%	90%	**44%**

Carbon reduction potential forecast (summary)

2025

Transport 2025 CapCarb

All units MtCO2e/yr	Emissions	% UK Transport CapCarb	% UK Transport emissions	% UK Infra CapCarb
Road	1.0	46%	1%	**16%**
Rail	0.9	41%	1%	**14%**
Shipping	0.1	6%	0%	**2%**
Aviation	0.2	7%	0%	**3%**
Total - Transport CapCarb	2.2	100%	2%	**34%**

Transport 2025 OpCarb

All units MtCO2e/yr	Emissions	% UK Transport OpCarb	% UK Transport emissions	% UK Infra OpCarb
Road	0.2	100%	0%	**0%**
Rail	N/A	N/A	N/A	N/A
Shipping	N/A	N/A	N/A	N/A
Aviation	N/A	N/A	N/A	N/A
Total - Transport OpCarb	0.2	100%	0%	0%

Transport 2025 UseCarb

All units MtCO2e/yr	Emissions	% UK Transport UseCarb	% UK Transport emissions	% UK Infra UseCarb
Road - Cars	46.8	33%	33%	**18%**
Road - Buses	5.0	4%	4%	**2%**
Road - Freight	11.9	9%	8%	**4%**
Road - Total	63.7	46%	45%	**24%**
Rail - Diesel	2.2	2%	2%	**1%**
Rail - Electric	0.7	1%	1%	**0%**
Rail - Total	2.9	2%	2%	**1%**
Shipping - Domestic	7.3	5%	5%	**3%**
Shipping - International	19.5	14%	14%	**7%**
Shipping - Total	26.8	19%	19%	**10%**
Aviation - Domestic	3.0	2%	2%	**1%**
Aviation - International	43.5	31%	31%	**16%**
Aviation - Total	46.4	33%	33%	**17%**
Total - Transport UseCarb	139.9	100%	98%	**53%**

2050

Transport 2050 CapCarb

All units MtCO2e/yr	Emissions	% UK Transport CapCarb	% UK Transport emissions	% UK Infra CapCarb
Road	0.7	37%	1%	**11%**
Rail	0.9	50%	1%	**15%**
Shipping	0.1	5%	0%	**1%**
Aviation	0.2	8%	0%	**3%**
Total - Transport CapCarb	1.9	100%	2%	**30%**

Transport 2050 OpCarb

All units MtCO2e/yr	Emissions	% UK Transport OpCarb	% UK Transport emissions	% UK Infra OpCarb
Road	0.0	100%	0%	**0%**
Rail	N/A	N/A	N/A	N/A
Shipping	N/A	N/A	N/A	N/A
Aviation	N/A	N/A	N/A	N/A
Total - Transport OpCarb	0.0	100%	0%	0%

Transport 2050 UseCarb

All units MtCO2e/yr	Emissions	% UK Transport UseCarb	% UK Transport emissions	% UK Infra UseCarb
Road - Cars	9.2	8%	8%	**7%**
Road - Buses	4.3	4%	4%	**3%**
Road - Freight	5.5	5%	5%	**4%**
Road - Total	19.0	17%	17%	**14%**
Rail - Diesel	0.5	0%	0%	**0%**
Rail - Electric	0.1	0%	0%	**0%**
Rail - Total	0.7	1%	1%	**1%**
Shipping - Domestic	8.7	8%	8%	**7%**
Shipping - International	33.0	29%	29%	**25%**
Shipping - Total	41.7	37%	36%	**32%**
Aviation - Domestic	3.5	3%	3%	**3%**
Aviation - International	48.1	43%	42%	**37%**
Aviation - Total	51.5	46%	45%	**39%**
Total - Transport UseCarb	112.8	100%	98%	**86%**

Box 2.D: Waste

Carbon reduction in decision-making

Carbon reduction is not generally a major part of the decision making of waste management companies and there is not a formal carbon reporting system. However, the EU Waste Framework Directive limits the amount of waste that can be sent to landfill in all EU countries, which therefore limits the carbon impact. Until 2012 the UK had limits to the amount of biodegradable municipal waste which could be sent to landfill and fines of £150-£200/tonne of biodegradable waste sent to landfill over the limits. The limits reduced year on year to 2021/22. However, with the introduction and ramp up of landfill tax there was sufficient motivation for landfill diversion that the fines were abolished.

In Local Authority procurement projects an Environment Agency (EA) software tool, WRATE, is used to compare proposals from a carbon equivalent perspective. Each bid is awarded a score, usually based on how much better the proposal is to a "do nothing" scenario. The use of WRATE is generally only in public sector procurement.

Carbon emissions baseline -2010

The main inclusions in the estimation of OpCarb and UseCarb are:

- OpCarb: Direct process emissions and energy consumption for all waste
- UseCarb: None identified

(refer to Chapter 3 for CapCarb methodology and further details on inclusions)

Waste 2010 CapCarb

All units MtCO2e/yr	Emissions	% UK Waste emissions	% UK Infra CapCarb
Total - Waste CapCarb	0.1	1%	**2%**

Waste 2010 OpCarb

All units MtCO2e/yr	Emissions	% UK Waste OpCarb	% UK Waste emissions	% UK Infra OpCarb
Direct releases	15.0	78%	77%	**10%**
Transport-related emissions	2.0	11%	11%	**1%**
Electricity consumption	0.1	1%	1%	**0%**
Other fuel consumption	2.1	11%	11%	**1%**
Total - Waste OpCarb	19.3	100%	99%	**13%**

Carbon reduction forecast

2025

Waste 2025 CapCarb

All units MtCO2e/yr	Emissions	% UK Waste emissions	% UK Infra CapCarb
Total - Waste CapCarb	0.1	0%	**1%**

Waste 2025 OpCarb

All units MtCO2e/yr	Emissions	% UK Waste OpCarb	% UK Waste emissions	% UK Infra OpCarb
Direct releases	12.7	81%	80%	**14%**
Transport-related emissions	1.3	8%	8%	**1%**
Electricity consumption	0.1	1%	1%	**0%**
Other fuel consumption	1.7	11%	11%	**2%**
Total - Waste OpCarb	15.8	100%	100%	**18%**

2050

Waste 2050 CapCarb

All units MtCO2e/yr	Emissions	% UK Waste emissions	% UK Infra CapCarb
Total - Waste CapCarb	0.0	0%	**0%**

Waste 2050 OpCarb

All units MtCO2e/yr	Emissions	% UK Waste OpCarb	% UK Waste emissions	% UK Infra OpCarb
Direct releases	8.3	79%	79%	**30%**
Transport-related emissions	0.9	9%	9%	**3%**
Electricity consumption	0.0	0%	0%	**0%**
Other fuel consumption	1.3	12%	12%	**5%**
Total - Waste OpCarb	10.6	100%	100%	**38%**

Box 2.E: Water

Carbon reduction in decision-making

In the water sector, particularly in England and Wales and Scotland, there has been a strong regulatory structure and clearly defined vision towards a lower carbon industry. Since 2009, water companies have been subject to mandatory CapCarb and OpCarb emissions reporting using a sector-specific methodology (developed by UKWIR).

There are no formal sector-specific carbon reduction targets in the water sector. Furthermore, no sector-specific regulatory incentives currently exist to promote carbon reduction or linking the latter to company performance. Nevertheless, carbon performance KPIs are currently being considered by the economic regulator in England and Wales amongst other comparative measures. Carbon reduction is mainly led by individual companies and carbon reduction measures in regulated capital are adopted if they are cost-beneficial or if they are linked to other direct business benefits. Water companies are also participants in the CRC scheme, hence there is an additional drive to reduce OpCarb emissions linked to energy use.

Carbon emissions baseline – 2010

The main inclusions in the estimation of OpCarb and UseCarb are:

- OpCarb: Direct process emissions, transport and energy consumption for water supply and water, wastewater and sludge treatment
- UseCarb: Energy use for heating water

(refer to Chapter 3 for CapCarb methodology and further details on inclusions)

Water 2010 CapCarb

All units MtCO2e/yr	Emissions	% UK Water CapCarb	% UK Water emissions	% UK Infra CapCarb
Water	0.6	0.7	3%	**11%**
Sewerage	0.3	0.3	1%	**5%**
Total - Water CapCarb	0.9	1.0	4%	**16%**

Water 2010 OpCarb

All units MtCO2e/yr	Emissions	% UK Water OpCarb	% UK Water emissions	% UK Infra OpCarb
Direct releases	2.8	58%	11%	**2%**
Transport-related emissions	0.6	12%	2%	**0%**
Electricity consumption	1.1	23%	4%	**1%**
Other fuel consumption	0.4	8%	2%	**0%**
Total - Water OpCarb	4.9	100%	19%	**3%**

Water 2010 UseCarb

All units MtCO2e/yr	Emissions	% UK Water UseCarb	% UK Water emissions	% UK Infra UseCarb
Water heating - Electricity	2.0	11%	8%	**1%**
Water heating - gas	15.2	79%	61%	**4%**
Water heating - other fuels	2.0	10%	8%	**1%**
Total - Water UseCarb	19.2	100%	77%	**5%**

Carbon reduction forecast

2025

Water 2025 CapCarb

All units MtCO2e/yr	Emissions	% UK Water CapCarb	% UK Water emissions	% UK Infra CapCarb
Water	0.8	0.8	3%	**13%**
Sewerage	0.2	0.2	1%	**4%**
Total - Water CapCarb	1.1	1.0	4%	**17%**

Water 2025 OpCarb

All units MtCO2e/yr	Emissions	% UK Water OpCarb	% UK Water emissions	% UK Infra OpCarb
Direct releases	2.8	67%	11%	**3%**
Transport-related emissions	0.4	9%	1%	**0%**
Electricity consumption	0.8	20%	3%	**1%**
Other fuel consumption	0.2	4%	1%	**0%**
Energy consumption	1.0	24%	4%	**1%**
Total - Water OpCarb	4.1	100%	17%	**5%**

Water 2025 UseCarb

All units MtCO2e/yr	Emissions	% UK Water UseCarb	% UK Water emissions	% UK Infra UseCarb
Water heating - Electricity	2.6	13%	10%	**1%**
Water heating - gas	14.2	74%	58%	**5%**
Water heating - other fuels	2.4	13%	10%	**1%**
Total - Water UseCarb	19.2	100%	79%	**7%**

