UK business opportunities of moving to a low carbon economy

FINAL REPORT

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Executive summary

The Paris Agreement on climate change action aims to limit global warming to well below 2°C and to pursue efforts to limit it to 1.5°C. This agreement came into force in November 2016 and requires major reductions in greenhouse gas emissions (GHG) by 2050 and net zero global emissions in the second half of this century. This transition will require goods such as renewable energy and energy efficient technologies, and services such as green bonds and the recycling of batteries for electric vehicles.

This transition to a low carbon economy (LCE) presents opportunities for UK businesses to supply the goods and services required by the UK and other countries. Businesses and government can enhance the exploitation of these global market opportunities through identification of, and investment in, the range of areas where UK businesses have particular strengths and leading technologies.

The aim of this report is to extend the analysis of opportunities for UK business to supply global markets for low carbon materials, goods and services that are anticipated to be required for transition to a low carbin economy. The report consists of six sections:

- Section 1 provides a brief introduction to the project
- Section 2 describes the timelines for the global transition to a low carbon economy,
- Section 3 considers the position of the current UK low carbon economy,
- Section 4 quantifies the size of the market opportunity for UK business in 2030 and 2050
- Section 5 describes the barriers to UK business capturing a larger share of the global market.
- Section 6 presents conclusions.on opportunities to increase UK share of future global markets.

The work was funded by the Committee on Climate Change (CCC) and delivered by Ricardo Energy & Environment supported by Trends Business Research and Ortus Economic Research Ltd.

To identify sectors where the UK might have “first mover advantage”, we compared the projected timelines for the global and UK low carbon transition, as outlined in the International Energy Agency’s (IEA) scenarios for global emissions reductions, and CCC’s scenarios and best estimates of the most cost effective path for reaching the UK’s 2050 target of an 80% reduction in GHG emissions compared to 1990.

A key finding of this analysis is that the UK and the EU were likely to make the transition to the low carbon economy around 10 years ahead of the world average. We also identified three sectors (electricity, transport and waste) where the UK is making major progress and investment in emission reduction and these clearly offer business opportunities in the UK home market, and global export markets. However there are also opportunities for UK business to supply goods and services in other sectors, and a range of new technologies will be needed to complete the global transition, particularly beyond 2050.

We also concluded that the technologies need to complete the global transition are broadly similar to those required by the UK market, although there were some geographical variations, for example: the UK is likely to deploy higher levels of off-shore wind and lower levels of solar PV than the global average.

The overall approach to the transition in other regions is also similar to that in the UK, and involves:

- Implementing energy efficiency measures, particularly in the period up to 2030.
- Deploying proven low carbon technologies. Costs for some of these will be expected to decrease with deployment, as has been the case recently with solar photovoltaic cells.
- Demonstration projects for other technologies that are close to deployment and/or require cost reduction, in preparation for wide scale deployment, particularly between 2030 and 2050.
- Investing in further research and innovation in hard-to-reduce sectors, such as aviation.
- Undertaking basic research and development on novel greenhouse gas removal technologies which are likely to be required to reach zero net emissions in the second half of the century

Current UK Competitive Position

Over the last 15 years, the UK has made a substantial investment in energy and low carbon technology research, development and demonstration (RD&D). For example, the Research Councils UK (RCUK) Energy Programme invested £839 million between 2003 and 2011, and a further £625 million is being invested between 2012 and 2018. Innovate UK has also funded a wide range of industrial RD&D projects, and knowledge transfer networks (KTN) in many sectors of the economy[1] that support business seeking to develop new materials, goods and services for the low carbon economy. These investments, and others related to the wider impact of climate change on business and society mean that the UK is well placed to obtain a share of the growing market associated with transition to a LCE, provided concerted action is taken by suppliers and government to ramp up export activities.

With the aid of our experts and stakeholder feedback, we have assessed whether there is a low, medium or high potential for UK business to capture market share in each of the main segments of the UK LCE market and identified some examples where the UK currently has particular strength, including:

- Electric Vehicles
- Transport telematics
- Off-shore wind
- Solar PV
- Smart Grids
- Energy storage
- Biofuels

We have also identified some technologies that will need to be fully deployed by 2050, where the UK could exploit its existing capabilities in other fields to capture a share of the global market. These include:

- Advanced materials and manufacturing, including design for reuse and waste recovery.
- Low carbon chemical processes using bioprocessing, catalysts and membrane technology

In addition, there are significant opportunities for the UK services sector to establish itself as a financial hub for green finance and gain a sizable share of the financial services associated with the estimated capital investment of between $1.5 and $6 trillion per annum needed to deliver the global transition.

Current Size of the UK LCE Market.

We used two methods to assess the size of the UK market for low carbon goods and services in 2015, which we estimated employed between 230 and 450 thousand people, and had a turnover of between £42 billion and £120 billion. The first method used the provisional results of ONS's Low Carbon and Renewable Energy Economy Survey published in late 2016. This assessed direct employment and turnover for the LCE sector only. The second method updated the estimates published by BIS of the size of the LCE market in 2013. This assessed both direct and indirect employment and turnover.

Size of the LCE Market Opportunities for UK Business

Our analysis suggests that the UK low carbon economy could grow from around 2% of UK Total Output in 2015 to up to around 8% by 2030, and around 13% by 2050. The projected compound annual growth rate for the low carbon economy is 11% per annum between 2015 to 2030, and 4% per annum between 2030 and 2050, which is substantially higher than the OECD's projection of average UK GDP growth of 2.3% per annum between 2015 and 2050[2] This corresponds to a UK LCE market size of between £210 billion and £600 billion in 2030 and between £510 billion and £1,400 billion in 2050. The levels of UK employment associated with the LCE are between 1.0 and 2.2 million in 2030, and between 2.5 and 5.0 million in 2050.

These projections are based on an assessment of the potential size of 25 selected areas of the UK and global LCE market in 2030 and 2050, and draw on the scenarios for technology deployment outlined in the IEA's Energy Technology Perspectives 2016 and technology roadmaps, the CCC's own scenarios and a number of estimates by market research organisations of current market size and growth rates.

These projections also include an estimate of the UK share of the global market, which is based on the UK's current share of global exports, and hence on the UK's current strengths in manufacturing and services. There is the potential to increase this share by building on UK strengths in research and innovation and by addressing barriers to market entry and growth outlined in Section 5 of this report.

[1] https://admin.ktn-uk.co.uk/app/uploads/2016/09/KTN-Annual-Report-2015_2016.pdf
[2] https://data.oecd.org/gdp/gdp-long-term-forecast.htm

1 Introduction

The Paris Agreement on climate change action entered into force in November 2016, having been ratified by the USA, China, India, Brazil, the EU and other countries. The Agreement aims to limit global warming to well below 2°C and to pursue efforts to limit it to 1.5°C. This will require major reductions in greenhouse gas emissions by 2050 and net zero global emissions in the second half of this century, which in turn will drive a transition to a low carbon economy (LCE) in both developed and developing countries. The LCE includes goods such as renewable energy and energy efficient technologies, and services such as green bonds and the recycling of batteries for electric vehicles.

This transition to a low carbon economy presents opportunities for the UK in provision of the goods and services required. This can be both in supplying the UK market as it makes the transition and also in supplying global markets. Businesses and government can enhance the exploitation of these opportunities through identification of and investment in the range of areas where the UK has particular business strengths and leading technologies.

The CCC published a review of the UK's research and innovation arrangements for delivering technologies required to meet the UK's climate change targets in 2010[3]. This report also identified opportunities for the UK to develop new technologies and take a lead in global markets, including in offshore wind, marine, Carbon Capture & Storage (CCS), smart grids, aviation and electric vehicle technologies. In 2013, the CCC also reported on opportunities to create new global markets for products from the energy-intensive sectors[4].

The aim of this report is to update and extend the analysis of opportunities for UK business to supply global markets for low carbon materials, goods and services that the LCE transition will create by:

- Exploring the timelines around the global transition to a low carbon economy.
- Quantifying the size of the global market for low carbon materials, goods and services
- Identifying potential export opportunities for UK's manufacturing and service sectors
- Assessing the potential UK share of the global market in example application areas.

This will feed into an updated assessment of the opportunities that transitioning to a LCE could provide for the UK's manufacturing sectors, to be undertaken by CCC in early 2017.

This report comprises five sections in addition to this introduction. Section 2 describes the timelines for the global transition to a low carbon economy, Section 3 considers the position of the current UK low carbon economy, Section 4 quantifies the size of the market opportunity for UK business in 2030 and 2050, and Section 5 describes the opportunities and barriers to UK business capturing a larger share of the future global market. Section 6 presents conclusions.

2 The timelines for the global LCE transition

The technologies needed to complete the global transition are boadly similar to those required by the UK market, although there were some geographical variations, for example: the UK is likely to deploy higher levels of off-shore wind and lower levels of solar PV than the global average.

The overall approach to the transition in other regions is also similar to that in the UK, and involves:

- Implementing energy efficiency measures, particularly in the period up to 2030.
- Deploying proven low carbon technologies. Costs for some of these will be expected to decrease with deployment, as has been the case recently with solar photovoltaic cells.
- Demonstration projects for other technologies that are close to deployment and/or require cost reduction, in preparation for wide scale deployment, particularly between 2030 and 2050.
- Investing in further research and innovation in hard-to-reduce sectors, such as aviation.

[3] "Building a low-carbon economy – the UK's innovation challenge ", The Committee on Climate Change, 2010
[4] "Managing competitiveness risks of low-carbon policies", The Committee on Climate Change, 2013.

- Undertaking basic research and development on novel greenhouse gas removal technologies which are likely to be required to reach zero net emissions in the second half of the century

2.1 Introduction

This section provides an overview of the timeline for the deployment of different technologies for the transition towards a low carbon economy, including both global and UK perspectives.

The information provided in this section is based on a number of key sources. This includes the scenarios developed under the IEA Energy Technology Perspectives 2016[5] and the CCC's reports on the Fifth Carbon Budget[6] and *'UK climate action following the Paris agreement'*[7] for information related to global and UK emission reductions respectively.

The timeline for the transition to a low carbon economy has been split into three district phases:

- Phase 1: 2017 to 2030 – this aligns with the time period for the pledges made by countries as part of the Paris Agreement
- Phase 2: 2031 to 2050 – this aligns with IEA models and UK's commitment to a reduction in emissions of at least 80% in 2050
- Phase 3: 2051 to 2100 – to align with the global objective to hold the increase in global temperature to below 2°C and to pursue efforts to limit it to 1.5°C

For Phases 1 and 2 information is presented for the following key emissions-reduction sectors[8]; power generation, transport, industry and buildings. For each sector the key activities/technologies are highlighted for the respective phases. Where information is available, other emission-reduction sectors such as agriculture, waste and F-gases are also covered. Information for Phase 3 is less detailed and as such an overview of the key trends that can currently be expected is provided.

2.2 Overview of key sources

2.2.1 IEA Energy Technology Perspectives 2016

The International Energy Agency (IEA) Energy Technology Perspectives 2016 sets out a series of scenarios for different levels of ambition up to 2050 – see examples in Table 1.

Table 1: Summary of IEA Energy Technology Perspective 2DS and 6DS Scenarios 2016[9]

Scenario	Description
2°C Scenario (2DS)	**2DS lays out an energy system deployment pathway and an emissions trajectory consistent with at least a 50% chance of limiting the average global temperature increase to 2°C.** The reductions in carbon dioxide emissions envisaged under the 2DS scenario go considerably beyond the Nationally Determined Contributions (NDCs) set out in the Paris Agreement[10].
6°C Scenario (6DS	**6DS is largely an extension of current trends and is used as the baseline against which to determine the additional investment in energy efficiency measures and renewable energy deployment that will be required by 2050.**

[5] IEA (2016) Energy Technology Perspectives 2016 - Towards Sustainable Urban Energy Systems
[6] Committee on Climate Change (2015) The Fifth Carbon Budget – The next step towards a low-carbon economy
[7] Committee on Climate Change (2016) UK climate action following the Paris Agreement
[8] This report is about business opportunities arising from transition to a low carbon economy. Later sections will refer to sectors based on analysis by the Office of National Statistics and in this work of the low carbon economy in the UK. Power generation, later termed low carbon electricity, and transport, are common to the two breakdowns. Other emissions-reduction sectors do not match 1:1 with low carbon economy sectors. As an example some areas of opportunity such as low carbon finance and adaptation are not included in the emission-reduction sectors.
[9] http://www.iea.org/publications/scenariosandprojections/
[10] https://www.iea.org/publications/freepublications/publication/ECCE2016.pdf

The IEA Energy Technology Perspectives provides a consistent approach at a global level at which different scenarios can be compared against each other. Further details about the Energy Technology Perspectives model approach and the assumptions used are detailed on the IEA website[11].