2050

Water 2050 CapCarb

All units MtCO2e/yr	Emissions	% UK Water CapCarb	% UK Water emissions	% UK Infra CapCarb
Water	1.2	0.9	14%	**20%**
Sewerage	0.2	0.1	2%	**3%**
Total - Water CapCarb	1.4	1.0	16%	**23%**

Water 2050 OpCarb

All units MtCO2e/yr	Emissions	% UK Water OpCarb	% UK Water emissions	% UK Infra OpCarb
Direct releases	2.4	89%	27%	**9%**
Transport-related emissions	0.3	10%	3%	**1%**
Electricity consumption	0.1	4%	1%	**0%**
Other fuel consumption	-0.1	-2%	-1%	**0%**
Energy consumption	0.0	1%	0%	**0%**
Total - Water OpCarb	2.7	100%	30%	**10%**

Water 2050 UseCarb

All units MtCO2e/yr	Emissions	% UK Water UseCarb	% UK Water emissions	% UK Infra UseCarb
Water heating - Electricity	0.5	11%	6%	**0%**
Water heating - gas	0.0	0%	0%	**0%**
Water heating - other fuels	4.3	89%	48%	**3%**
Total - Water UseCarb	4.8	100%	54%	**4%**

Carbon reduction: cost reduction and economic value

2.60 Through selected case studies, the Main Report makes a case that there is a link between carbon reduction and cost reduction when considering the delivery or operation of new infrastructure assets. In reality, the relationship between carbon reduction and cost reduction is complicated. This section aims to provide additional clarity on this subject.

2.61 "Reducing carbon, reduces cost" is a core message in the Main Report that communicates an important principle about resource and energy efficiency in a clear and simple way. However, the reality of the connection between carbon and cost is complex and not all reductions in carbon inevitably lead to reduced cost.

2.62 As outlined in Chapter 1, there are pull and push factors for carbon reduction. Push factors, triggered by government policy, require public and upfront private sector investment to achieve carbon reduction. In this sense carbon reduction means an increase in cost. From a UK-wide perspective an emissions reduction of 80% by 2050 is has been forecasted, by the Committee on Climate Change, that it will equate to a cost of 1-2% of the national GDP in 2050[11]. Nonetheless, such cost is justified on the basis that carbon reduction is required in order to avoid long term economic impacts to the UK, linked to severe effects of Climate Change. Pull related factors, generally imply a correlation between carbon reduction and cost reduction through avoiding carbon related taxes, reducing fossil fuel electricity use, and associated costs, or using less resource when constructing or maintaining infrastructure assets.

2.63 Carbon reduction measures in infrastructure assets can be cost positive, zero cost or cost negative on a whole life basis. This can be illustrated graphically with the use of Marginal Abatement Cost of Carbon (MACC) curves (Chart 2.O:, which were originally developed by McKinsey. MACC curves analyse and prioritise the options available for reducing carbon and the marginal abatement costs associated with their implementation. The marginal abatement cost is the implementation cost to reduce one tonne of carbon.

2.64 Chart 2.O: shows a MACC curve for the UK as published by CBI in 2007[12]. The curve illustrates that there are cost negative and cost positive measures to reduce each tonne of carbon in the UK, in a particular year (the measures above the horizontal axis are cost positive). Each measure's reduction potential is represented by the width of each bar (in $MtCO_2e$). The curve indicates that depending on

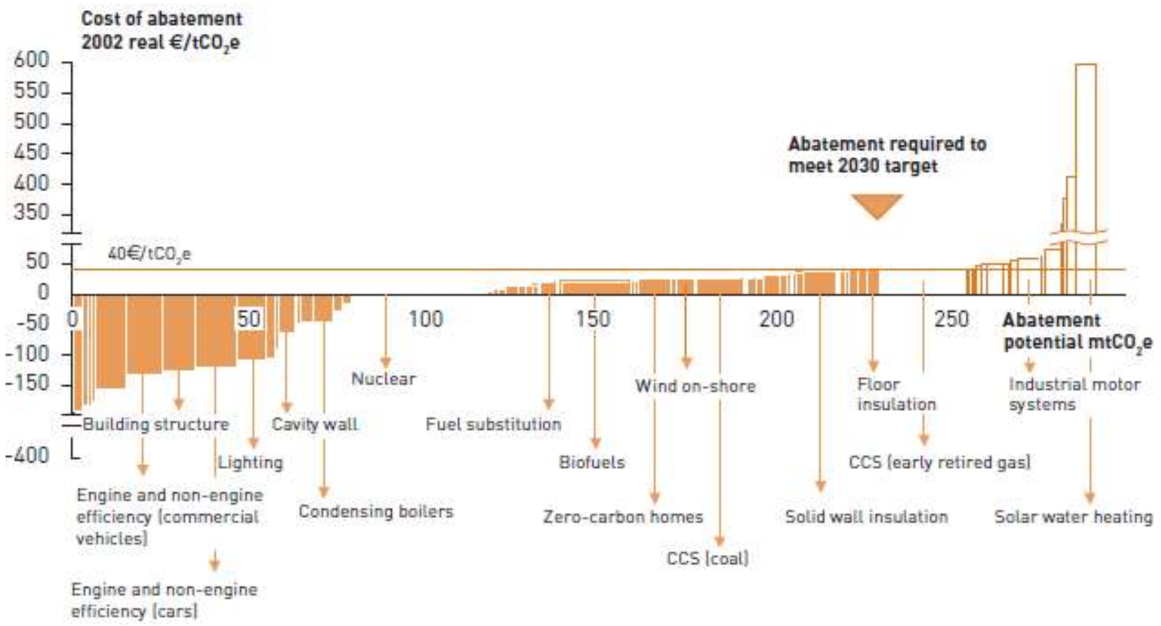
[11] "Building a low-carbon economy – the UK's contribution to tackling climate change", Committee on Climate Change, 2008. http://www.theccc.org.uk/publication/building-a-low-carbon-economy-the-uks-contribution-to-tackling-climate-change-2/ (last accessed on 19.07.13)

[12] CBI Climate Change Task Force, "Climate change: Everyone's business" (2007)

the price of carbon (for example £40/tonne in 2030), some of the cost positive measures are becoming cost-beneficial to implement.

2.65 Although there are many limitations in the development and use of MACC curves, particularly to inform policy making, and can involve complex economic analysis, they can been used in a more simplistic way at organisational level (such as the case of Royal Mail, NHS and others) to rank the types of carbon reduction measures applicable to their organisation according to their whole life costs and reduction potential for a particular period in time. Infrastructure asset owners can also consider adopting this approach to see which carbon reduction measures they can implement that are linked to cost reduction in their organisation, either now (i.e. the measures below the horizontal axis) or in the future (i.e. depending on how they are likely to be affected by carbon pricing mechanism that impacts their operational costs, such as the Carbon Reduction Commitment, the EU Emissions Trading Scheme or others).

Chart 2.O: UK Marginal Abatement Cost of Carbon (MACC) Curve



Source: CBI Climate Change Task Force, "Climate change: Everyone's business" (2007), analysis by McKinsey & Co

2.66 CapCarb reduction is generally linked to resource efficiency. The less resource used for the manufacturing of materials or construction methods to deliver new infrastructure assets, the lower the resulting CapCarb and the lower the capital cost. Reducing the amount of resources in infrastructure, therefore results in CapCarb reduction.

2.67 Noting that CapCarb of one organisation is the OpCarb of another (for example the energy requirements for manufacture of construction materials are OpCarb for the materials manufacturer, but CapCarb for the asset owner using this material to build new infrastructure). If this OpCarb is priced then it could influence choice in the materials selection in infrastructure, based on CapCarb.

2.68 OpCarb reduction can also be linked to resource efficiency, particularly when focusing on emissions from operational energy use or other consumables (for example chemical use) to operate new or existing infrastructure. The more energy efficient an asset is or the less other operating resources are being used, the lower the OpCarb and Opex. Similarly, the recovery of energy that would be otherwise wasted in operational infrastructure (for example, spare kinetic and dynamic energy in moving water, wasted heat from sewers or from the friction resulting from the braking of high-speed trains or cars) can also result in OpCarb or UseCarb reduction, through the deployment of energy recovery technologies (for example, small hydro-turbines in existing water mains, heat pumps in sewers or buried HV cables, amongst others). Although such measures require an upfront investment, the benefits over the whole life of an infrastructure asset may prove for such measures to be overall cost beneficial. Such upfront investment is effectively less if the inefficient assets need replacing anyway because they are old. Reductions in operating costs in this sense can therefore be the result of reduced energy costs (either through consuming less energy or generating own energy independent of volatile grid electricity prices), reduced resources to operate assets or reduced carbon costs that directly affect an organisation (such as is the case for the Carbon Reduction Commitment Energy Efficiency Scheme).

2.69 Given the above there can be a correlation between CapCarb and Capex reduction and OpCarb and Opex reduction. Such relationship, however, is not necessarily a causation where carbon reduction is the primary driver for reducing cost. Infrastructure owners that were consulted as part of this study, expressed the view that carbon reduction targets adopted in their organisation, encouraged their teams to look at infrastructure delivery through a different lens and focused their cost reduction efforts on finding innovative ways for reducing capital or operational resource use, instead of keeping the focus solely on the reduction of margins or labour costs in the lower tiers of the supply chain. Other consultees representing equipment or material suppliers believed that keeping a focus on carbon reduction has enabled them to better understand where operational inefficiencies are in their organisation (from their manufacturing processes to the way they manage their supply chain). The adoption of carbon reduction targets has driven them to become more innovative and eliminate such waste and to become more competitive in the market place.

2.70 As mentioned in previous sections of the report, if CapCarb/Capex reduction is achieved in isolation, there might be unintended consequences that may increase OpCarb and Opex over the life of an asset - this could increase the whole life cost. It is therefore important to consider carbon and cost reduction on a whole life basis.