The difference between the scenarios can be compared to identify the reduction in emissions for different sectors. Table 2 summarises the percentage contribution to reduction in emissions between the 6DS and 2DS for the period 2015-2050 by sector.

Table 2: Percentage contributions by sector to reductions at 2030 and 2050 in energy related CO_2 and Green House Gas (GHG) emissions between 6DS and 2DS scenarios[12]

Sector	2030	2050
Agriculture	0	0
Commercial	5	6
Residential	8	7
Transport	16	19
Industry	26	21
Other transformation	5	7
Power	39	39

The information presented in Table 2 indicates the following key global trends over the 2015-2050 period with respect to relative energy related global reductions in CO2 and Green House Gas (GHG) emissions:

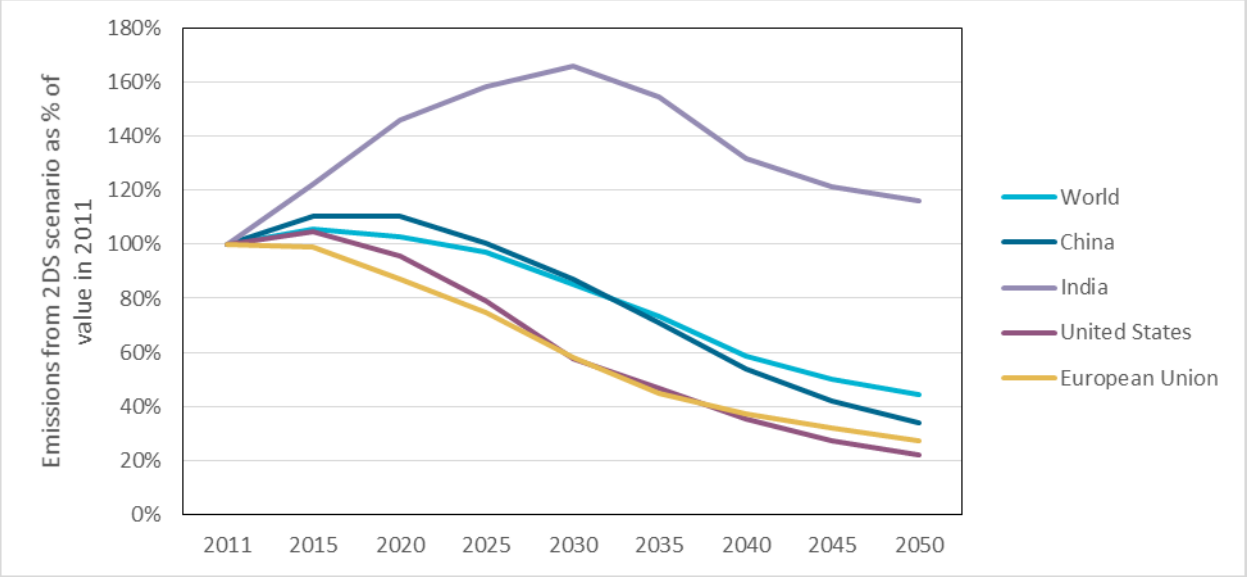
- The largest relative contributor to emissions reductions in 2030 and 2050 is the power generation sector, which was responsible for 47% of global energy related emissions in 2014[13];
- The transport and industry sectors, which were responsible for 43% of global energy related emissions in 2014, also make major contributions to emissions reduction in 2030 and 2050;
- All other sectors contribute about 20% of emissions reductions in 2030 and 2050

Sectors that will make the largest contribution to global emissions reductions in 2030 and 2050 are power generation, transport and industry. These are prime candidates for significant business opportunities arising from the low carbon transition.

The IEA scenarios also illustrate the relative time of the low carbon transition in different regions of the world. Figure 1 presents relative projected changes in emissions from 2011 levels for the world and major regions and countries.

[11] http://www.iea.org/etp/etpmodel/ and http://www.iea.org/etp/etpmodel/assumptions/
[12] http://www.iea.org/etp/explore/
[13] http://www.iea.org/publications/freepublications/publication/CO2-emissions-from-fuel-combustion-highlights-2016.html

Figure 1: Emissions with time compared to 2011 figures for some major countries/ regions compared with the overall projection for the world



Source: International Energy Agency, Energy Technology Perspectives 2016 - www.iea.org/etp2016

The UK (which is included in the projections for EU in Figure 1) and USA are projected to make the transition about 10 years earlier than the world average.

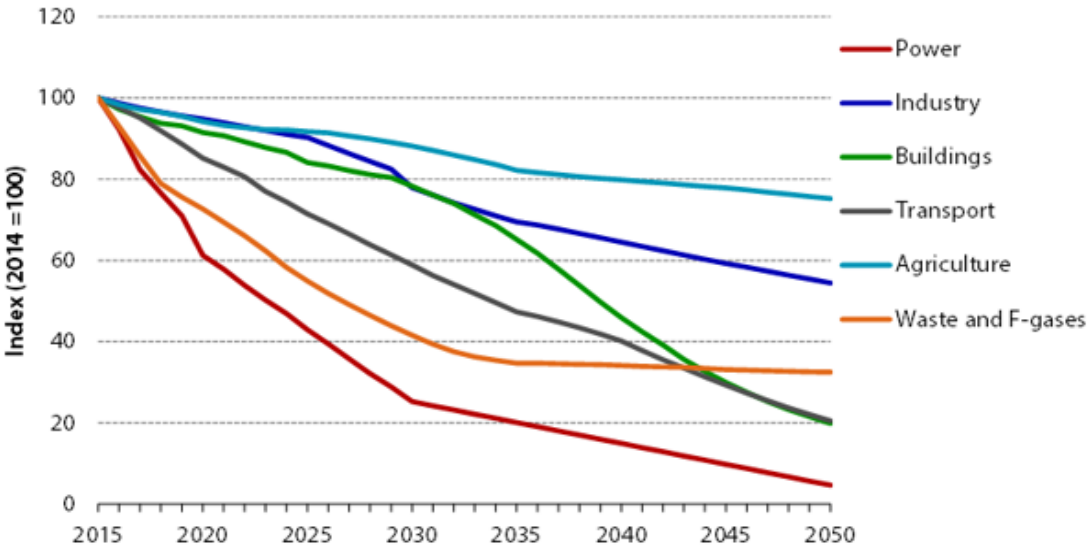
For countries, including the UK, that make the low carbon transition earliest, there may be opportunities to supply technology, products and services to countries that make the transition later.

2.2.2 CCC Fifth Carbon Budget Scenarios

To understand in which sectors the UK might have "first mover advantage", we examined the analysis in support of CCC's Fifth Carbon Budget[14] [15], which provides estimates of carbon emissions and reductions for a number of scenarios across the power, transport, industry, agriculture, waste and F-Gas emission-reduction sectors for the period 2014-2050 (see Figure 2). We explored CCC's Central Scenario, which represents the CCC's best estimate of the cost effective path for reaching the UK's 2050 target of at least an 80% reduction in emissions of greenhouse gases compared to 1990.

[14] Committee on Climate Change (2015) The Fifth Carbon Budget – The next step towards a low-carbon economy
[15] Committee on Climate Change (2015) Sectoral scenarios for the Fifth Carbon Budget – Technical Report

Figure 2: Central scenario emissions paths to 2050[16]



Projected reductions of emissions by time and sector are summarised in Table 3.

Table 3: Summary of UK projected emissions reductions by time and sector

Sector	% UK CO_2 Emissions in 2014	2015 – 2030	2030-2050
Power	23 %	Very significant reduction in emissions (about 75%)	Further reduction in emissions at a slower rate (about a further 20%)
Transport	23 %	Significant reduction in emissions (about 45%)	Further significant reduction in emissions (about another 35%
Waste and F-gases	7 %	Major reduction in emissions (about 60%)	Relatively low further reduction by 2035, then flattens off (about another 5%)
Buildings	16 %	Modest reduction in emissions (about 25%)	Significant reduction in emissions (about another 55%)
Industry	21 %	Modest reduction in emissions (about 25%)	Modest reduction in emissions (about another 20%)
Agriculture	9 %	Relatively low reduction in emissions (about 15%)	Relatively low reduction in emissions (about another 10%)

The progression with time reflects the relative ease of and effort in addressing emissions in the sectors. A major early focus is the power sector with almost complete elimination of emissions projected by 2050 through the deployment of renewable electricity, nuclear or CCS technologies.

Progress in emissions reductions from transport is projected to be relatively linear to 2050 through the progressive deployment of battery electric, hybrid plug in electric and fuel cell electric vehicles, and by shifting car journeys to low and no carbon alternatives e.g. public transport, cycling and walking.

In the waste sector and F-gas sector, a rapid reduction in emissions is envisaged prior to 2030 due to reductions in emissions from landfill, and leaks from refrigeration and air conditioning equipment.

In the other sectors, a modest or low rate of reduction is anticipated between 2015 and 2050, except in the buildings sector, where the more significant emissions reduction is anticipated from 2030 to 2050 through increased energy efficiency and the use of low carbon space heating technologies.

[16] Source – Figure 1.14 from Committee on Climate Change (2015) Sectoral scenarios for the Fifth Carbon Budget – Technical Report

Sectors where UK is making major progress and investment in emissions reductions, clearly offer opportunities in the home market and also offer opportunities for supply to global markets

2.3 Phase 1: 2017 to 2030 – A more energy efficient world

2.3.1 Power Generation

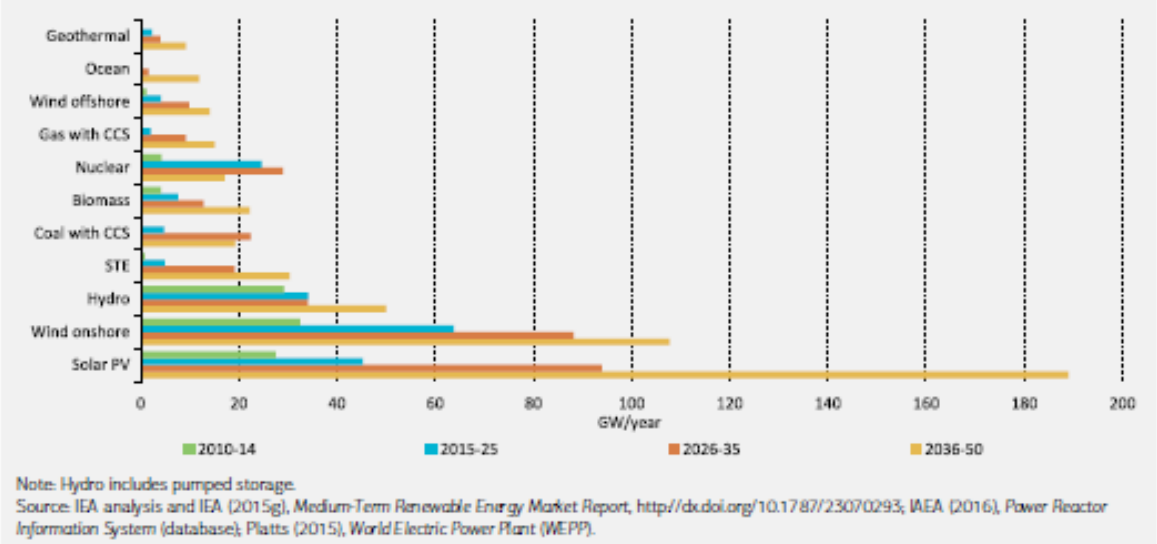
- **Key technologies globally include solar PV, on-shore wind, hydro and nuclear**
- **Key technologies within the UK will include renewables including offshore wind, nuclear, CCS and bioenergy**
- **The initial deployment of less mature technologies will be required**

To reduce the carbon intensity of power generation at a global level up to 2030 key technologies identified by the IEA will include onshore wind, solar PV, and hydro, with increasing importance of nuclear, as shown in Figure 3.