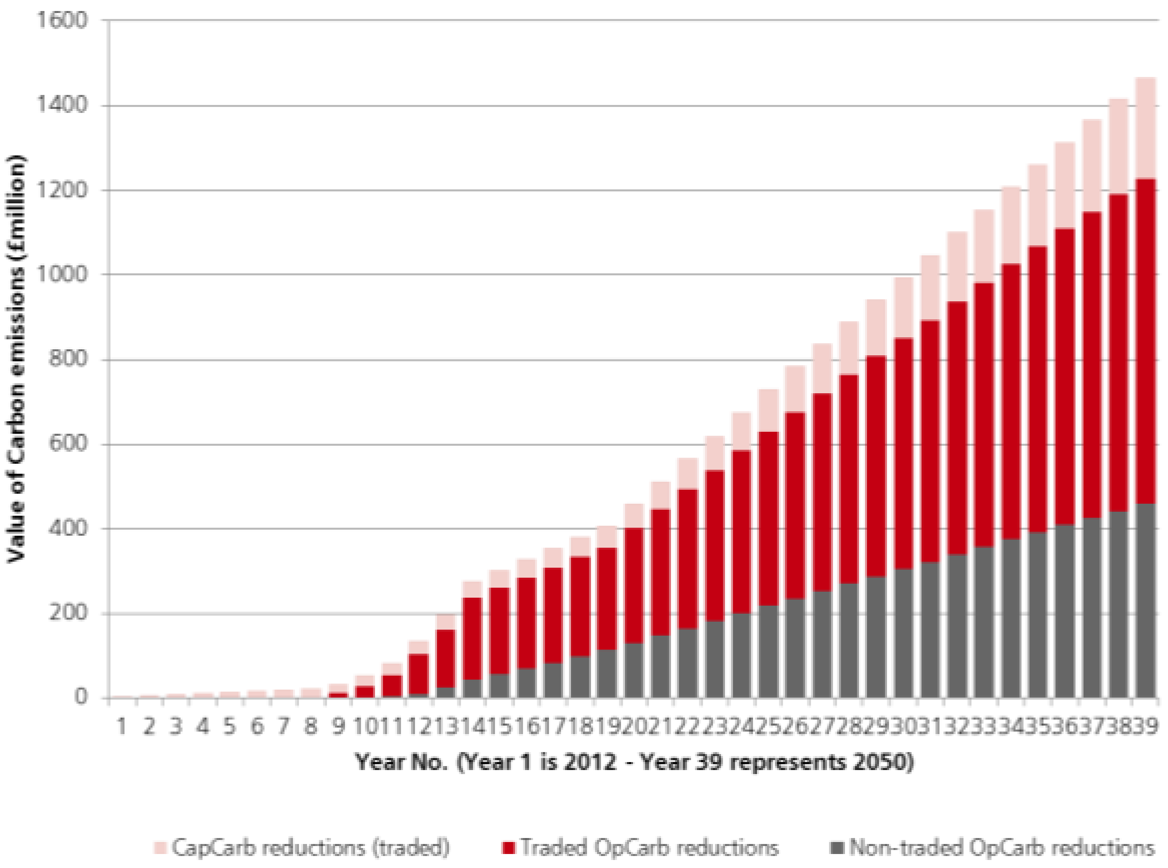
2.71 When considering carbon reduction targets in an organisation, it is important to understand the short and long-term cost implications of meeting these targets. As shown in the MACC curve example in Chart 2.O:, it is important to understand the total reduction potential of the cost-negative carbon reduction measures and whether such reduction would be sufficient to meet any carbon reduction targets. If for example any carbon reduction targets set are too ambitiously (if also reflecting a low carbon price), then the organisation needs to understand that cost-positive measures may need to be adopted to meet these targets. Setting overly-ambitious targets, if current and future cost implications are not thoroughly assessed, could therefore result in increased overall costs for an organisation.

2.72 Carbon could also be valued in economic terms to assess what net benefits (if any) could be brought to the UK economy if carbon reduction was achieved in the long-term. Such monetary value is separate to any cost savings achieved that are mainly linked to reductions in the resources used to build and operate new infrastructure. A high-level carbon valuation has been carried out on the potential CapCarb and OpCarb reductions from UK infrastructure between 2010 and 2050. The valuation methodology has adopted DECC's guidelines and has valued any carbon reductions using traded and non-traded carbon price forecasts for years 2010 to 2050.

2.73 Results show that UK infrastructure has the potential to achieve 3.5MtCO_2e/yr CapCarb and 20MtCO_2e/yr OpCarb reductions by 2050. Such reductions incorporate the effects of the decarbonisation of the electricity grid as well as efficiencies in materials production and design and construction practices. OpCarb reductions also assume reductions in infrastructure sectors as projected in the OpCarb reduction section above.

2.74 Such reductions could be monetised using UK current and future carbon price projections (as developed by DECC) for emissions in the traded and non-traded carbon markets. Using a discount rate of 3.5% for the first 30 years (2012 – 2042) and 3.0% until 2050[13], the monetary value of the UK infrastructure CapCarb and OpCarb reductions in 2050 is forecast to be £1.46 billion (in 2013 prices). The value of cumulative reductions between 2010 and 2050 is forecast to be £3.1 billion for CapCarb and £18.6 billion for OpCarb. Such forecasts assume that most CapCarb emissions fall under the EU Emissions Trading Scheme (i.e. the traded carbon market), since they are associated with energy use in the supply chain, whereas 37% of OpCarb emissions fall under the non-traded carbon market (reflecting the proportion of emissions that are not related to energy use). The monetised value of OpCarb is higher than the value of CapCarb. This is illustrated in Chart 2.P. It can also be observed that the majority of the benefits arise mainly in the future.

Chart 2.P: Chart



Source: Green Construction Board

2.75 Assessing the economic impact of these carbon savings to the UK is not a straight-forward issue and any forecast economic benefits should be treated with caution. At one level, a saving of traded carbon should be a benefit to the UK economy as this cost will not be carried by an industry and/or passed through to customers (e.g. the Energy sector and particularly power generation, which falls under the EU Emissions Trading Scheme). However, there may be cost implications of pursuing a lower carbon route – for example price premiums on low carbon materials (e.g cement, steel, and others). The focus should be in the net effect of any benefits to the UK on a whole life basis. Where

[13] From guidance in the Green Book

the traded price of carbon is partly a tax (through the carbon price floor), then the reduced emissions will lower the tax receipts for the HM Treasury. This is however a transfer payment and so it does not have a net effect on the economy. In terms of non-traded emissions, there is a clear economic impact which is exempt for the avoided social, political and economic costs arising from any severe impacts of climate change (e.g. sea level rise). Nevertheless this would assume that the Government's projected non-traded price of carbon is a true reflection of all the externalities of climate change.

3 Carbon data analysis

Approach

3.1 The focus of the data analysis was to answer three questions that are fundamental to the Infrastructure Carbon Review, namely:

- "Where is the carbon?" – Establish a current baseline for the infrastructure industry
- "How much can reasonably be reduced?" – Identify feasible reduction potentials

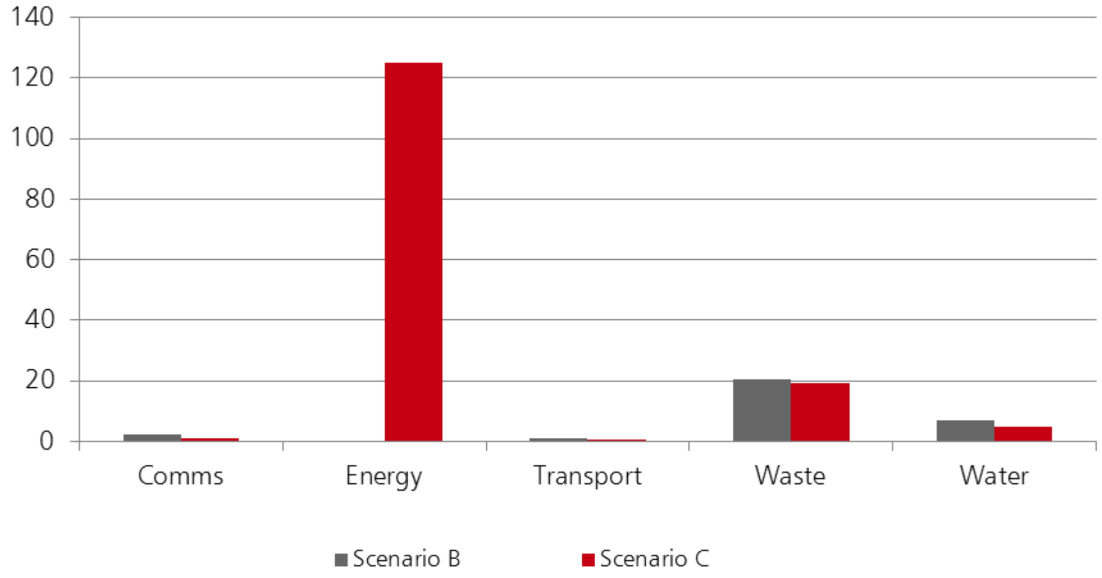
3.2 The baseline is calculated for 2010, which is the most recent year for which all data is available and maintains consistency with the GCB Low Carbon Routemap for the Built Environment. Future emissions are estimated under four different scenarios for both 2025 and 2050 to align with the government's Industrial Strategy "Construction 2025" and the legally-binding targets of the Climate Change Act respectively.

3.3 Emissions associated with infrastructure services across the UK are calculated as the sum of CapCarb, OpCarb and UseCarb for each sector. All scope 1 and 2 emissions are included, and scope 3 emissions are also accounted for where data is available – namely for CapCarb and emissions associated with fuel processing.

3.4 Previous studies have typically reallocated all emissions associated with the production of energy to the consuming sector, with the undesirable consequence that the Energy sector was shown to have zero OpCarb. Although this creates a strong incentive for all consumers to reduce their emissions through minimising energy consumption, it also transfers ownership of those emissions away from the Energy sector, which is in a position to reduce some of these emissions through investment.