The position in the UK will be similar, increasing the share of low carbon generation through a range of different mixes of technologies such as renewables including offshore wind, nuclear and plants with carbon, capture and storage fitted. Bioenergy is also identified as having an important role, but is limited by sustainable supply. The implementation of technologies such as offshore wind and CCS during this period will be important for the UK to meet 2050 targets. Reduced support from UK Government for CCS Research, Development and Demonstration (RD&D) could impact the deployment of this technology.

Other technologies will start to be deployed, but this will increase post 2030, and are covered in phase 2 below. The deployment of less mature technologies will be important to enable these to become lower cost options in future phases in order to meet 2050 targets.

Figure 3: Global deployment rates for low carbon power technologies in the 2DS[17]



Note: Hydro includes pumped storage.
Source: IEA analysis and IEA (2015g), *Medium-Term Renewable Energy Market Report*, http://dx.doi.org/10.1787/23070293; IAEA (2016), *Power Reactor Information System* (database); Platts (2015), *World Electric Power Plant* (WEPP).

2.3.2 Transport

- **Energy efficiency improvements in conventional internal combustion engines and use of biofuels**
- **Ongoing electrification of vehicles**

[17] Source – Figure 1.8 from IEA (2016) Energy Technology Perspectives 2016 - Towards Sustainable Urban Energy Systems

- **Technologies to improve efficiency of different transport modes such as materials substitution to reduce weight, advanced lubricants and advanced aerodynamics**

To meet the IEA 2DS requires a number of changes in the transport sector across all modes of transport. In this phase improvements in conventional internal combustion engines will continue to be important in improving energy efficiency. This will be complemented by replacement of fossil liquid fuels with biofuels – initially in trucking and aviation and by electrification of passenger vehicles, with 2 and 3 wheel vehicles and light freight phased in rapidly – in particular in OECD countries, China and India. Electric vehicles could include battery electric vehicles (BEVs), Plug in Hybrid Electric Vehicles (PHEVs) and Fuel Cell Electric Vehicles (FCEVs), which include fuel cell systems and hydrogen storage, though the FCEV stock is expected to remain marginal in this phase.

Possible technologies for public buses include overhead energy supply, batteries and supercapacitors together with inductive charging and contact based systems and battery swapping concepts. The use of hydrogen buses up to 2030 is also included as part of the UK's Fifth Carbon Budget central scenario.

Hybridisation of trucks is anticipated to start slowly in this phase and increase in the next phase. The aviation sector, in addition to initial deployment of biofuels, will also need continued deployment of energy efficient technologies.

At the sub-system level it is anticipated that the phase to 2030 will see deployment of technologies to improve energy efficiency of road transport. These may include: material substitution to reduce weight, low rolling resistance tyres, advanced lubricants, advanced aerodynamics, exhaust heat recovery, powertrains with low energy consumption per unit load (this could include hybridisation and electrification).

Similarly, for rail transport, deployment is anticipated of technologies to improve energy efficiency of trains, for example material substitution to reduce weight, improved aerodynamics, designs allowing higher capacity, powertrains with low energy consumption per unit load (mainly electric motors).

In addition to vehicle technologies, the phase to 2030 is also expected to exhibit development of information and communication technologies for travel demand management. This includes: providing information for car sharing and bike rental systems, car-pooling users and public transport; and automatic identification and data capture to enable real time variable congestion charging and regulate access to segments of the road network.

2.3.3 Industry

- **Deployment of energy efficiency measures within industrial sectors**
- **Use of low carbon fuels and feedstock and increased recovery of excess energy**
- **CCS identified as key technology within the UK**

For the IEA 2DS emission requirements industrial energy consumption needs to be decoupled from the increasing demand for materials. Under the 2DS industrial energy use will increase slightly through to 2050, but CO_2 emissions will peak in 2020. This requires a reduction in the carbon intensity of energy used in industrial sectors.

In the short term (up to 2020) this change is primarily driven by energy efficiency (Best Available Technology deployment), with energy efficiency measures varying between sectors and processes. The use of low carbon fuels and feedstocks and increased recovery of excess energy will also be important. This includes the electrification of industrial processes to meet 2DS requirements.

Similar action has been identified for the UK with emission reductions driven by technologies covering better energy management and process control, the use of more energy efficient plant and equipment, waste heat recovery and use of bioenergy in space and process heat. CCS is again identified as a key technology, with CCS cluster developments enabling its use in key industry sectors, including iron and steel and chemicals. Depending on technological developments, hydrogen could also be used as an alternative to CCS. As noted above, the reduced support from UK Government for CCS RD&D could impact the deployment of this technology

More innovative low carbon processes may start to be deployed from 2020, but this will be more predominant post 2030, and are detailed in phase 2 below.

2.3.4 Buildings

- **Reduce heating and cooling energy demands in buildings, both retrofit and for new build**
- **Components/controls to improve the energy efficient building e.g. lighting, appliances**
- **Use of heat pumps to provide heat for homes and businesses**

There are a range of technologies and options identified for limiting emissions from buildings. The IEA scenarios place an important focus on reducing heating and cooling energy demands from urban buildings in order to achieve targets. The IEA identifies near term action (through to 2025), with a focus on the following, much of which will need to be promoted through relevant policies/targets:

- Driving uptake in deep energy renovations of existing buildings
- Promote and strive for near zero energy buildings in new construction
- Promoting high performance building envelopes – air sealing, insulation, highly insulating windows and cool roofs.
- Increasing the promotion and use of solar thermal and heat pump technology for space heating and cooling and condensing boilers for gas heating/hot water.
- Promotion of heat pump water heaters
- Promotion of solid state lighting and other innovative designs while phase out traditional incandescent and halogen bulbs
- Promote efficient appliances and cooking technologies

The UK scenarios cover similar areas including the use of heat pumps and heat networks, the continuing implementation of insulation, and increased use of heating controls and energy efficient lighting and appliances within buildings. The CCC scenarios also highlights low carbon heat could be provided through hybrid heat pumps, or adding hydrogen to the gas grid. There are currently technological and acceptance issues limiting the implementation of these technologies.

2.3.5 Other Sectors

The IEA scenarios do not focus on Agriculture, Waste and F-gases, but the following is identified from the UK's Fifth Carbon Budget scenario:

Agriculture: Emissions could be reduced through a range of measures, for example the reduction of N_2O though improved fertiliser use, livestock measures to reduce methane, waste and manure management, e.g. anaerobic digestion, and improvements in machinery fuel efficiency.

Waste and F-Gases: Under the Fifth Carbon Budget, the improvements in these sectors relate to the full diversion of biodegradable waste streams from landfill and the replacement of f-gases by low carbon alternatives in uses such as refrigeration and air conditioning.

2.4 Phase 2: 2031 to 2050 – A more resource efficient world

This phase will build on the work, and foundations provided in earlier years, as well as developments in new areas. Given the timeframes and uncertainties around technological developments and uptake, information on the key technologies during this phase is less certain.

However, there are a number of key aspects included in the 5th Carbon Budget and IEA 2DS scenarios that provide an indication of what is expected or required during the period 2030 – 2050 to meet future targets, such as the UK's target in 2050 or the IEA 2DS.

2.4.1 Power Generation

- **Key low carbon technologies are solar PV, onshore wind and hydro**
- **Use of other low carbon generation technologies such as offshore wind will increase**

- **Other solutions relevant to electricity generation and distribution increase in deployment, such as smart urban (or city) energy networks.**

The IEA 2DS indicates that beyond 2030, the amount of electricity generated by onshore wind, solar PV, hydro and nuclear continues to increase. However other low carbon power technologies, including biomass, geothermal, ocean, offshore wind, solar thermal electricity and fossil fuels with CCS, also increase as the level of renewables increases to 64% of electricity generation.

This is also reflected in the UKs Fifth Carbon Budget scenarios, which expects the decarbonisation of the power sector will continue in order to provide low carbon electricity, as electricity consumption increases due to electrification in transport, heat and other applications. CCS also plays an important part in these scenarios, although alternative routes to decarbonisation such as higher levels of renewables or nuclear are also considered.

In addition to changes in generation through the deployment of low carbon technologies, the IEA identifies other solutions are also relevant to electricity generation and its distribution. These include:

- District Heating & Cooling networks
- Energy from Waste technologies (role of this is identified as modest in IEA report)
- Energy recovery at wastewater treatment plants
- Use of excess heat from industrial processes through thermal networks
- Smarter urban energy networks
- Smarter distribution grids
- Advanced metering infrastructure

Such technologies may have started to come on-line in the previous phase, but their deployment will increase throughout this second phase.

2.4.2 Transport

- **Increased electrification of vehicles, including heavy duty transport**
- **FCEVs – main use for hydrogen in fuel cells**
- **More high speed rail**
- **Stronger uptake of alternative / low carbon fuels, for example biofuels and methane**

The IEA highlights that the following trends can be expected during the period 2030-2050:

- Annual sales of EVs rising from 28% of light duty vehicles in 2030 to 69% in 2050.
- Increased share of FCEVs in this phase – through deployment of FCEVs among light duty vehicles
- Increased electrification of heavy duty transport.
- Development of more high speed rail (HSR) to provide an alternative to intra-continental air travel particularly in non-OECD countries
- Expect a stronger uptake of alternative fuels vehicles and low carbon fuels in the longer term.

This aligns with the UKs Fifth Carbon Budget, which expects surface transport to have reached near full decarbonisation by 2050 through a continuation of technologies implemented in Phase 1. This includes for example the increasing market uptake of electric vehicles and potential increased uptake of other technologies such as hydrogen instead of battery electric vehicles[18].

[18] The Fifth carbon Budget includes an alternative scenario in the transport sector which involves the widespread uptake of hydrogen technologies, rather than battery electric vehicles.

2.4.3 Industry

- **Increased deployment of innovative low carbon process technologies, including integration of CCS into industrial processes**
- **Emission reductions through recycling solutions**

The IEA identifies that over the period, 2030-2050, other measures will need to contribute to achieve the target. This includes using innovative low carbon process technologies (i.e. those not yet demonstrated, but could become commercially available by 2050), many of which require the integration of CCS into industrial processes. Examples include the use of CCS in cement kilns, the use of smelt reduction or direct reduced iron technology in steel making, inert anode technology in aluminium production and chemical production from biomass based process routes.

In the longer term recycling solutions will also account for emission reductions, primarily in iron and steel and aluminium sectors, but also plastic recycling to alleviate the demand for primary chemicals.

The UKs Fifth Carbon Budget is consistent with the IEA, in that it identifies CCS will continue be a key technology to meets targets at least cost, particularly as it will help reduce emission across heavy industry.

2.4.4 Buildings

- **Continuing improvements in energy efficiency e.g. lighting and appliances**
- **Use of highly insulated, integrated building envelopes**
- **Integrated heating and cooling solutions with net-zero emissions**
- **Solar solutions – including solar cooling technologies and solar thermal systems**
- **Potential use of hydrogen from natural gas to provide low carbon heat**

Building on the implementation of technologies and solutions in Phase 1, the IEA identified the following examples of what can be expected to be implemented up to 2050, alongside greater enforcement of near zero energy building standards in new construction:

- Deep energy renovations of buildings, including implementation of energy efficiency measures, such as the use of energy efficient technologies and building envelope improvements.
- Energy efficient technology solutions include as advanced lighting e.g. LEDs – continued deployment in OECD countries and particular focus on other countries, water heating technologies e.g. instantaneous condensing gas water heaters, heap pump water heaters, solar thermal systems to provide high proportion of annual water heating load, low cost solar cooling technologies
- Advanced building envelope materials e.g. insulations, windows, including highly insulated, integrated building envelopes
- Reduce cooling and heating demands through improved insulation, use of reflective surfaces low-emissivity glass windows, solar control, exterior shading, reflective roadways and pavements, improved doors, air sealing and distribution systems and energy or heat recovery equipment.
- Building design considerations for new construction including orientation, shape, profile, materials, technology choices, passive ventilation and solar heating contributions,
- Geothermal technologies as part of new constructions utilising local natural water resources
- Integration of energy efficient building and district energy

Overall, a similar rate of investment in energy saving measures is expected in phases 1 and 2, but 2.5 times the level of savings that needs to realised in phase 2 (2030-2050) compared with phase 1.