3.5 In contrast, in this study all emissions have been allocated on the basis of control in order to send a strong message to each sector that collective action is required by all to meet the challenging carbon reduction targets established in UK law. By allocating emissions on the basis of control, the responsibility for those emissions are shared equitably – the Energy sector is responsible for the conversion, transmission and distribution losses and the consumer is responsible for the energy they actually use. The result is that the Energy sector can reduce its OpCarb through investing in renewable electricity generation and by reducing transmission and distribution losses of the electricity and gas supply networks and increasing efficiency of the energy production process. These two alternative methods of allocating emissions are compared in Chart 3.A: below:

Chart 3.A: Alternative methods of allocating emissions for the 2010 baseline



Source: Green Construction Board

3.6 The data analysis has built upon existing studies and government statistics wherever possible. Key references include:

- DECC (2012) *Digest of UK Energy Statistics (DUKES)*
- DECC (2012) *Energy Consumption UK (ECUK)*
- DECC (2007) *2050 Pathways Calculator (Pathways)*
- Defra (2013) *UK GHG Inventory (UK GHGI)*
- Defra (2012) *Guidelines to Defra & DECC's GHG Conversion Factors for Company Reporting (Defra GHG CFs)*
- Green Construction Board (2013) *Low Carbon Routemap for the Built Environment (GCB Routemap)*
- NAO (2013) *Planning for Economic Infrastructure*
- ONS (2013) *Construction output figures – data tables (ONS data)*

Core assumptions

3.7 The analysis accounts for emissions of carbon dioxide, methane and nitrous oxide in line with the Defra GHG Conversion Factors for Company Reporting 2012 and the UK GHG Inventory, which only reports this subset of the 'Kyoto basket' of six GHGs for the sectors evaluated in this study.

3.8 International aviation and shipping emissions associated with the use of UK infrastructure have been included in the Transport sector's UseCarb total, on the basis of departing journeys. This therefore includes all emissions from international journeys departing the UK and excludes all emissions from international journeys arriving in the UK. This is consistent with the Committee on Climate Change's (CCC) recent *International Aviation & Shipping Review* which recommended that such emissions should be formally included in carbon budgets and DECC's December 2012 presentation to Parliament[14] which confirmed their commitment to "a 2050 target that includes a share of international aviation and shipping emissions."

Methodology – UK carbon emissions

Baseline

3.9 The scale of the infrastructure industry's emissions are contextualised through comparison with the UK's total carbon footprint, which is taken from Defra's consumption-based account of GHG emissions. This accounts for all emissions associated with UK residents' consumption, regardless of whether they occur within the UK's territorial boundaries or are imported from overseas. In contrast to the UK's territorial emissions which have fallen by 20% since 1990 in line with the Kyoto Protocol, its overall carbon footprint has risen by approximately 10% during the same period as the UK economy has shifted away from manufacturing towards the service sector and a greater proportion of consumer goods are imported from overseas as a result.

3.10 The baseline for 2010 of 981MtCO_2e has been taken directly from Defra's *UK's Carbon Footprint 1993-2010* and includes emissions from international aviation and shipping associated with UK consumption.

3.11 A corresponding consumption-based footprint has been estimated for 1990 by extrapolating the ratio of the UK's consumption and territorial GHG accounts during the period 1993-2004 back to 1990. The estimated ratio in 1990 was then multiplied by UK territorial emissions to estimate the total UK carbon footprint as 892MtCO_2e, as shown in Chart 3.B: below.

[14] DECC (2012) *International aviation and shipping emissions and the UK's carbon budgets and 2050 target*

Chart 3.B: Estimation of the UK's carbon footprint in 1990

Source: Green Construction Board

Future projections

3.12 The legally-binding target of an 80% reduction in greenhouse gas emissions from 1990 levels by 2050 introduced by the Climate Change Act refers to the UK's territorial emissions and does not include 'imported' emissions associated with UK consumption that occur overseas. Furthermore, it does not currently include international aviation and shipping emissions.

3.13 DECC has, however, set the first four carbon budgets to leave sufficient headroom for the inclusion of international aviation and shipping emissions and "recognises that… [they] should be treated the same as emissions from all other sectors"[15], while deferring a decision on their formal inclusion under the target to 2015 to allow more time for international negotiations. This study therefore treats the 80% reduction target as if it does include emissions from international aviation and shipping.

3.14 A recent CCC review of consumption-based carbon accounting concluded that territorial emissions remain the most appropriate method for government budgets and targets given accounting conventions and available policy levers[16]. However it also notes that the intention underlying the Climate Change Act is to reduce the UK's total carbon footprint, which should therefore also reduce the consumption based emissions by at least 80% from a 1990 baseline by 2050.

3.15 Translating this into a carbon reduction target, for the purposes of this report only, it would be just 178MtCO_2e in 2050, and the infrastructure industry would account for over 90% of that total with emissions of 165MtCO_2e.

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15 *Ibid.*
16 Committee on Climate Change (2013) *Reducing the UK's carbon footprint and managing competitiveness risks*

Table 3.A: Equivalent consumption-based emissions reduction targets

Description	Units	2025	2050
UK carbon reduction target	%	50	80
Estimated UK carbon footprint - 1990 baseline	$MtCO_2e$	892	892
Corresponding target footprint	$MtCO_2e$	446	178
Forecast 'best practice' infrastructure emissions	$MtCO_2e$	362	165
Infrastructure emissions as a proportion of UK target	%	81	92

Methodology – UK infrastructure carbon baseline

Cross-sector considerations

3.16 The definition of infrastructure provided in Table 2.A: includes all buildings that are specific to the delivery of the infrastructure service, for example pumping stations in the Water sector and airport terminal buildings in the Transport sector. All other buildings related to office and administrative use are not included in the definition of infrastructure and their associated emissions are therefore not allocated to the industry in this analysis.

3.17 Defra publish two conversion factors for grid electricity, on the basis of electricity generated and electricity consumed. The difference between the factors relates to how transmission and distribution losses are allocated, however both factors reallocate all conversion losses to the consumer. A 'loss-free' factor has been calculated by multiplying the Defra 'generated' conversion factor by the ratio of gross electricity generated to primary energy used. The resulting value is used to allocate both energy consumption emissions and those associated with losses to their respective sectors. The Defra conversion factor only includes companies whose primary activity is electricity generation[17] and the same inclusions have been used to calculate primary energy use.

3.18 Since completion of this analysis the 2013 Defra data on conversion factors has been released. An analysis of the potential impacts of these conversion factors has been completed and the difference is less than 0.5%. As such the study has not been updated for the 2013 emissions factors.

CapCarb

3.19 Construction output data for the infrastructure industry has been multiplied by an emissions intensity to estimate CapCarb for each sector. This 'top-down' approach is consistent with that used in the *GCB Routemap*.

3.20 The emissions intensity is calculated as the total carbon footprint of UK construction, calculated by CenSA using a Multi-Regional Environmentally-Extended Input-Output Model, divided by the total construction output recorded by the Office of National Statistics. This method is 'boundary free' and includes all upstream emissions, regardless of where they occur in the world or in which sector they occur.

3.21 The resulting CapCarb intensity value of $0.28ktCO_2e$/£million is approximately half of the corresponding value for 'Construction' published in Annex 13 of the 2012 *Defra GHG CFs*. The value used here includes the same monetary flows as ONS construction output data, whereas the higher

[17] Defra (2012) *2012 Guidelines to Defra/DECC's GHG Conversion Factors for Company Reporting: Methodology Paper for Emission Factors*

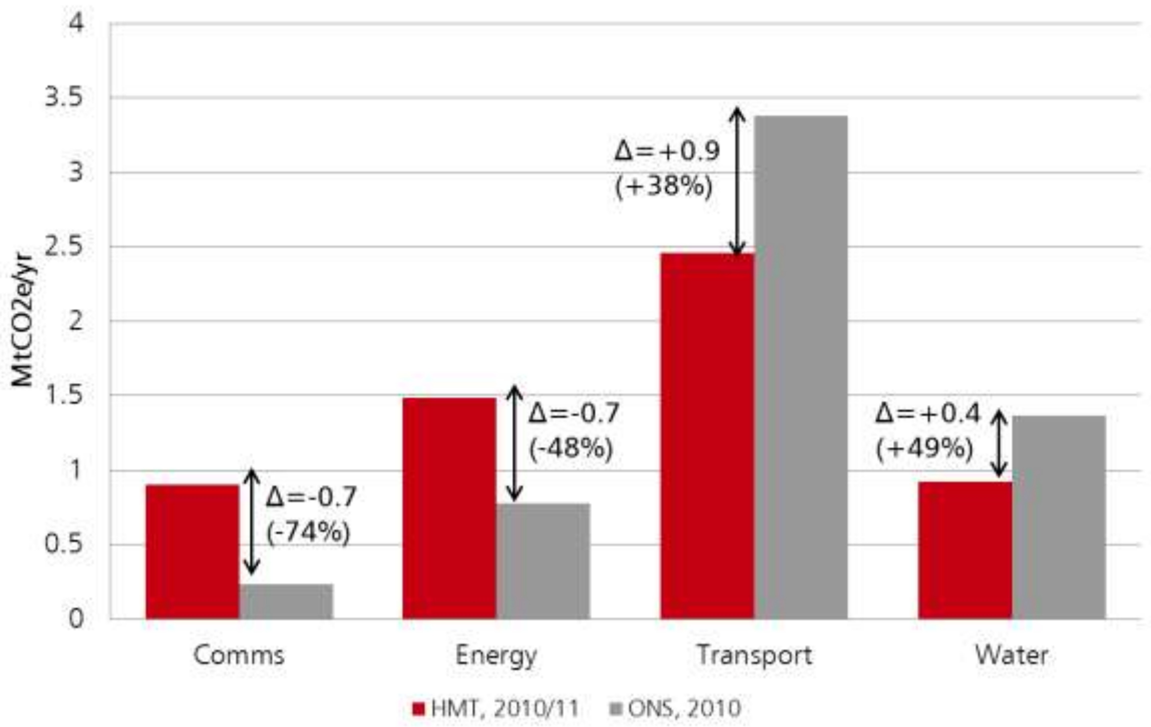
Defra value excludes compensation of employees, gross operating surplus and taxes and is based on an older two-region input-output model[18].

3.22 Separate emissions intensities were not available for buildings and infrastructure, therefore an average value has been used that accounts for all UK construction. Confidence in the estimated CapCarb emissions could be significantly improved if intensities specific to the infrastructure industry, or its component sectors, were available.

3.23 The ONS publishes construction output data for the whole infrastructure industry, subdivided into seven categories, on the basis of the ONS Purchase Enquiry, which does not include the Waste sector and is sensitive to response rates from major firms. Infrastructure spend in 2010, as reported by the National Audit Office using HM Treasury data[19], has therefore been used to divide the total construction output of the whole infrastructure industry into the five sectors considered here. The construction output data used is non-seasonally adjusted, in 2010 prices.