The UK's Fifth Carbon Budget also highlights the potential use of hydrogen produced from natural gas (with CCS) as an alternative means of providing low carbon heat. This includes converting parts of the

gas grid to hydrogen use, together with the use of hydrogen boilers to provide heat for residential, commercial and public buildings.

2.4.5 Greenhouse gas removal technologies

In addition, the CCC report *'UK climate action following the Paris agreement'*[19] includes some further indications of the potential trends that could be increasingly relevant for this phase in order to meet the UK's 2050 target.

Greenhouse Gas Removal Technologies (GGR) are already included as part of the scenario to 2050 in terms of bioenergy with carbon capture and storage, afforestation and wood in construction, with the removal of up to 67 MtCO2/year from these options.

2.5 Phase 3: 2051 to 2100 – A sustainable, low carbon world

- **Continued deployment of low carbon technologies from earlier phases, though deployment rates may now be declining**
- **Focus on hard to decarbonise sectors such as aviation, agriculture and parts of the industry**
- **Refined fuel demand decrease due to electrification and/or switch to hydrogen**
- **Potential for geoengineering and other greenhouse gas removal technologies**

Information beyond 2050 on the types of technologies that will be implemented is limited, and tends to relate to higher level trends rather than sector specific actions due to the uncertainty of what will happen in this phase. While the ETP 2016 2DS and the UK's Fifth carbon Budget do not give any information for the period beyond 2050, the CCC report *'UK climate action following the Paris agreement'*[20] highlights the following in relation to continued savings beyond 2050:

- Continued deployment of low-carbon measures to replace high carbon stock e.g. vehicles power generators, heating systems
- Continued displacement of fossil fuelled engines by electric and hydrogen vehicles. In addition, motorcycles, construction vehicles and aircraft support vehicles could be fully decarbonised.
- Increased use of heat pumps, district heating and low carbon hydrogen in buildings to reduce emission. Potential for a more rapid move away from gas for heating, should it become uneconomical to maintain the gas grid.
- After 2050 refining output and refining emissions will continue to reduce as transport and heating are electrified or switched to hydrogen, lessening the demand for refined fuels.

In addition, beyond 2050 there will be a need to focus on sectors where emissions are still expected to remain. This includes aviation, agriculture and parts of industry.

- Within the aviation sector some further emission reductions could be possible through improvements in fuel efficiency and take up of biofuels, however further reductions would require further options. This could include for example; advanced low carbon fuels, alternative propulsion methods e.g. LNG, hydrogen, nuclear, solar, hybrid planes, greater shifts away from aviation to alternatives by consumers
- Emissions from agriculture will be mainly from livestock and fertilisation of soils. Emissions could potentially be reduced beyond 2050, for example through increased diet change, food waste reduction, breakthroughs in genetically modified livestock, novel crops and precision livestock farming.
- It is envisaged that remaining emissions from industry will be primarily from fuel combustion, process emissions and residual CCS emissions from manufacturing (such as iron & steel, food & drink), water management and construction sectors. Further electrification or the use of hydrogen may be possible to reduce fuel combustion emissions. Process and CCS emissions

[19] Committee on Climate Change (2016) UK climate action following the Paris Agreement
[20] Committee on Climate Change (2016) UK climate action following the Paris Agreement

will be more difficult to decarbonise. The sector may be able to reduce emission through less carbon intensive products and increased reuse of products and materials.

The report also covers Geoengineering options in order to help achieve targets, including spraying reflective particles into the upper atmosphere, enhancing the reflectivity of clouds by spraying particles, and enhancing the reflectivity of land surfaces. However, there is a larger degree of uncertainty regarding such approaches and further exploration of these options would be required. Greenhouse Gas Removal, which is already included in Phase 2, would also have a potential role in this phase, as other options of greenhouse gas removal as developed.

Other sources do provide scenarios with some information on the period 2050-2100. The recent report *'Bending the Curve'*, published by the University of California[21] identifies a series of clusters for moving towards a low carbon economy:

- Science Solutions Cluster
- Societal Transformation Solutions Cluster
- Governance Solutions Cluster
- Market- and Regulations-Based Solutions Cluster
- Technology-Based Solutions Cluster
- Natural and Managed Ecosystem Solutions Cluster

This highlights the wider activities in addition to technology based solutions that need to be considered. For the technology based cluster, the report indicates the various solutions, if fully implemented, could reduce global warming by as much as 1.5 degrees Celsius by 2100. Therefore, solutions identified would continue to be implemented beyond 2050. This includes technologies such as photovoltaics, wind turbines, battery and hydrogen fuel cell electric light-duty vehicles and more efficient end-use devices, together with innovations for the complete electrification of energy and transport systems and improvements to building efficiency.

2.6 Timeline Analysis Conclusions

This section has identified the key technologies likely to be required to move towards a low carbon economy, based on the IEA's ETP 2016 and the UK's Fifth carbon Budget scenarios.

The overall approach to transition to a low carbon economy is:

- Implement known and developing energy efficiency measures
- Deploy technologies that have been developed and are known. Costs for some of these will be expected to decrease with deployment, as has been the case recently with solar photovoltaic cells
- Demonstrate other technologies that are close to deployment
- This leaves hard-to-reduce sectors, such as aviation, where further innovation is likely to be required
- Greenhouse gas reduction technologies may be required to reach zero net emissions in the second half of the century

The expected deployment of technologies in the UK and globally is broadly similar. There are some obvious differences based on geography – offshore wind is likely to provide a higher proportion electricity for UK than globally and solar PV a lower proportion.

Clearly there is a range of technologies that can be implemented, and also a degree of uncertainty in terms of when they will be deployed in reality. However key trends for each phase have been identified and are in Table 4 below.

[21] and http://www.ccacoalition.org/en/resources/executive-summary-report-bending-curve-10-scalable-solutions-carbon-neutrality-and-climate

Table 4: Summary of technology requirements by emissions-reduction sector and time

Emissions-reduction sector	2017-2030	2030-2050	2050-2100
Power generation	• Key technologies globally include solar PV, on-shore wind, hydro and nuclear • Key technologies within the UK will include renewables including offshore wind, nuclear, CCS and bioenergy • The initial deployment of less mature technologies will be required	• Key low carbon technologies are solar PV, onshore wind and hydro • Deployment of other low carbon generation technologies such as offshore wind will increase • Other solutions relevant to electricity generation and distribution increase in deployment such as smart urban (or city) energy networks	• Continued deployment of low carbon technologies from earlier phases though deployment rates may be declining • Focus on aviation, agriculture and parts of the industry sectors • Refined fuel demand decrease due to electrification and/or switch to hydrogen • Potential for geoengineering and other greenhouse gas removal technologies
Transport	• Energy efficiency improvements in conventional internal combustion engines and use of biofuels • Ongoing electrification of vehicles • Technologies to improve efficiency of different transport modes such as materials substitution to reduce weight, advanced lubricants and advanced aerodynamics	• Increased electrification of vehicles, including heavy duty transport • FCEVs – main use for hydrogen in fuel cells • More high speed rail • Stronger uptake of alternative / low carbon fuels, for example biofuels and methane	
Industry	• Deployment of energy efficiency measures (BAT) within industrial sectors • Use of low carbon fuels and feedstock and increased recovery of excess energy • CCS identified as key technology within the UK	• Increased deployment of innovative low carbon process technologies, including integration of CCS into industrial processes • Emission reductions through recycling solutions	
Buildings	• Reduce heating and cooling energy demands in buildings both retrofit and for new build • Components/ controls to improve the energy efficient building e.g. lighting, appliances • Use of heat pumps to provide heat for homes and businesses	• Continuing improvements in energy efficiency e.g. lighting and appliances • Use of highly insulated, integrated building envelopes • Integrated heating and cooling solutions with net-zero emissions • Solar solutions – including solar cooling technologies and solar thermal systems • Potential use of hydrogen from natural gas to provide low carbon heat	

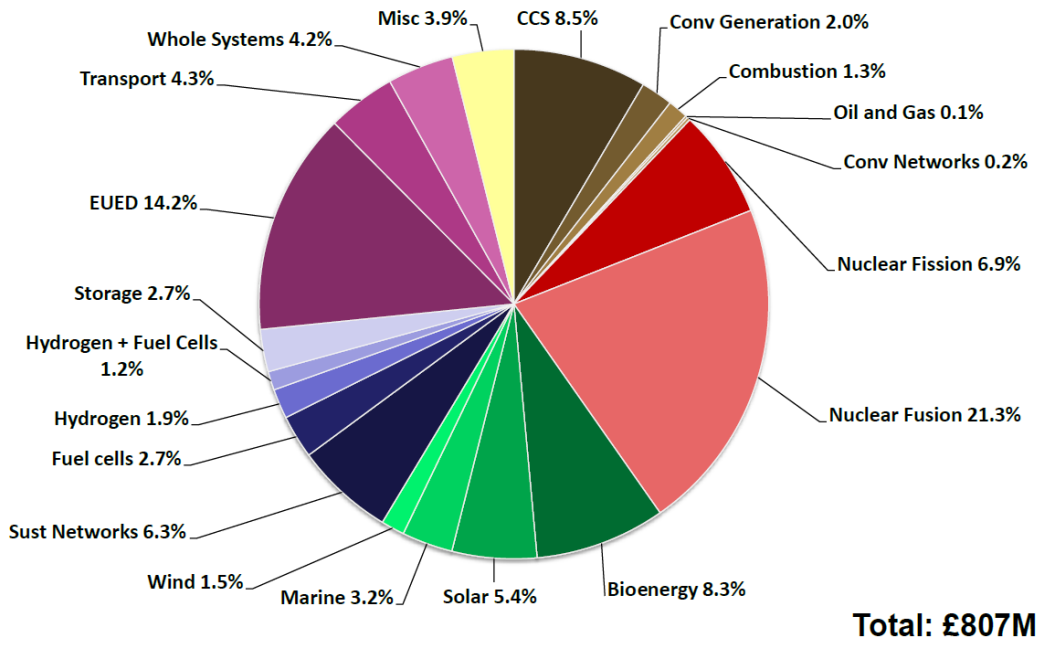
3 Current UK Competitive Position

- Used two methods to assess the size of the UK LCE in 2015
- Estimated employment of 230,000 to 450,000
- Estimated turnover of £42 billion to £120 billion
- Broadly stable over 2013 to 2015

3.1 Low carbon technology RD&D

Over the last 15 years, the UK has made a substantial investment in energy and low carbon technology research, development and demonstration (RD&D). For example, the Research Councils UK (RCUK) Energy Programme invested £839 million between 2003 and 2011, and a further £625 million is being invested between 2012 and 2018. Analysis by the programme managers at EPSRC, indicates that this investment has been made across a wide range of technical areas, including renewable energy, alternative fuels, low carbon transport, nuclear power, energy storage and CCS, as well as energy efficient electricity and heat generation, distribution and end use, as illustrated in the Figure 4 below.

Figure 4: Breakdown of Energy Programme investment up to 2014 by technology area[22].



About one third of all RCUK research grants are made through the Supergen initiative in sustainable power generation and supply[23], [24], [25], which has provided core funding to 14 hubs undertaking basic research on energy technologies at low state of technology readiness (TRL) since 2001, and is continuing to support six hubs under its fourth phase of investment working on:

- Alternative energy carriers (such as hydrogen),
- Bioenergy,
- Energy networks,
- Energy storage,

[22] Research Councils UK, Energy Portfolio Breakdown, EPRSC, April 2014
[23] Supergen Introduction and background, RCUK 2016, http://www.rcuk.ac.uk/documents/energy/supergenintroductionbackground-pdf/
[24] Supergen Draft Programme Strategy, RCUK 2016, http://www.rcuk.ac.uk/documents/energy/supergenprogrammestrategy-pdf/
[25] Supergen Benchmarking report, RCUK, 2016, http://www.rcuk.ac.uk/documents/energy/supergenphase3-benchmarking-pdf/

- Fuel cells,
- Offshore renewable energy,

The RCUK also has 10 national research centres which act as focal points for mid TRL applied research and development in the energy technologies, including:

- The UK Energy Research Centre (UKERC),
- The National Centre for Energy Systems Integration (CESI),
- The EPSRC Centre for Power Electronics, CCS Research Centre (UKCCSRC),
- The Dynamics of Energy, Mobility and Demand (DEMAND) Centre
- The Centre for Energy Epidemiology (CEE)
- The Centre on Innovation and Energy Demand (CIED),
- The Centre for Industrial Energy, Materials and Products (CIE-MAP),
- The Interdisciplinary centre for Storage, Transformation and Upgrading of Thermal Energy (i-STUTE).
- The Centre for Sustainable Energy Use in Food Chains (CSEF).

In addition, 8 out of 11 Innovate UK catapult centres[26] are commercialising research work in energy or supporting the development of sustainable solutions for UK manufacturing, business, and society:

- The Offshore Renewable Energy Catapult,
- The Energy Systems Catapult,
- The Future Cities Catapult,
- The Transport Systems Catapult,
- The High Value Manufacturing Catapult,
- The Compound Semiconductor Applications Catapult,
- The Satellite Applications Catapult,
- The Digital Catapult.

As part of its mission to support innovation, increased productivity and growth in UK business Innovative UK also funds a range of industrial research, development and demonstration (RD&D) projects[27],, and knowledge transfer networks (KTN) in many sectors of the economy[28] that support business seeking to develop new materials, goods and services for the low carbon economy and specialist interest groups in emerging technology areas such as sustainability and the circular economy and energy harvesting.

These investments in research and innovation, and others related to the wider impact of climate change on business and society (e.g. adaptation), mean that the UK is well placed to obtain a share of the growing market for the materials, goods and services needed by the transition to a low carbon economy provided concerted action is taken by suppliers and government to ramp up export activities[29].

Technologies where UK is investing in research and innovation are candidates for UK opportunities from transition to a low carbon economy.

3.2 UK strengths in low carbon innovation

During our review, we identified a substantial volume of world class research, and innovative product designs in all of the areas that we made estimates of potential global market size (See section 4).

In many cases, the UK research has the potential to produce a new generation of low carbon products and services, and work is under way to commercialise the results through the Catapult Centres and Industrial Research Centres. (See Section □)

[26] https://catapult.org.uk/about-us/about-catapult/
[27] Innovate UK, Delivery Plan 2016/17, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/514962/CO300_Innovate_UK_Delivery_Plan_2016_2017_WEB.pdf
[28] https://admin.ktn-uk.co.uk/app/uploads/2016/09/KTN-Annual-Report-2015_2016.pdf
[29] https://www.carbontrust.com/media/504208/ctc829-a-must-win-capitalising-on-new-global-low-carbon-markets.pdf

With the aid of our experts and stakeholder feedback, we have assessed whether there is a low, medium or high potential for UK business to capture market share in each of the main segments of the UK low carbon economy market (Table 5) and identified some examples of areas where the UK currently has particularly strength based on an assessments of UK low carbon capabilities produced by the Foreign & Commonwealth Office (FCO), UK Trade & Industry (UKTI) and Carbon Trust[30] and Low Carbon Coordination Innovation Group (LCCIG)[31].

Table 5: Assessment of UK potential to capture market share and examples of current UK strengths

Low carbon economy (LCE) sector	Potential to capture market share	Examples of current UK strengths
Energy efficient products	Medium	Smart Grids, advanced building design, materials and manufacturing systems
Energy from waste and biomass	Low to Medium	Biofuels, waste recycling techniques
Low carbon electricity	Medium	Off-shore wind, energy storage, solar PV
Low carbon services	High	Finance, insurance, consultancy
Low emission vehicles, infrastructure, fuels cells and energy storage	Medium to high	Power systems & transmissions, batteries, logistics, telematics,
Other products and services	Medium to high	Membranes, catalysts, bioprocessing

These ratings are intended as high level assessments looking at the short to medium term potential for UK business to capture global market share by 2030. The list of example UK strengths is not exhaustive, and there are other promising but less well known technologies that could be included from sector strategies and sector benchmarking reports[32] by BIS and regional/country strategies[33].

If we look over the immediate time horizon, research is underway to develop the next generation of innovations that will be needed to enable and deliver the circular economy and on the technologies that will enable UK society and the global economy to adapt to the impact of climate change. We expect that many of these technologies will take advantage of the UK's strengths in advanced manufacturing and materials; robotic, autonomous and digital systems; and energy storage.

3.3 UK Export Performance

Analysis of global production and trade data between 2010 and 2014[34], indicates that 75% of UK exports (by Value) related to:

- Financial services (11.6%)
- Wholesale and retail products (11.5%)
- Transport equipment (11.1%)
- Machinery and electricity products (9%)
- Chemicals and related products (8.2%)
- Business services (8.1%)
- Professional services (6.1%)
- Metals / Metal Products (4.9%)

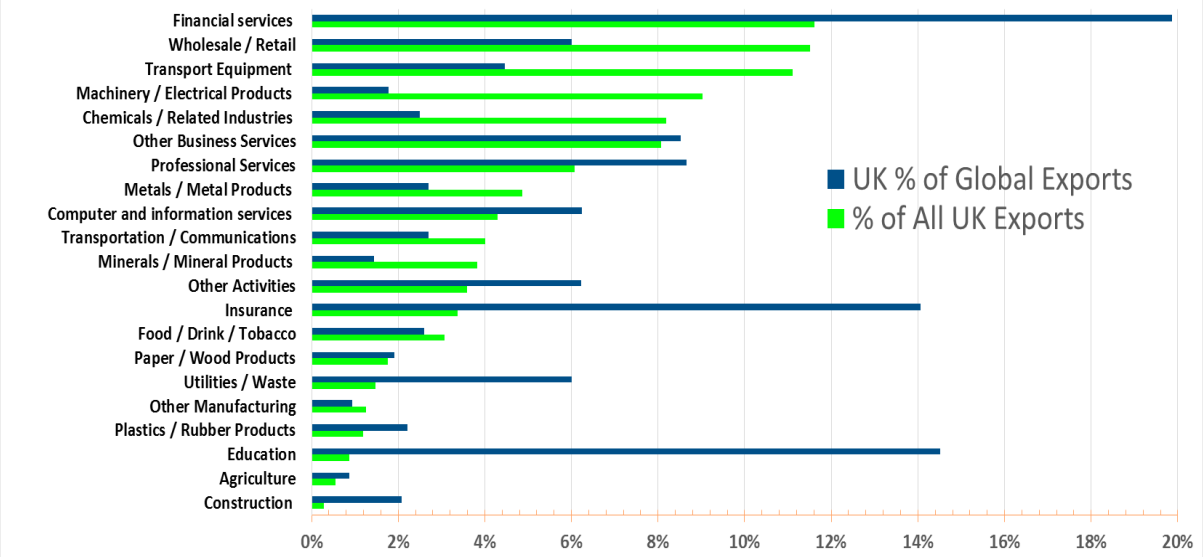
[30] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/199886/UK_Capabilities_Report_EN.pdf
[31] https://www.carbontrust.com/media/190038/tina-bioenergy-summary-report.pdf
[32] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/34647/12-1207-benchmarking-uk-competitiveness-in-the-global-economy.pdf
[33] 2014-17 Business Plan, Scottish Enterprise, https://www.scottish-enterprise.com/~/media/5793a121a3ff431a8453f4b0c83b8744.ashx
[34] As published in the World Input-Output Database, http://www.wiod.org/home. For details of the method see: Timmer, M. P., Dietzenbacher, E., Los, B., Stehrer, R. and de Vries, G. J. (2015), "An Illustrated User Guide to the World Input–Output Database: the Case of Global Automotive Production", Review of International Economics., 23: 575–605

- Computer and information services (4.2%)

In 2014, UK business captured approximately 3.6% of global export market. Sectors that captured more than this percentage of the global export market for their particular category of materials, goods services are considered to have a comparative advantage[35]. Of these nine sector groupings listed above, six of exceeded this threshold, whilst three (metals / metal products, chemicals and related products, and machinery / electrical products) do not. In part, these market shares reflect the shift in UK industry towards production of higher value added materials, goods and services, and the globalised nature of the some manufacturing sectors. The six sectors groupings with comparative advantage are broadly similar to the sectors identified by BIS's benchmarking of revealed comparative advantage of in 2003 and 2008[36], although mineral products and the food and drink sector have lost competitive position.

The results of analysis for all sector groupings are shown in Figure 5. The UK's share of the global export market for Low Carbon Economy related materials, goods and services might be maximised by helping sectors that generate a significant share of UK exports to develop new products, and by investment in sectors with future growth potential where the UK has a competitive advantage.

Figure 5: Analysis of UK Exports and UK Share of the Global Export Market by sector grouping



Markets which represent a relatively high proportion of UK exports and particularly where the UK has a high share of global exports give areas where low carbon opportunities may start from a strong current base.

Research and innovation investments (Section 3.1) may lead to enhancing the UK share of global exports.

3.4 Current UK low carbon goods and services market

The current UK market for low carbon goods and services has been estimated using an established method described in detail in Appendix 1.

A baseline for the market was set with the publication of the report 'The size and performance of the UK low carbon economy' by BIS in 2015[37]. This work, which was led by TBR, set out employment, turnover and gross value added (GVA) data for a range of sectors that made up the low carbon economy, as of 2013.

[35] http://www.rbs.com/content/dam/rbs/Documents/News/2014/08/UK%20export%20performance%20August%202014.pdf
[36] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/34647/12-1207-benchmarking-uk-competitiveness-in-the-global-economy.pdf
[37] The Size and performance of the UK low carbon economy, BIS, March 2015.

The current work sought to update the BIS baseline with data for 2015. The analysis is based on the performance of 5,600 businesses known to operate across the low carbon economy and which were in existence in both years, viz 2013 and 2015.

Subsequent to the publication of the BIS report, ONS undertook survey work to generate its own data for the low carbon and renewable energy economy. While there was significant commonality between the sectors used, there were also important definitional differences such as in the way supply chain effects were incorporated.

Headline data by group is presented below in Table 6 to Table 8 to show changes in employment, turnover and GVA between 2013 and 2015.

Table 6: Low carbon employment 2013 – 2015

Sector Group	2013	2015	Change
Energy Efficient products	94,200	90,900	-3.5%
Low carbon electricity	140,800	139,400	-1.0%
Low carbon heat	32,600	30,800	-5.4%
Low carbon services	28,000	28,600	2.0%
Low emission vehicles, infrastructure, fuels cells and energy storage	18,100	18,400	1.5%
Waste processing, energy from waste and biomass	146,900	141,300	-3.8%
Total	**460,600**	**449,400**	**-2.4%**

Source: TBR/OrtusER 2017

The view is that, overall, the low carbon economy lost some jobs in the period between 2013 and 2015. However, as the data only covers one year (2015), the change may not be statistically significant so should be treated with caution. The BIS report showed that between 2010 and 2013 employment in the low carbon economy grew by 3.8% per annum[38].

Table 7: Low carbon turnover (£M) 2013 – 2015

Sector Group	2013	2015	Change
Energy efficient products	16,400	17,000	4.1%
Low carbon electricity	33,300	29,500	-11.4%
Low carbon heat	4,900	5,100	4.2%
Low carbon services	3,700	4,000	8.5%
Low emission vehicles, infrastructure, fuels cells and energy storage	8,800	9,600	10.1%
Waste processing, energy from waste and biomass	54,600	57,300	5.0%
Total	**121,700**	**122,600**	**0.8%**

Source: TBR/OrtusER 2017

The turnover data are also broadly static, though the change between the two years is marginally positive. Turnover over the period 2010 to 2013, grew by 7.6% on an annual basis[39].