3.24 A sensitivity analysis has been undertaken to investigate the impact on the resulting CapCarb emissions of the two methods of dividing total infrastructure construction output into its constituent sectors. The Waste sector is not included in this analysis as it is not included in the ONS data. The results are shown below in Chart 3.C: and although the percentage differences are large, the absolute difference in CapCarb emissions is less than 1MtCO2e/yr for all sectors, which is equivalent to just 0.2% of all emissions associated with UK infrastructure.

Chart 3.C: Sensitivity analysis of construction output data allocation



Source: Green Construction Board

[18] John Barrett *pers. comm.*

[19] NAO (2013) *Planning for economic infrastructure*

3.25 A further sensitivity analysis has been undertaken for the Water sector alone through comparison with projected CapEx and CapCarb emissions during the five year AMP5 period and is presented in Table 3.B.

Table 3.B: CapCarb sensitivity analysis for Water sector

Data	Units	This study	*Keil et al.* (2013)
Annual CapEx	£mil	£3,251	£4,824
Capital intensity	ktCO2e/£mil	0.282	Water = 0.565 Sewerage = 0.415
CapCarb emissions	$MtCO_2e$	0.9	2.3
CapCarb proportion of total	%	13%	33%
OpCarb emissions	$MtCO_2e$	6.3	4.7
Total emissions under control	$MtCO_2e$	7.2	7.0
Data type		Actual	Projected

3.26 It should be noted that the data from *Keil et al.* (2013) is based on the business plans that companies submitted for the PR09 planning process, and "Ofwat's decisions… excluded some of the proposed schemes." Furthermore, the uncertainty assigned by some companies to their projected carbon emissions was as high as 100% due to the use of a relatively crude top-down methodology, with estimates divided into as few as three categories in some cases.

3.27 Nevertheless, the resulting capital intensity values for the Water sector are significantly higher than the value calculated by this study and based on infromation from the *GCB Routemap* for all UK construction. As more data becomes available this analysis should be updated to use a capital intensity specific to the infrastructure industry, and ultimately, separate intensities specific to each sector within the industry.

3.28 The results in Table 3.B: suggest that the methodology used here, based on ONS construction output data, may underestimate CapCarb in some sectors of the infrastructure industry. However, no alternative source of CapCarb data was identified for the whole industry therefore the ONS data was used to ensure the results would be consistent between sectors. Having undertaken a sensitivity on such discrepancies in CapCarb in sectors where additional CapCarb data was available, the overall conclusions from this study have not altered.

OpCarb and UseCarb

3.29 The distinction between OpCarb and UseCarb has been made on the basis of whether the infrastructure industry controls the emissions. A summary of the inclusions for each sector is shown in Table 3.C: below.

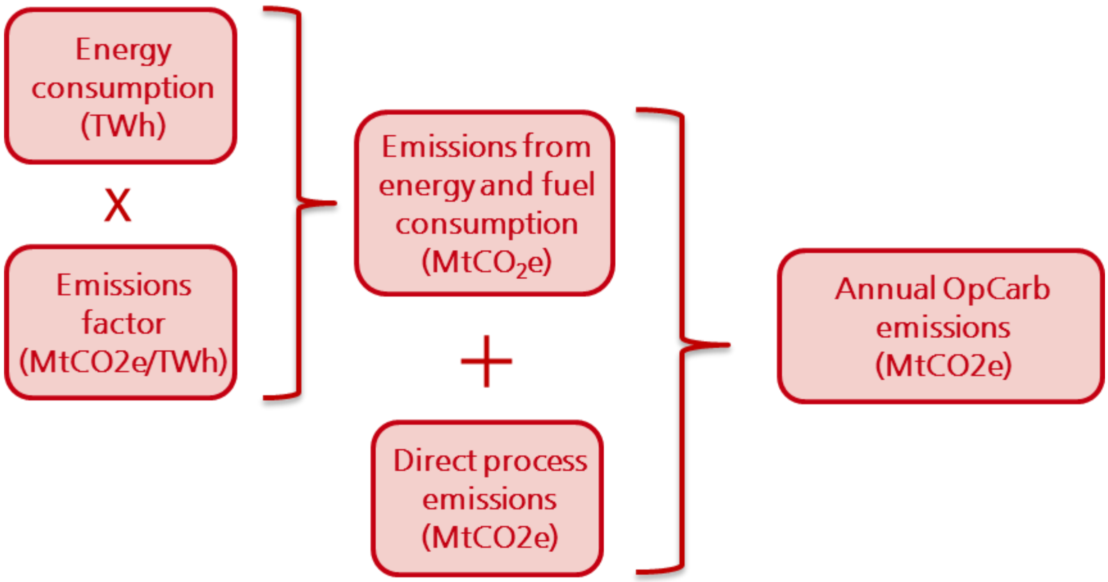
Table 3.C: OpCarb and UseCarb inclusions by sector

Sector	OpCarb	UseCarb	GCB Routemap
Communications	Wireless, home and transport network electricity consumption	Enterprise network, data centre and user device electricity consumption	Not included

Energy	All losses from production and supply of electricity and natural gas	Energy use not accounted for in other infrastructure sectors	Zero (reallocated to consumers)
Transport	Public lighting electricity consumption	All vehicle energy consumption, including international aviation and shipping.	Public lighting electricity consumption
Waste	Direct process emissions and energy consumption for all waste	None identified	Landfill emissions and transport energy consumption for construction and demolition waste
Water	Direct process emissions and energy consumption	Energy use for heating water	Energy consumption only

3.30 The method used to calculate all operational emissions is illustrated in Chart 3.D: below and a sector-specific discussion of inclusions and data sources follows.

Chart 3.D: Calculation process for OpCarb emissions



Source: Green Construction Board

Communications

3.31 Electricity consumption data have been sourced from the report *SMARTer2020*[20], which provides a 'bottom-up' estimate of global emissions from the communications sector, subdivided into the

[20] GeSI & BCG (2011) *SMARTer2020*

following categories: Networks (fixed and mobile); Data centres; and User devices. A detailed breakdown of the inclusions under networks is provided by Malmodin et al.[21]

3.32 *SMARTer2020* estimates UK communications network emissions on the basis of global market share. We have assumed that the use of diesel generators in the UK Communications sector is negligible, as such generation would principally occur under "back-up" scenarios therefore they do not represent "typical" operation and excluded from the calculation.

3.33 The resulting electricity consumptions have been multiplied by the 'loss-free' conversion factor used in this study, rather than the value used in *SMARTer2020*, to estimate the OpCarb and UseCarb of the Communications sector in a way that is consistent with the other sectors.

Energy

3.34 Energy sector OpCarb has been calculated from conversion, transmission and distribution losses in the production and supply of electricity and natural gas, using data sourced from *DUKES (2010)*. Emissions from 'energy-from-waste' schemes are allocated to the Waste and Water sectors which control those waste materials, despite their use for electricity generation.

Transport

3.35 Transport sector OpCarb is limited to street lighting and signage. This has been estimated as the total electricity consumption for public lighting to maintain consistency with the *GCB Routemap*.

3.36 Transport UseCarb includes all vehicle emissions. Traction electricity consumption (road and rail) is sourced from *ECUK* and total emissions from domestic liquid fuel consumption are sourced from *UK GHGI*. Emissions from international aviation and shipping ("navigation") departures have been calculated from the energy consumption data in the *UK GHGI* memo item for international fuel bunkers.

3.37 Transport of construction materials is included in the CapCarb emissions and has therefore been subtracted from the Transport sector UseCarb total. An SFfC study[22] was used to estimate the transport emissions intensity of the construction industry in 2008, which was then assumed constant to estimate total construction transport emissions in 2010.

Waste

3.38 For the Waste sector, non-transport energy consumption and direct process emissions are sourced from *ECUK* and *UK GHGI* respectively. Energy demand for operational transport (e.g. waste collection and transport) has been calculated from ONS data on total waste arisings in the UK[23] and Annex 14 of the *Defra GHG CFs.* A proportion of the incinerated waste will be used to generate electricity, however the emissions are allocated to the Waste sector on the basis of control.

Water

3.39 Non-transport energy consumption by fuel type (including electricity) has been taken from *ECUK* and direct process emissions have been sourced from Table 6 of the *UK GHGI.* Energy demand for operational transport (e.g. sludge tankering) has been estimated as the difference between the total energy consumption reported in the Water UK *Sustainability Report 2010/11* and *ECUK*, following an adjustment of 1% to remove office energy consumption, as estimated in the *GCB Routemap*.

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[21] Malmodin J, Moberg A, Lunden D, Finnveden G, Lovehagen N (2010) Greenhouse Gas Emissions and Operational Electricity Use in the ICT and Entertainment & Media Sectors. *Journal of Industrial Ecology* 14(5):770-790

[22] SFfC (2010) *Construction carbon 15% target by 2012: Baseline carbon assessment for 2008*

[23] ONS (2011) *Total waste arisings in UK*

3.40 UseCarb has been estimated from the energy consumption by fuel type for water heating in domestic and commercial buildings, taken from *ECUK*.

Methodology – UK infrastructure carbon reduction potential

Cross-sector considerations

3.41 Four different scenarios have been analysed for both CapCarb and OpCarb to highlight the scale of the opportunity to decarbonise the infrastructure industry. In contrast UseCarb has only been calculated for a single 'post-decarbonisation' scenario, as control over the necessary emissions reductions lies outside of the infrastructure industry.

CapCarb

3.42 The scenarios considered are detailed in Table 3.D: below. There are three variables, namely the rate of growth in infrastructure CapEx; reductions in CapCarb intensity achieved by the infrastructure industry; and reductions delivered by other sectors.

Table 3.D: CapCarb reduction potential scenarios

Scenario	Description
Reference scenario	CapCarb emissions in 2010
Worst-case scenario	Infrastructure investment continues at historic rates No reduction in CapCarb intensity
Baseline scenario	Forecast growth in investment Infrastructure industry takes no action Other industries implement carbon reductions with positive ROI
Central scenario	Forecast growth in investment All industries implement carbon reductions with positive ROI
Best practice scenario	Forecast growth in investment Infrastructure implements all technologically feasible reductions Other industries implement carbon reductions with positive ROI

3.43 Historic and forecast net growth rates in capital investment for the different infrastructure sectors are taken from the *GCB Routemap,* and presented Table 3.E: below. They are based on long-term trends in *ONS data* for the following categories: Electricity, Harbours, Railways, Roads, Water, Sewerage and Other (Gas, Air [Aviation] and Communications). The 'Other' category is split in the *GCB Routemap* as 27% Gas, 36% Aviation and 37% Communications.