[38] Ibid, see Table 31.
[39] Ibid, see Table 33.

The differences in growth rates between the sector groupings between 2013 and 2015, also suggest that additional data are needed before definitive judgements can be made on the way the low carbon economy is performing.

Table 8: Low carbon GVA (£M) 2013 – 2015

Sector Group	2013	2015	Change
Energy efficient products	7,300	7,300	-1.3%
Low carbon electricity	10,400	10,500	0.1%
Low carbon heat	1,700	1,800	5.8%
Low carbon services	1,800	2,000	8.8%
Low emission vehicles, infrastructure, fuels cells and energy storage	1,300	1,300	1.1%
Waste processing, energy from waste and biomass	21,900	19,200	-12.3%
Total	**44,500**	**42,000**	**-5.6%**

Source: TBR/OrtusER 2017

Overall, the data suggest that any growth identified in the work for BIS may have stalled. However, the data are not robust enough to provide a definitive statement. In the period 2010 to 2013, there was annual growth of 8.7%[40].

The lack of consistency between the three data sets could also be interpreted as indicating changes within the low carbon sector, e.g. margins are tightening in some sectors, yet loosening in others, especially as the nature of activity changes, e.g. nuclear focuses on decommissioning, offshore wind farms increase output and technical/financial challenges continue to be felt in marine. However, the previously mentioned caution is reiterated.

For comparison, ONS data from the 2013 and 2014 surveys are presented in Table 9 and Table 10 below. These data show a possible slow down, though ONS urge caution due to large margins of error, along with differences in method across the two years..

Table 9: ONS low carbon and renewable energy direct employment 2013 - 2014

Low carbon economy (LCE) sector group	2014	2015	Change
Energy efficient products	155,500	142,500	-8.4%
Energy from waste and biomass	11,500	10,000	-13.0%
Low carbon electricity	40,500	47,000	16.0%
Low carbon heat	7,000	3,500	-50.0%
Low carbon services	13,000	15,000	15.4%
Low emission vehicles, infrastructure, fuels cells and energy storage	11,000	15,000	36.4%
Total	**238,500**	**233,000**	**-2.3%**

Source: ONS

[40] Ibid, see Table 35.

Table 10: ONS low carbon and renewable energy direct turnover (£M) 2013 - 2014

Low carbon economy (LCE) sector group	2014	2015	Change
Energy efficient products	21,900	19,900	-9.1%
Energy from waste and biomass	5,600	4,400	-21%
Low carbon electricity	12,400	12,200	-1.6%
Low carbon heat	1,400	1,200	-14%
Low carbon services	1,200	700	-44%
Low emission vehicles, infrastructure, fuels cells and energy storage	3,800	3,800	-
Total	**46,300**	**42,200**	**-8.9%**

Source: ONS

The similarities between the data showing change in Table 6 and Table 9 indicate a degree of consistency. It should be noted that the ONS data are for 2014 and 2015, rather than 2013 and 2015.

The apparent lack of growth, compared to the period up to 2013 would seem consistent with changes to key policy measures, e.g. reduction in feed in tariffs and local challenges to planning consents for onshore wind.

Direct comparison of the data from the two sources cannot be made due to the differences in definition.

It could be suggested that the results in Table 6 to Table 9 omit some activities that could be considered as part of the low carbon economy. For instance, activities associated with adaptation to climate change are not included. As an initial trial, further analysis was undertaken to investigate the 'Adaptation' sector. (See Appendix 1B). This sector includes the design, production, installation and maintenance of products and services aimed at adapting to the effects of climate change.

4 Global opportunities for UK Manufacturing

Analysis suggests:

- UK LCE could grow from 2% of UK total output in 2015 to up to around 8% by 2030 and 13% by 2050
- Compound annual growth rates of 11% per annum between 2015 and 2030 and 4% per annum between 2030 and 2050
- UK LCE market size of between £230 billion and £640 billion in 2030 and between £510 billion and £1,400 billion in 2050
- Employment associated with the LCE between 1.1 and 2.4 million in 2030 and between 2.5 and 5.0 million in 2050

4.1 Approach to the quantification of market opportunity

We approached the quantification of the size of market opportunity for UK manufacturing in six stages:

1. Assessing the current size of the UK and global market for selected low carbon technologies and services, based on reported levels of deployment and market research reports.
2. Deriving estimates of the future global market size for the selected low carbon technologies and services in 2030 and 2050, based on the IEA's 2DS scenario and technology roadmaps, national technology cost forecasts and published estimates of future global market sizes.
3. Deriving estimates of future UK home market size for the selected low carbon technologies and services in 2030 and 2050, based on CCC scenarios and sector analysis, or pro rata estimates of UK market size based the ratio of UK GDP to global GDP or future electricity demand.
4. Making assumptions about the proportion of the total global market size that the UK might expect to capture, based on the UK's current share of global exports in the most relevant sector grouping (Figure 5) and the proportion of the global sector output that is traded internationally.
5. Combining the estimates of UK home and export market and exploring variants of the IEA 2DSand CCC's scenarios to obtain the estimated UK share of the global market for the selected low carbon technologies and services in 2015, 2030 and 2050, expressed as a range.

Deriving compound annual rates of growth for groups of technology areas, and applying these to the UK low carbon market statistics (Table 6 to Table 10) to obtain a ball park estimate of the overall potential size of the UK market for low carbon materials, goods and services in 2030 and 2050.

4.2 Future global low carbon economy markets

Global market opportunities arising from the transition to a low carbon economy were developed using an iterative process as illustrated in Figure 6.

- An initial review of roadmaps for transition to a low carbon economy identified over 500 discrete opportunities, which were reduced to 100 potential new global export markets by screening out:
    - Duplicates and "generic" opportunities e.g. increased energy efficiency
    - Well established technologies & incremental developments
    - Opportunities not applicable to the UK market
    - Difficult to value niche market opportunities
    - Out of scope topics (e.g. nuclear energy)
- The remaining opportunities were grouped into 50 market segments (see Appendix A4.4) of which 25 were selected in consultation with CCC for further assessment, including opportunities in areas:
    - Of existing, particular or emerging UK strength in the global export market (18)
    - Where the UK is considered to be lagging behind major competitors, competing with lower cost economies, or constrained by resource availability (5)
    - At an early stage of technology development (2)

It was not intended that this work should be comprehensive in considering all possible opportunities for the UK arising from transition to a low carbon economy. Considering the seven low carbon economy sectors used by ONS and TBR (See Table 6), the approach has been:

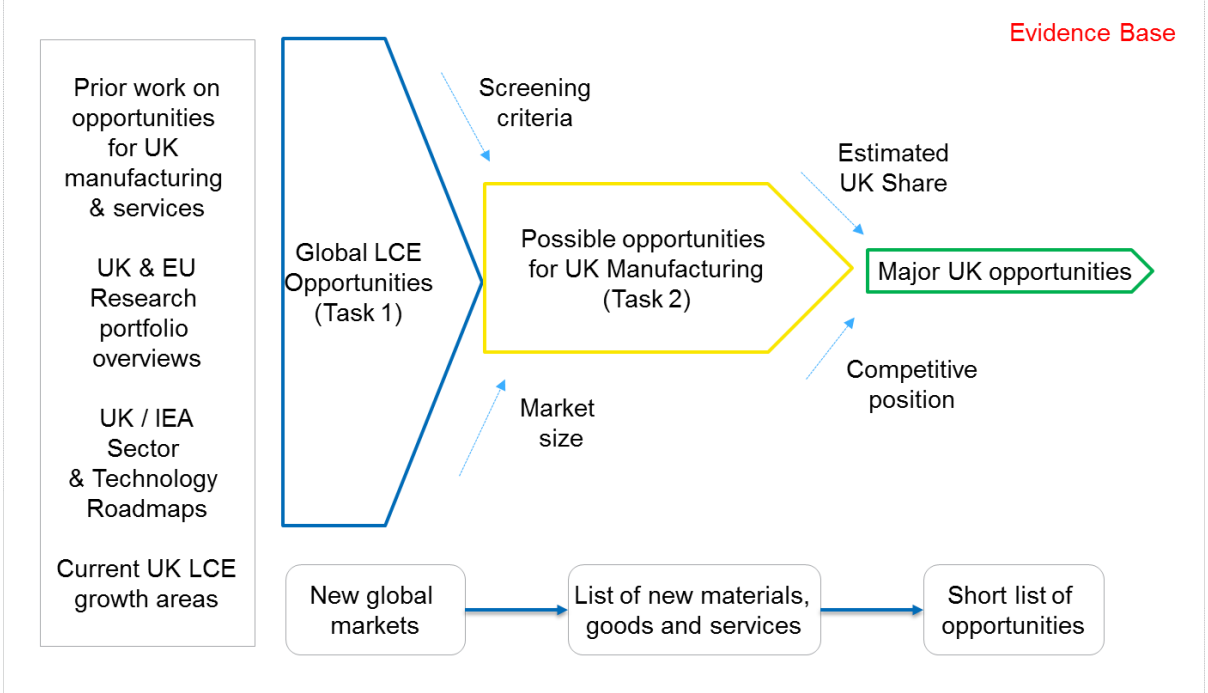
- Low carbon electricity – this has been considered in detail with separate estimates for all of the sub-sectors apart from hydropower and nuclear
- Low emission vehicles – this has been considered in detail with separate estimates for six aspects of low emission vehicles
- Low carbon services – low carbon finance and insurance have been considered but not other low carbon advisory services
- Low carbon heat - has not been considered
- Energy from waste and biomass – one example, that of biofuels has been considered
- Energy efficient products – selected examples have been considered

The alignment of the sectors considered by ONS and TBR and the opportunities analysed further are in Appendix 2.

In addition, we also examined two areas of the LCE not covered by ONS:

- Adaptation – an initial estimate has been made of the size of the opportunity
- Circular economy - an initial estimate has been made of the size of the opportunity (see Box 1).

Figure 6: Iterative approach to selected opportunities for UK from transition to low carbon economy



4.2.1 Low Carbon Electricity

Our estimates of the potential global market size for six selected opportunities within the low carbon electricity sector are given in Figure 7. These identified a potential global market size of between £260 bn and £360 bn per year in 2030 and £580 bn and £900 bn per year in 2050, with a compound annual growth rate (CAGR) of 5 to 7% between 2015 and 2030 and 4% to 5% between 2030 and 2050.

Our assessment of the potential future global market size for products and services related to the generation of low carbon electricity is based on the forecast level of electricity generated from wind, marine and solar PV technologies in 2030 and 2050, compared with reported generation in 2013.

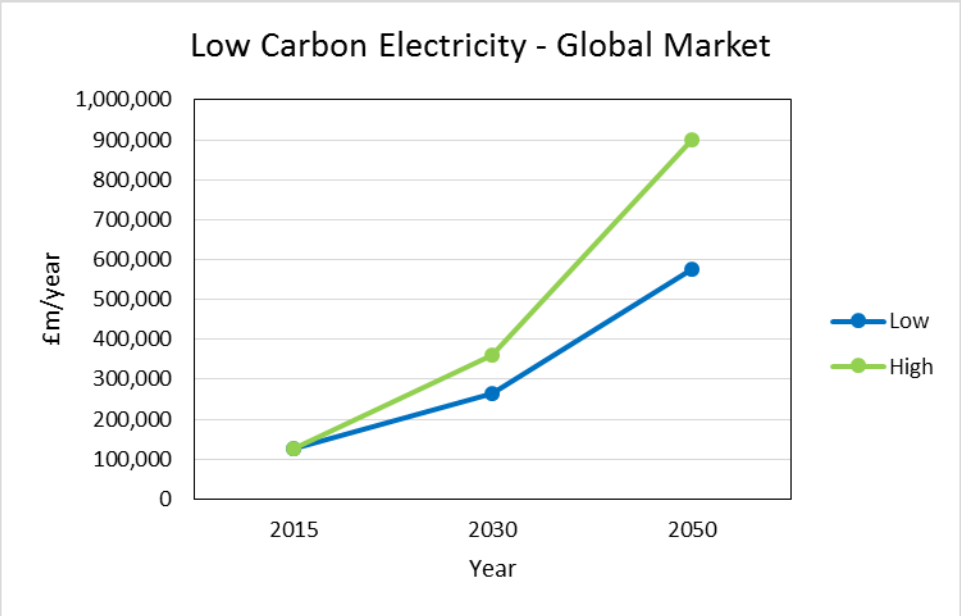
The annual capital investment required to deliver these electricity outputs was estimated using the investment costs per GW and anticipated technology cost reductions outlined in the IEA's technology roadmaps[41]. For Solar PV, capital costs were based on NREL forecasts of future technology costs[42], as there has been a significant reduction in solar PV costs since the IEA roadmap was prepared.

The annual capital investment in Carbon Capture and Storage (CCS) schemes was estimated from IEA's review of progress of CCS technology development[43]. The "No CCS in Power" (NCCP) variant of the 2DS scenario was used to generate high estimates for renewables and low estimates for CCS.

The capital investment associated with Energy Storage needed to enable variable renewables to deliver between 67% and 75% of global electricity generation by 2050 was also factored into the assessment.

These assessments included an allowance for end-of-life replacement (normally after 20 years), but did not include the costs of Operation and Maintenance (O&M) which potentially could increase the market for products and services by 12% to 140% depending on the technology and location of deployment.

Figure 7: Estimated global market size for selected low carbon electricity sectors in 2015, 2030 and 2050



[41] https://www.iea.org/roadmaps/
[42] http://www.nrel.gov/analysis/data_tech_baseline.html
[43] https://www.iea.org/publications/freepublications/publication/20YearsofCarbonCaptureandStorage_WEB.pdf

4.2.2 Low Emission Vehicles

Our estimates of the potential global market size for five selected opportunities within the low emission vehicles are given in Figure 8. These identified a potential global market size of between £1.0 tn and £2.0 tn per year in 2030 and £3.6 tn and £7.6 tn per year in 2050, with a CAGR of 26% to 29% between 2015 and 2030 and 6% to 7% between 2030 and 2050.

Our assessment of the potential future global market size for products and services related to low emission vehicles is based on the forecast sales of light duty Battery Electric Vehicles (BEV), Plug-in Hybrid Electric Vehicles (PHEV) and Fuel Cell Electric Vehicles (FCEV) under the 2011 IEA road map for Electric and Plug-in Hybrid Vehicles[44] and the 2016 Global EV outlook[45]. These assume a much higher rate of EV deployment is needed post 2030 to avoid temperature increases above 2°C than some other market projections[46]. The High Hydrogen ("High H_2") variant of the 2DS scenario was used to generate high and low estimates with FCEV displacing sales of PHEV under the high scenario[47],

The annual capital investment required to realise the forecast global sales of each type of Electric Vehicle was estimated using the initial purchase cost of vehicles and anticipated cost reductions published in the technical annex to the 2015 IEA Technology Road Map for Hydrogen and Fuel Cells[48].

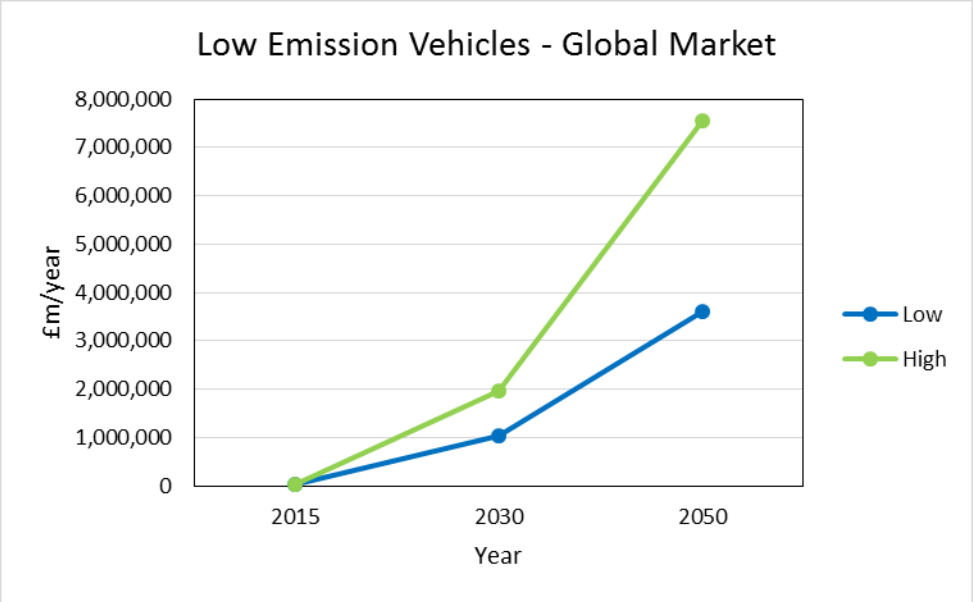
The proportion of the annual investment in EVs related to transmission systems, electric motors, and batteries was also calculated, but excluded from the overall total market size to avoid double counting.

The annual capital investment required to provide public and workplace charging solutions to support the uptake of electric vehicles, and of building a hydrogen refuelling infrastructure was also included.

The annual revenue from logistics and telematics services associated with the provision of Integrated Mobility Products and Services and Advanced Driver Assistance Systems needed to improve overall transport integration and efficiency was also estimated based on a 2015 report by Frost & Sullivan[49].

These assessments do not include the costs of Operation and Maintenance (O&M) of electric vehicles or supporting infrastructure, or the costs of deploying medium and heavy duty electric vehicles.

Figure 8: Estimated global market size for selected low emission vehicles in 2015, 2030 and 2050



[44] https://www.iea.org/publications/freepublications/publication/technology-roadmap-electric-and-plug-in-hybrid-electric-vehicles-evphev.html
[45] https://www.iea.org/publications/freepublications/publication/Global_EV_Outlook_2016.pdf
[46] https://about.bnef.com/blog/electric-vehicles-to-be-35-of-global-new-car-sales-by-2040/
[47] http://www.iea.org/publications/freepublications/publication/TechnologyRoadmapHydrogenandFuelCells.pdf
[48] https://www.iea.org/media/freepublications/technologyroadmaps/TechnologyRoadmapHydrogen_Annex.pdf
[49] https://www.sitra.fi/julkaisut/Selvityksi%C3%A4-sarja/Selvityksia102.pdf

4.2.3 Low Carbon Financial Services

Our estimates of the potential global market size for two selected opportunities within the low carbon services sector are given in Figure 9. These identified a potential global market size of between £66 bn and £280 bn per year in 2030 and £110 bn and £460 bn per year in 2050, with a CAGR of 12 to 15% between 2015 and 2030 and 2 to 3% between 2030 and 2050.

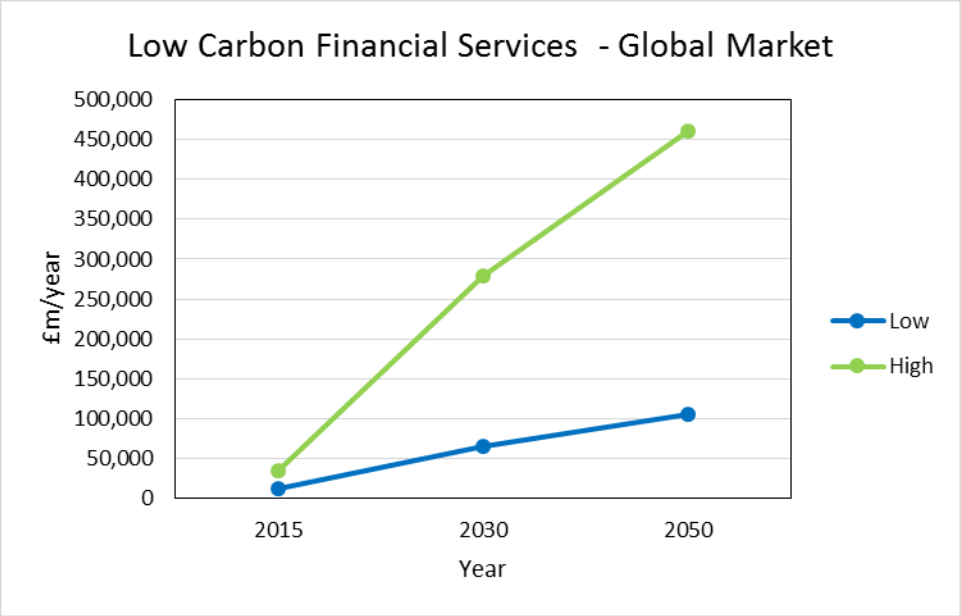
Our assessment of the potential future global market size for low carbon financial services is based on the range of estimates of annual capital investment required to transform the global energy supply system by 2050 and simultaneously meet emissions targets consistent with restricting the rise in average global temperature to less than 2 degrees.

These estimates were collated in the 2016 Review by the City of London that examined the potential for the UK to act as an international hub for green finance[50] and correspond to average annual low carbon investments equivalent to between 1.4% and 6% of global GBP. This latter estimate is higher than previous estimates for the global low carbon transition, which range up to 2.5% of global GDP[51],

The assessment assumes that 5% of the capital raised is related to financial services[52], and a further 0.4%[53] is spent on the financial services related to insuring the performance and lifetime of low carbon technologies and energy savings and that typical premium rates are 1% to 3% of the initial investment[54].

The assessments **exclude** financial and advisory services related to project and programme de-risking consultancy, weather related performance risks, climate change risks and other risks, manufacturers' and contractors' warranties and home insurance products related to the deployment of low carbon technologies. These additional services were not included in the assessment due to a lack of data, but in some cases can increase the proportion of project costs spent on financial services to 15%.

Figure 9: Estimated global market size for low carbon financial services in 2015, 2030 and 2050



[50] https://www.cityoflondon.gov.uk/business/economic-research-and-information/research-publications/Documents/research%202016/globalising-green-finance.pdf
[51] Finance: Supporting the transition to a global green economy, (Extract from: Towards a green economy, Pathways to Sustainable Development and Poverty Eradication), UNEP, 2011, http://web.unep.org/greeneconomy/sites/unep.org.greeneconomy/files/field/image/15.0_finance.pdf
[52] Cost of raising equity, OFGEM/CEPA, 2010, https://www.ofgem.gov.uk/publications-and-updates/cost-raising-equity-cepa-2010
[53] Based on analysis of OECD Insurance Statistics, 2005-2012, https://stats.ukdataservice.ac.uk/metadata/OECD/Insurance/2113031e.pdf
[54] Financial Risk Management Instruments for Renewable Energy Projects, UNEP, 2004, http://www.unep.org/pdf/75_Risk_Management_Study.pdf

4.2.4 Other Low Carbon Products and Services

Our estimates of the potential global market size for six selected opportunities within other low carbon products and services sectors are given in Figure 10. These identified a potential global market size of between £1.1 tn and £1.6 tn per year in 2030 and £2.8 tn and £4.5 tn per year in 2050, with a CAGR of 6 to 8% can be expected between 2015 and 2030 and 5% between 2030 and 2050. Biofuels, bioprocessing, catalysts and membranes are approximately 70% of the global market for this group of products and reflect the transition to lower energy / low carbon industrial processes.