3.44 The ONS does not report construction output data for the Waste sector therefore its growth rate has been matched to *Pathways'* central capital cost estimate for that sector. Financing costs have not been included in this analysis to reflect the composition of the ONS construction output data.

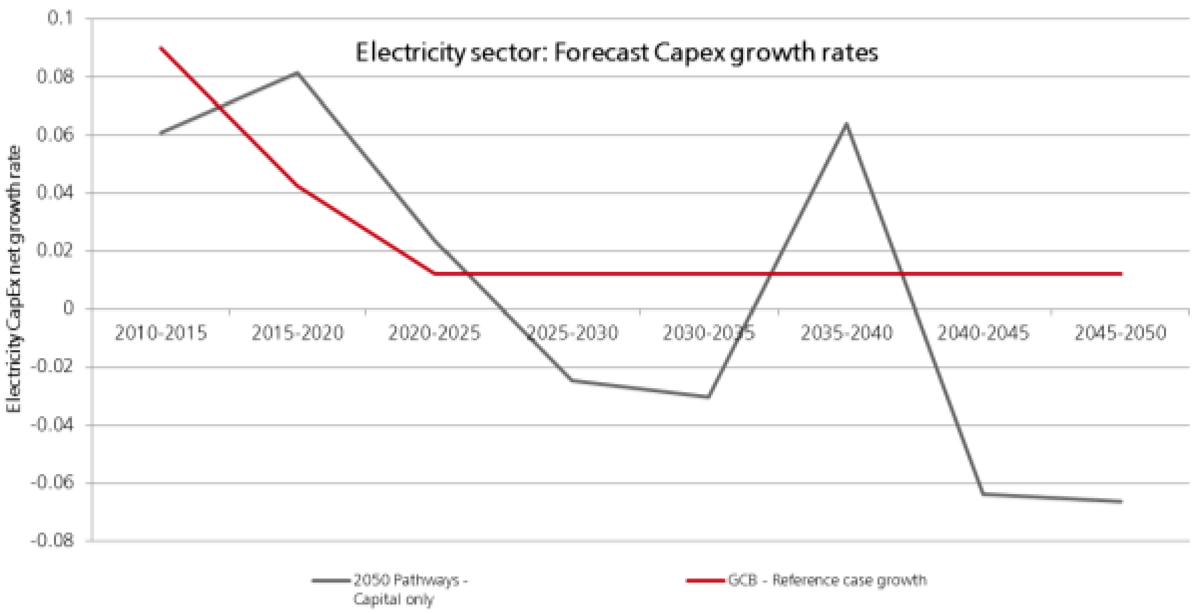
Table 3.E: Infrastructure industry net CapEx growth rates by sector

Sector	Historic rate	Forecast rate
Communications (Other)	1.3%	1.3%
Energy – Electricity	1.2%	2012-17 = 9.0% 2018-50 = 1.2%
Energy – Gas (Other)	1.3%	1.3%
Transport – Aviation (Other)	1.3%	1.3%
Transport – Harbours	0.0%	0.0%
Transport – Railways	1.7%	1.7%
Transport – Roads	0.0%	0.0%
Waste	2012-2020 = -1.0% 2013-2050 = -2.5%	2012-2020 = -1.0% 2013-2050 = -2.5%
Water – Sewerage	0.6%	0.6%
Water – Water	3.2%	3.2%

3.45 The forecast CapEx growth rates are discussed on p34 of the *GCB Routemap Final Report*, which states in reference to Electricity that "The current high growth rate of 9% p.a. can be linked to the introduction of RO 'banding' in 2006. It is expected that this high rate of growth will continue until RO is abolished in 2017. We then expect spend to return to its long-run rate of 1.2% p.a."

3.46 This assumption has been tested through comparison with the *Pathways* central cost estimates and is considered a reasonable approximation for average forecast annual growth in the Electricity sector, as demonstrated in Chart 3.E: below.

Chart 3.E: Comparison of *GCB Routemap* and *Pathways* growth rates for Electricity CapEx



Source: Green Construction Board

3.47 The reduction potentials have been taken from the *GCB Routemap* with the following levers under the control of the infrastructure industry:

- Materials efficiency from lean design process (Central = 3%; Best practice = 5%)
- Improvements in site efficiency (Central = 26%; Best practice = 49%)

The remaining levers, which relate to material production and transport, are considered to be outside the control of the infrastructure industry.

3.48 The reductions in CapCarb intensity achieved through efficiencies in the supply chain under the Central Scenario are discussed in Section 5.9.1 of the *GCB Routemap*, along with the original studies that were referenced to informed those decisions. These reductions include the effect of grid decarbonisation in other countries, simplified to only reflect forecasts for South Africa and China, which have the greatest impact on UK CapCarb emissions, controlling 17% and 11% respectively.

OpCarb and UseCarb

3.49 The four different OpCarb scenarios considered are detailed in Table 3.F: below:

Table 3.F: OpCarb reduction potential scenarios

Scenario	Description
Reference scenario	OpCarb emissions in 2010
Worst-case scenario	Future growth in demand for infrastructure services is met by current technologies without any decarbonisation

Central scenario	Emissions reductions delivered through themix of technological and behavioural change modelled in *Pathways* MARKAL pathway. Uses 2010 grid electricity emissions factors to highlight benefits of immediate action
Offsetting scenario	Further reductions below the Central scenario achieved through auto-generation of renewable electricity Uses 2010 grid electricity emissions factors to highlight benefits of immediate action
Grid decarbonisation scenario	Offsetting scenario, using forecast grid electricity emissions factors to demonstrate the impact of decarbonising the electricity supply

3.50 *Pathways* has been used as the basis for estimating future operational emissions. This comprehensive model developed by DECC forecasts energy demand and direct process emissions for various 'pathways' which are built up from a set of sector-specific assumptions. The pathway "analogous to core MARKAL 3.26" has been selected for this study as the *GCB Routemap* states that its Central Scenario is also analogous to the core MARKAL model[24]. "The MARKAL approach is a widely recognised and internationally supported model that allows the investigator to consider ideal pathways for energy system change, under decarbonisation constraints, in a technology-rich framework with sound economic basis."[25]

3.51 The *Pathways* model was published in 2010, based largely on 2007 data from *DUKES*. The forecasts have been adjusted by the ratio of this study's baseline and *Pathways'* forecast for 2010 for each sector of infrastructure in order to eliminate the effect of any subsequent revisions in the underlying data. Each sector was found to agree with the data available in 2010 to within 3%, however subsequent revisions to the *UK GHGI* have increased the direct process emissions of the Water sector by 35%, which is accounted for here by re-baseline *Pathways* forecast of those emissions.

3.52 Future scope 1 grid electricity emissions factors have been calculated by dividing *Pathways* forecasts of direct emissions associated with electricity generation by the corresponding total primary energy used for electricity generation.

3.53 Future scope 3 emissions factors have been estimated for different types of power generation and the resulting weighted average is added to the scope 1 factors to produce a grand total emissions factor. It is assumed that operational scope 3 emissions for electricity generated from hydrocarbons will remain approximately constant as they primarily relate to emissions from the combustion of fuels for thermal processing, not the consumption of electricity. Renewable electricity has been assumed to have zero operational scope 3 emissions, neglecting any associated maintenance activities[26]. Scope 3 emissions from nuclear power have been estimated as 0.01MtCO_2e/TWh(e) on the basis of the average global intensity reported from seven peer-reviewed journal publications summarised in two studies by POST (2006, 2011). This value is higher than a corresponding UK-specific, but as yet unpublished, study by the University of Manchester.

3.54 The potential for self-generation of renewable electricity in each sector (except Energy) has been estimated following discussion with industry experts. Self-generation of renewable energy has not been allocated to the Energy sector due to its smaller scale when compared to utility-scale generation in the Energy sector and also on the basis of control of such generation by the individual

[24] GCB Routemap

[25] AEA (2011) *Pathways to 2050 – Key Results: MARKAL Model Review and Scenarios for DECC's 4th Carbon Budget Evidence Base: Final Report*

[26] This is not strictly true for all renewable energy source such as biomass where Scope 3 emissions from transport of biomass fuel could be important.

infrastructure sectors. These assumptions are summarised in Table 3.G: and discussed in further detail for each sector below.

Table 3.G: Assumed potential for self-generation of renewable electricity in UK infrastructure sectors, outside Energy

Sector	2025	2050	Sensitivity
Communications	0%	0%	34%
Energy	N/A	N/A	N/A
Transport	2%	5%	95%
Waste	0%	0%	2%
Water	4%	10%	22%

3.55 The 'sensitivity' in Table 3.G: indicates the impact of erroneous estimates on the resulting OpCarb emissions. If renewable auto-generation potential in the transport sector is actually 10% higher than estimated, the resulting error in the sector's forecast OpCarb would be 9.5%, whereas a similar error in the estimate for the waste sector would only affect its OpCarb by 0.2% due to the high proportion of non-electricity-related emissions in that sector.

3.56 The results indicate that only the Transport sector is particularly sensitive to the estimates of renewable auto-generation potential, which is due to the fact that it only includes electricity consumption for street lighting. As shown in Chapter 2, emissions from trains (either diesel or electricity) are treated as UseCarb.

Communications

3.57 The Communications sector is not included in *Pathways.* Operational and user-device energy consumption have therefore instead been taken from *SMARTer2020* which provides estimates for 2020. The resulting average annual growth rates in energy consumption have been calculated for the period 2011-20 (4.2% and 0.6% for infrastructure operation and user devices respectively) and extrapolated to estimate the sector's OpCarb and UseCarb in 2025 and 2050.

3.58 Although relatively low confidence is attached to the results of these extrapolations (particularly to 2050) it is considered an acceptable approach as the Communications sector has a well-established high rate of technological change and innovation.

3.59 Professional judgement is that it is realistic to assume zero increase in energy efficiency as the worst case scenario in the Communications sector as the forecast growth in data traffic is partly enabled by technological developments that provide improved levels of service. For example, high speed broadband increases traffic as consumers use the internet in new ways (e.g. streaming music, videos and TV). It would be illogical to assume that future demand for services could be met by current technologies when the two are inherently linked. Furthermore, many of the forecast reductions in network energy consumption are not controlled by the UK infrastructure industry.

3.60 The 'Worst-case' scenario has therefore been taken to include the tenfold reduction in energy consumption per unit traffic between 2011 and 2020 forecast in SMARTer2020. Further gains identified in the 'Central' scenario relate to network restructuring with wider adoption of femtocells.

3.61 The relevance to UK infrastructure of assumptions made in SMARTer2020's calculation of global ICT network footprints have been reviewed by UK Communications sector experts. That study assumes that core network energy consumption is insensitive to growth in wireless network traffic[27]. This has been challenged as it is expected that the vast majority of data does consume core network resources. Furthermore, power consumption is expected to increase as 4G coverage is rolled out in parallel to existing 3G networks in the UK, which is apparently not accounted for in the SMARTer2020 calculation.

3.62 SMARTer2020 also assumes that home network electricity consumption per subscriber will fall by 3% per annum during the period 2011-2020. However, a significant increase in energy demand is expected in the UK from the planned expansion in fibre-to-curb networks and associated exponential growth in home data traffic which is "outstripping both Moore's Law and the rate of improvement in energy efficiency, and has done for several years"[28].

3.63 It is therefore likely that the 'Worst-case' scenario underestimates the OpCarb emissions associated with the UK Communications sector due to differences between UK and global networks and consumer behaviour.

3.64 Renewable self-generation potential would likely be limited to wireless networks as there is limited scope for fixed networks. Although technically feasible (e.g. solar power base stations are already in use in remote areas overseas) the increased maintenance costs are expected to prevent significant uptake.

Energy

3.65 The grid decarbonisation scenario is the only forecast that has been made for the Energy sector. The 'Worst-case' and 'Central' scenarios have not been considered as the forecast increase in UK electricity demand is predicated on the grid decarbonising and thereby incentivising the electrification of transport and other infrastructure services. It is important to note at this point that emissions reductions due to the decarbonisation of the grid are the most important and that if the decarbonisation route fails, scenario forecasts discussed in this section and in Section 2 may be altered.

3.66 All data has been sourced from *Pathways* and from the calculations for other infrastructure sectors.

Transport

3.67 Operational energy consumption has been taken from the *GCB Routemap* Central Scenario, which assumes 0.5% annual growth in outdoor lighting demand and a 70% reduction in energy intensity from technological improvements.

3.68 UseCarb has been estimated using the vehicle emissions in *Pathways*, which includes assumptions on modal shift, technology substitution and efficiency improvements.

Waste

3.69 Direct process emissions have been taken from *Pathways*, however that model does not estimate the energy demand of the Waste sector. Operational energy consumption has been estimated following discussion with Waste sector experts by assuming that all gas oil is used on landfill sites for transport and compaction of waste and all other energy is consumed by energy-from-waste (EfW) and recycling schemes. The consumption of each fuel has then been scaled in proportion to the tonnage of waste disposed at landfill or delivered to EfW and recycling plants.

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[27] GeSI (2011) *SMARTer2020* – Figure 3, p209

[28] E&T (2012) *Growth in data traffic 'could consume the power grid'*

3.70 A constant energy intensity per tonne of waste treated has been assumed for all disposal routes. Negligible improvements in energy intensity are expected at landfills as few new sites will be constructed. The increase in energy demand associated with more advanced thermal treatment and recycling processes is expected to be offset by efficiency improvements from innovation.

Water

3.71 Direct process emissions have been taken from the rebaselined *Pathways* 'Waste' module, where they are included as 'sewage sludge'. Operational energy consumption has been estimated following discussion with Water sector experts. The historic trend of energy intensity reductions delivered through innovation being negated by more stringent discharge consents is expected to continue, resulting in negligible improvements in overall energy intensity.

3.72 Potential reductions in operational transport demand (e.g. minimising sludge tankering) and increased energy recovery from sewage sludge above the constant 75% level assumed in *Pathways*, have also been estimated. The energy mix of the Water sector has been assumed constant from 2011 when a number of large sludge driers were decommissioned.

3.73 OpCarb emissions which result from water heating have been taken from *Pathways*, which includes assumptions on demand reduction, electrification and improvements in efficiency.

4 Literature review analysis

Literature review context

4.1 The literature review, undertaken as part of the Infrastructure Carbon Review study, focussed on developing a user-friendly reference tool (available from the GCB/BIS websites) with a view of building an understanding of the current state of the infrastructure sector in relation to carbon reduction. The analysis included reviews of relevant literature targeted at the five infrastructure sectors analysed as part of the study.

4.2 A total of 227 sources of literature were reviewed. These included different types of carbon relevant publications throughout the five infrastructure sectors. They ranged from sector-specific tools for estimating and reporting carbon emissions at project level, to broader strategic and policy documents on carbon reduction best practice. All documents reviewed were further categorised according to their content and to the infrastructure sector they were applicable to. A snapshot of the number and type of the literature sources reviewed is included in Table 4.A.

Table 4.A: Categorisation of literature sources reviewed

Sector	Best practice	Definition & data	Guidelines	Policy	Review	Tools	(blank)	Total
All	11	14	12	19	26	7	6	**95**
Energy	5	1		6	5		10	**27**
Communications	5	2	3		8		1	**19**
Transport	15	5		1	2		1	**24**
Waste	2	1	3	2	3	1		**12**
Water	6	1	5		3			**15**
(blank)		1	1	3	1	4	25	**35**
Grand Total	**44**	**25**	**24**	**31**	**48**	**12**	**43**	**227**

4.3 General/Common Findings:

- All sectors showed clear commitments to reducing carbon I and highlighted various benefits for doing so.
- All sectors had organisations which produced a plan for the future which referenced carbon reduction; this was either purely carbon focussed or part of an overall sustainability focussed action plan. The length of these plans varied from covering the next few years up to 2015 for the Transport sector, to 2050 in the Energy sector.
- All sectors highlighted the need for large investments in infrastructure to meet future demand in a sustainable manner.
- OpCarb emissions take priority of CapCarb in the majority of literature and are better understood by sectors.

- Innovation as a key enabler for long term emissions but ambiguous in most literature of how this will be effectively encouraged and implemented.

Communications

Sector overview

4.4 British Telecom was separated from the Post Office in 1981and was privatised in 1984, with the final government stake being sold in 1993. A phased programme of market liberalisation started in 1981, and in 1982 a licence was granted to Cable & Wireless to run a competing network through its subsidiary, Mercury Communications Ltd. This "duopoly" lasted until 1991, when further liberalisation allowed a range of new competitors into the market. During the 1990's, the combination of market liberalisation and the widespread adoption of Internet-based technologies led to rapid development in the telecoms sector, culminating in the speculative Dot-Com Bubble that finally burst in 2000/2001. This led to a period of consolidation in the industry that has continued to the present day.

4.5 The mobile industry in the UK got off the ground in 1985 when the Government licensed two national operators (Cellnet and Racal-Vodafone) to provide cellular radio services. 3G licenses were awarded in 2000 to One-2-One (which became T-Mobile (UK), now part of Everything Everywhere - EE) and TIW (now Hutchison 3G UK, which trades as "3"), BT3G (now Telfonica O2 UK), Vodafone and Orange 3G (now part of EE). The UK's first 4G services were launched by EE in October 2012.

4.6 Despite the growth of competition in most aspects of the telecoms market, the fixed access network has continued to display many of the characteristics of a natural monopoly. An attempt was made in the early 1980's to introduce competition into the fixed access network by permitting cable TV companies to provide telephone services, but this was only partially successful. In 2006, BT's local network was moved into a separate division (Openreach) to ensure that BT and its competitors would have equality of access to this critical resource.

4.7 The Communications Act of 2003 introduced a new industry regulator, the Office of Communications (Ofcom), to replace the Office of Telecommunications (Oftel). Ofcom's remit includes areas related to telecoms such as television broadcasting and radio spectrum.

Selective messages on carbon reduction

4.8 **Baseline:** The telecommunications sector seems to have developed a baseline with the majority of data coming from the SMART2020 group of publications. The current data shows that emissions will increase up to 2020; however the industry sees itself as enablers of emissions in other sectors, the results of which far outweigh its own emissions.

4.9 **Targets:** No overall sector targets identified however many individual telecommunications companies have set themselves targets, these vary in ambition however do highlight a commitment within the industry to reduce their own emissions and not just be enablers for other sectors.

4.10 **Key Challenges:** Improving energy efficiency within the sector whilst rapidly expanding will be a key challenge.

Transport

Sector overview

Role of Central Government

4.11 The Department for Transport (DfT) is responsible for setting policy across all transport modes. It provides guidance and funding to English local authorities to help them run and maintain their road networks, improve passenger and freight travel and develop new major transport schemes. Through the Highways Agency is invests in, maintains and operates around 4,300 miles of strategic road network – motorways and trunk roads throughout England.

4.12 The DfT also sets the strategic direction for the rail industry in England and Wales, funding investment in infrastructure through Network Rail, awarding and managing rail franchises and regulating rail fares; supports the maritime sector by producing the overall strategy and planning policy for ports in England and Wales; sets national aviation policy; and, seeks to maintain high standards of safety and security in transport.

Local Transport

4.13 At a local level the council, as Local Transport Authority, is responsible for transport planning, passenger transport and highways.

4.14 Transport for London (TfL) is the local government body responsible for most aspects of the transport system in Greater London. In the six largest conurbations outside of London, district councils are the highway authorities, whilst Passenger Transport Executives (PTEs) are responsible for the overarching, conurbation-wide Local Transport Plans as well as public transport planning and delivery, including developing, investing in and promoting new public transport schemes. In some cases, PTEs are the operators of public transport, such as some ferry services. However, the vast majority of public transport in PTE areas is operated by private companies.

4.15 Five of the PTEs are responsible to Integrated Transport Authorities (ITAs) made up of councillors appointed by the constituent district councils. However, all of these arrangements are evolving as more Combined Authorities are created and Local Enterprise Partnerships (LEP) and Local Transport Boards (LTB) take on new roles in relation to transport.

4.16 LTBs are new bodies which will have responsibility for funding for major local transport schemes. This funding previously held and awarded by DfT will be devolved to LTBs from 2015. LTBs are administrative arrangements by which constituent Local Transport Authorities and Local Enterprise Partnerships take decisions on how the devolved funding is to be spent in the areas they cover.

Roads

4.17 In England, the Highways Agency is the authority for trunk roads and motorways. Local Highway Authorities are responsible for all other roads. In the metropolitan areas the Highway Authorities are the district councils. Outside of the metropolitan areas the Highway Authority is either the unitary authority or the county council (where there is no unitary authority).

Rail

4.18 Rail infrastructure is the responsibility of Network Rail (a private sector monopoly owner, not for dividend company limited by guarantee). Network Rail's funding is provided by the Department for Transport and is determined by a complex process based on five year funding and investment Control Periods.

4.19 Network Rail is overseen by the Office of Rail Regulation (ORR), the independent economic and safety regulator for the railways. Every five years, ORR conduct a review of Network Rail's plans for the next five year Control Period to ensure that the plans are consistent with the level of revenues which can be reasonably derived from fares and other sources.

4.20 Passenger train services are managed and operated by Train Operating Companies (TOCs), usually through franchises awarded by the DfT. The franchises specify which passenger services are to be run, the quality and other conditions such as station facilities, the cleanliness of trains and reliability. Rail freight is a free market with the largest operators being EWS (owned by DB, the German state railway) and Freightliner. All are open access operators which means that each can bid to run services on any part of the network.

4.21 By and large franchisees do not own their trains; instead they generally lease or hire their rolling stock from rolling stock companies. They work with TOCs to determine the sorts of engines and carriages required to deliver the desired customer services. They also have a responsibility to help develop services by phasing out older rolling stock to make way for modern, more convenient and safer trains.

4.22 The Rail Delivery Group brings together the owners of Britain's train operating companies, freight operating companies and Network Rail to provide leadership to Britain's rail industry, coordinating and leading cross industry initiatives.

Bus Network

4.23 Outside London, buses are a free market meaning that anyone (subject to minimum safety and operating standards) can start up a bus service. In this environment, bus operators are free to run whatever services they like as well as decide the fares they will charge and the vehicles they will use.

4.24 Although in theory, it is a competitive market, in reality, most bus services are provided by five large companies who rarely compete against each other (Arriva, First, Go-Ahead, National Express and Stagecoach). Local Transport Authorities are only allowed to support bus services where no commercial service has been provided. They do this through tendering those services, with the private sector competing to provide them. About 20% of bus services outside London are provided in this way. In a limited number of areas local transport authorities still own bus companies (known as 'municipals'). However these municipal companies still operate in the same deregulated free market as elsewhere outside London.

4.25 Within London the bus services are operated by private operators and subject to periodic competition but are all regulated by London Buses which is a subsidiary of Transport for London.

Aviation

4.26 Aviation is fully privatised and deregulated although competition for landing slots in London, especially at Heathrow, regulates supply. The Government has just received submission to the Davies Commission which will consider future aviation capacity and this will determine long-term supply in the market. ***bilateral restictions, standards***

Maritime

4.27 UK registered shipping is subject to UK and EU legislation but privately owned and operated. Legislation is often bypassed by use of flags of convenience, with fleets registered offshore in states such as Panama.

Selective messages on carbon reduction

4.28 **Baseline:** The transport sector seems to have a good baseline established regarding the overall contribution to UK GHG emissions (21%). There is also detailed information of how the emissions are split across different parts of the transport sector.

4.29 **Targets:** The transport sector is primarily driven by the Climate Change Act (2008) reductions targets and the government has set out policies to help the sector achieve these. Apart from national targets other key organisations such as the Highways Agency have set themselves individual targets (25% reduction by 2015 from a 2009/10 baseline).

4.30 **Key Challenges:** The transport sector is built up from different subsectors such as road, rail, shipping and aviation all of which face different challenges in terms of carbon reduction. A large part of the challenge will be aligning incentives and policies which bring about the overall sector reductions whilst still providing a competitive and diverse transport sector required for economic growth. More specific challenges are those with aviation whereby international agreement is required before meaningful targets can be set.

4.31 **Enablers:** Strong organisational direction, DfT has published very clear reports and guidelines on its vision to lower emissions from domestic transport and how it plans on delivering these aims. These include 3 clear pathways to lower carbon solutions including: supporting a shift to new technologies and cleaner fuels; Promoting lower carbon choices and using market mechanisms to encourage a shift to lower carbon. This alongside industry leading organisations such as the Highways Agency mean that there is a clear desire and drive towards lower carbon transport sector.

Waste

Sector overview

4.32 Waste arisings fall into a number of main categories; municipal, commercial and industrial (C&I) and construction and demolition (C&D). Within these categories there are hazardous and non-hazardous wastes and inert wastes. There are specific targets relating to municipal waste recycling and limiting the amount of waste to go to landfill. However, for C&I and C&D waste there is restrictive legislation, such as Pre-Treatment Regulations, which mean that but not specific targets. Across all types of waste the key message is the Waste Hierarchy. This is the concept of Reduce, Reuse, Recycle, Recovery. The aim is to minimise the waste produced by reducing waste through design and prevention, then reusing materials to prevent them from becoming waste, then recycling materials, followed by recovery, with landfill being the least preferred option.

4.33 The waste sector is predominantly privatised, with only some Local Authorities managing collection and disposal in house. The majority of waste is collected, managed and treated by private waste management companies. Local Authorities tend to let waste collection contracts with a period of 7 years, in line with the useful economic life of refuse collection vehicles. The contracts typically include collection of separate dry recyclables (paper, card, metals, plastics etc.), organic waste (garden and/or kitchen) and residual waste. The material streams are then managed separately. For C&I waste contracts are let directly with waste management companies and are usually let on a cost basis. Many companies have recycling initiatives where Increasingly C&D waste is reused on site (so it is not technically waste) with packaging material being recycled, minimising the amount of waste which is disposed of.

4.34 The government's key incentive for minimising waste to landfill is Landfill Tax. It was introduced in 1996 at £7/tonne for standard waste and £2/tonne for inert waste (which does not produce methane in landfills). It is now £72/tonne and £2.50/tonne and will rise to £80/tonne for standard waste in 2014. This has been an efficient incentive to divert waste from landfill for both the public and private sector.

Selective messages on carbon reduction

4.35 **Baseline**: Environmental Services Agency (ESA), which represents 80% of the Waste sector (by turnover) has set out a clear carbons emissions procedure including Scope 1, 2 and 3 emissions in line with national standards.

4.36 **Targets:** No industry wide carbon reduction targets found however individual companies did set themselves targets. The industry is primarily driven by the governments obligation to meet EU Waste Directive targets which encourage more sustainable waste management options to be undertaken by diverting waste away from landfill and increasing recycling rates.

4.37 **Key Challenges:** Funding the large infrastructure investments required will be a key challenge with estimates of £7.5-20billion worth of investment required to meet the demand of more sustainable waste infrastructure. The planning implications of developing this infrastructure also increase time and cost putting off investors. However ESA is confident that with the right long term incentives and improvements in the planning framework that there are private sector investors available to fund this growth. Much of the focus in the waste sector is on resource efficiency which inherently leads to OpCarb savings and despite knowing large amounts of infrastructure is required seems to be very little attention on how to achieve this with a low CapCarb cost.

4.38 **Enablers:** The sector is commercially strong with growth estimates of 3-4% a year for the next few years and 37% by 2020, this should encourage the investment required for infrastructure development. Carbon reduction in this sector is incentivised by multiple aspects, e.g. landfill tax and renewables incentives from energy from waste. Potential technological innovations in the coming years could greatly improve carbon reduction potential and commercial success, however the industry seems to be lacking a collaborative research council to efficiently drive research and development in the sector.

Water

Sector overview

4.39 Since privatisation of the water sector in 1989, water supply and sewerage services have been provided in England and Wales, on a regional monopoly basis, by 22 privately-owned water-only and water and sewerage companies. The situation in Scotland is different with one public sector company (Scottish Water) and in Northern Ireland, water and sewerage services remain part of the regional government. Flood defence, navigation, water resource planning and the protection of environmental quality duties are managed by the Environment Agency, the main environmental regulator for England and Wales.

4.40 The UK water industry is heavily regulated to ensure water and environmental quality standards are met and that customer interests on service and affordability are protected. The UK economic regulators in the sector are Ofwat (for England and Wales), the Water Industry Commission (for Scotland) and Utility Regulator (for Northern Ireland). Drinking water quality is regulated by the Drinking Water Inspectorate, whereas environmental quality in the sector is regulated by the Environment Agency in England and Wales, SEPA in Scotland and the Northern Ireland Environment Agency in Northern Ireland.

4.41 Customer interests in the sector are represented by the Consumer Council of Water and other industry bodies, such as Water UK, British Water and UKWIR have been important cross-industry players who have been developing and driving forward strategies to address key sector regulatory and customer challenges, including carbon reduction.

Selective messages on carbon reduction

4.42 **Baseline**: Companies have been required to formally submit their emissions data to OFWAT since 2008, With the support of the UKWIR tool developed for OpCarb calculations the industry has a relatively reliable baseline for OpCarb emissions. CapCarb emissions are still relatively poorly understood with large variations between companies approach and accuracy.

4.43 **Targets:** No mandatory targets set by the two regulatory authorities OFWAT or DEFRA, however efficiency targets set by OFWAT inherently help reduce OpCarb. There are a number of voluntary targets set by companies however these vary greatly across the industry in regards to ambition and clarity, with some not stating baselines to which reductions will be calculated against.

4.44 **Key Challenges:** The balance between achieving mandatory water quality targets and current carbon reduction goals in an equitable and affordable manner is seen as the key challenge in the industry.

4.45 **Enablers:** There is a strong regulatory structure and clearly defined vision towards a lower carbon industry and there has been progress on developing a baseline for emissions. A greater understanding of impacts of increased water quality against emission would help regulators set appropriate targets. UKWIR will play a key role in the research and development of innovations in the industry and is a good example of industry collaboration to develop knowledge for common goals.

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