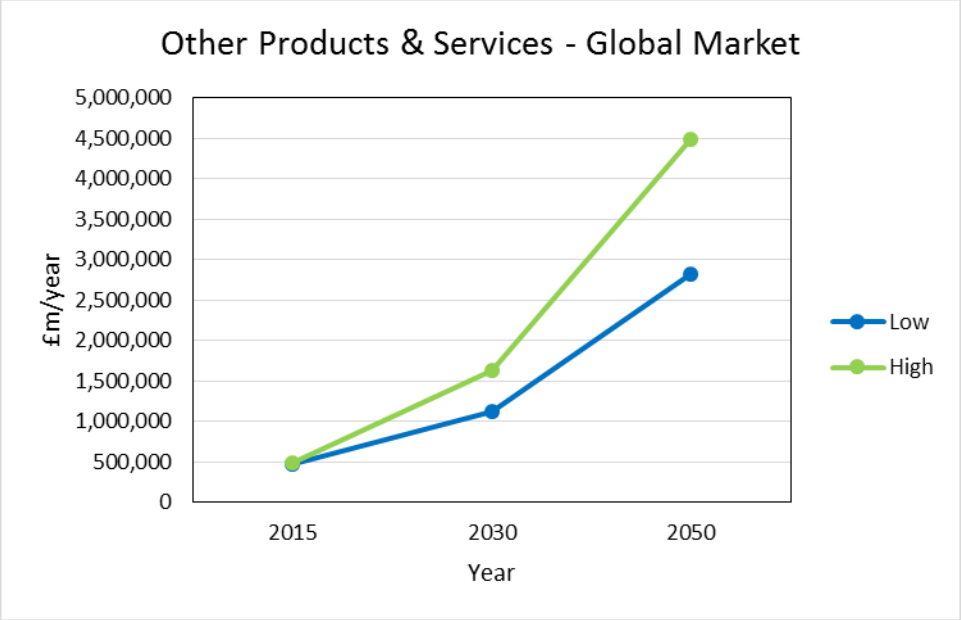
Our assessment of the potential future global market size for other low carbon products and services was based on the assessment of the potential market for selected products and services, including:

- Advanced insulation of buildings
- Alternative batteries (for electric vehicles)
- Alternative magnets (for the motors in electric vehicles)
- Biofuels
- Industrial bioprocessing
- Industrial catalysts
- Membranes for separation processes
- Recycling of Lithium batteries (from electric vehicles)
- Smart grids (including smart meters, home automation, demand response, grid management, control and automation and high voltage transmission reinforcement)

We excluded products related to electric vehicles from our analysis of the market size of other low carbon products and services, since the costs of these are already included within the estimates for low emission vehicles. This reduced the annual market size by 15% in 2030 and 20% in 2050.

A range of sources of market data was used to build estimates for growth in the markets for these technologies from 2015 to 2030 and 2050. These included the IEA roadmap for sustainable buildings, market forecasts by consultants and market analysts, and estimates of EV sales described in section 4.2.2.

Figure 10: Estimated global market size for other products and services considered in 2015, 2030 and 2050



Box 1: Market opportunities associated with the Circular Economy

"A circular economy is one that keeps products, components and materials at their highest use and value at all times. It is an alternative to the current linear economy, where we make, use and then dispose of products, components and materials. A circular economy can stimulate innovation in areas like product design, re-use and remanufacturing facilities, business models as well as new forms of finance."

(Towards a circular economy – context and opportunities, London Waste & recycling Board, 2015)

The literature did not provide sufficient detailed information on global impact on the circular economy to enable the overall size of the market opportunity in 2030 and 2050 to be quantified. There are some partial estimates for current markets, for example CLEPA (the European Association of Automotive Suppliers) puts the vehicle remanufacturing market in Europe at US$ 10 to 12 billion.

There are many estimates of the benefits of the circular economy, but not of the market value. For example, a report on the potential benefits of a circular economy in London estimates that:

- Circular economy opportunities in the build environment will add £3-5bn to GDP by 2036
- The annual circular economy with savings in the textiles sector of over £1bn by 2036
- The annual circular economy savings in the plastics sector will be at least £200m by 2036
- The circular economy opportunities in the food sector will add £2-4bn to GDP by 2036
- The circular economy savings in the electrical and electronic equipment will be at least £900m by 2036

The circular economy represents a radical shift in perspective—as it involves redesigning products to increase product lifetime and end of life component reuse, new business models based on shared use rather than individual ownership, and changes in consumer behaviour to eliminate waste. The disruptive nature of its approach means that it will have a major impact on all sectors of the economy.

4.3 Size of the LCE opportunity for UK business

Our estimates of the size of the opportunity for UK business to provide the products and services that will be needed during the global transition to low carbon economy are based on:

- An estimate of the size of the UK market in 2015, 2030 and 2050
- An estimate of the share of the global market that UK will capture, assuming that export performance is as currently for relevant sectors – as illustrated in Figure 5 in Section 3.2.

Current export performance for sector groups that relate to low carbon products and services gives a starting point for estimating the size of the UK opportunity from global transition to a low carbon economy.

Section 5 considers possibilities to increase UK market share in areas of strength

In this analysis, the size of the UK market is a major factor in assessing the potential turnover that UK companies could realise, since exports only represented around 25% of turnover across the 8 sector groupings supplying the products and services considered by our market assessments (see Table 11

Table 11: Current levels of global imports/exports, UK exports and UK share of global export market[55]

Sector Grouping[56]	% Global Output imported/exported	UK % of Global export market	% UK Output Exported
Chemicals / Related Industries	26.3%	2.5%	43.8%
Computer and information services	9.9%	6.2%	12.6%
Metals / Metal Products	19.4%	2.7%	40.7%
Machinery / Electrical Products	37.1%	1.8%	48.1%
Transport Equipment	31.3%	4.5%	62.6%
Construction	0.9%	2.1%	0.5%
Financial services	8.0%	19.9%	30.7%
Insurance	8.5%	14.1%	14.9%
Total (8 sectors)	**18.7%**	**3.7%**	**24.3%**

[55] Based on analysis of World Input Output Tables 2010 to 2014, World Input-Output Database http://www.wiod.org/home (November 2016)
[56] These sector groupings are as used in World Input Output Tables (see previous footnote). Each of the low carbon sectors considered in the current work was associated with a sector grouping that was considered to give the best fit. Figures from Table 6 were then used in analysis of the UK share of the global market. The association of sector groupings with the low carbon products and services considered is given in Appendix 2 and in sub-sections 4.3.1 to 4.3.4.

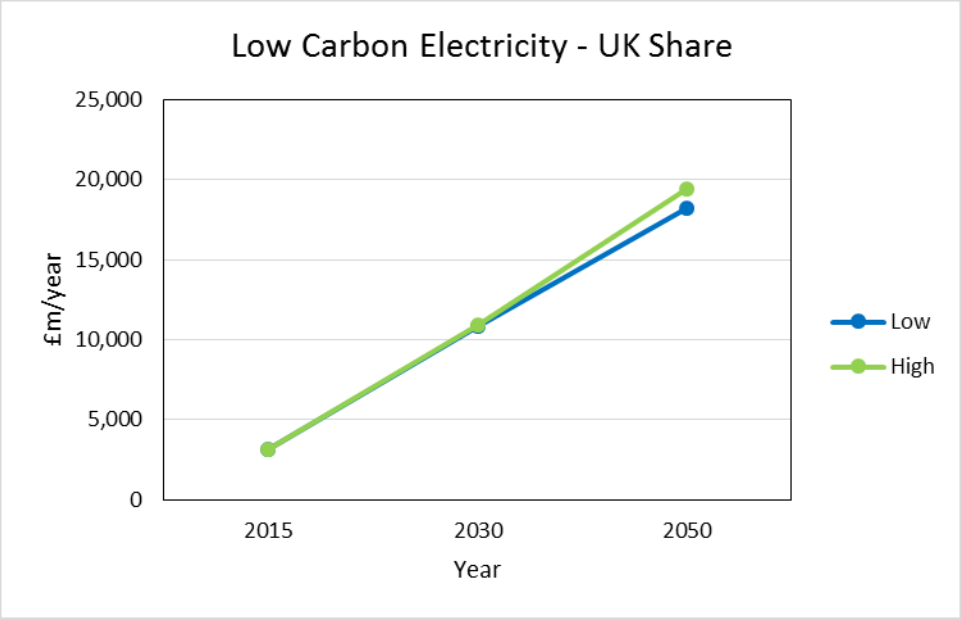
4.3.1 Low Carbon Electricity

Estimates of the opportunity for UK business for the low carbon electricity sector are given in Figure 11. These identified a potential global market size of £11 bn per year in 2030 and £18 bn and £19 bn per year in 2050, with a CAGR of 9% can be expected between 2015 and 2030 and 3% between 2030 and 2050.

The assessment of potential UK share of the global market for low carbon electricity related products and services, is based on obtaining the same percentage of the global export market as is currently obtained in sectors supplying machinery and electrical products, and related services, and on estimates of the annual capital investment needed to achieve the decarbonisation of the UK electricity generation sector by 2050 as envisaged under the scenarios used by CCC in developing the 5th Carbon Budget.

For consistency with the assessments of global market size outlined in Section 4.2.1, the UK assessments used the same estimates of capital cost per GW and an allowance for end-of-life replacement (normally after 20 years). They also did not include the costs of Operation and Maintenance (O&M).

Figure 11: Estimated UK share of global market for selected low carbon electricity sectors in 2015, 2030 and 2050



4.3.2 Low Emissions Vehicles

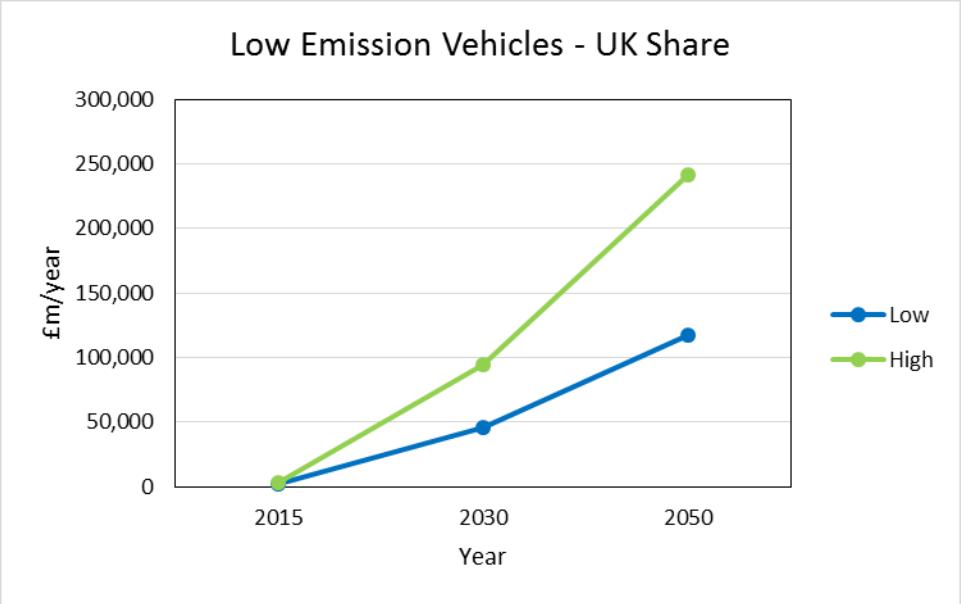
Estimates of the opportunity for UK business for selected products and services relating to low emission vehicles are given in Figure 12. These identified a potential global market size of between £46 bn and £95 bn per year in 2030 and £120 bn and £240 bn per year in 2050, with a CAGR of 22 to 26% can be expected between 2015 and 2030 and 5% between 2030 and 2050.

The assessment of potential UK share of the global market for products and services related to low emission vehicles is based on obtaining the same percentage of the global export market as is currently obtained in sectors supplying transport equipment and related services. It is also based on estimates of the annual capital investment needed to increase the share of Electric Vehicles sold to 60% of annual sales of light duty vehicles by 2030, and 100% by 2050 as envisaged under the scenarios used by CCC in developing the 5th Carbon Budget, with high and low estimates depending on the proportion of FCEV sold.

For consistency with the assessments of global market size outlined in Section **Error! Reference source not found.**, the UK assessments used the same estimates of initial purchase costs of electric vehicles. They also do not include Operation and Maintenance (O&M) costs or the costs of medium and heavy duty electric vehicles.

It is assumed that the UK market for logistics and telematics evolves at the same rate as the global market, and that the UK market is in proportion to its share of the global market for light duty vehicles. It is also assumed that annual sales of UK light duty vehicles remain at 2015 levels in line with recent trends in vehicle registrations[57], whereas global sales increase by over 200% between 2015 and 2050[58].

Figure 12: Estimated UK share of global market for selected low emission vehicles in 2015, 2030 and 2050



[57] Table VEH0252, Department for Transport, 2015, Vehicle Licensing Statistics https://www.gov.uk/government/collections/vehicles-statistics
[58] Figure 2, IEA Technology Roadmap: Electric and plug-in hybrid electric vehicles, 2011.

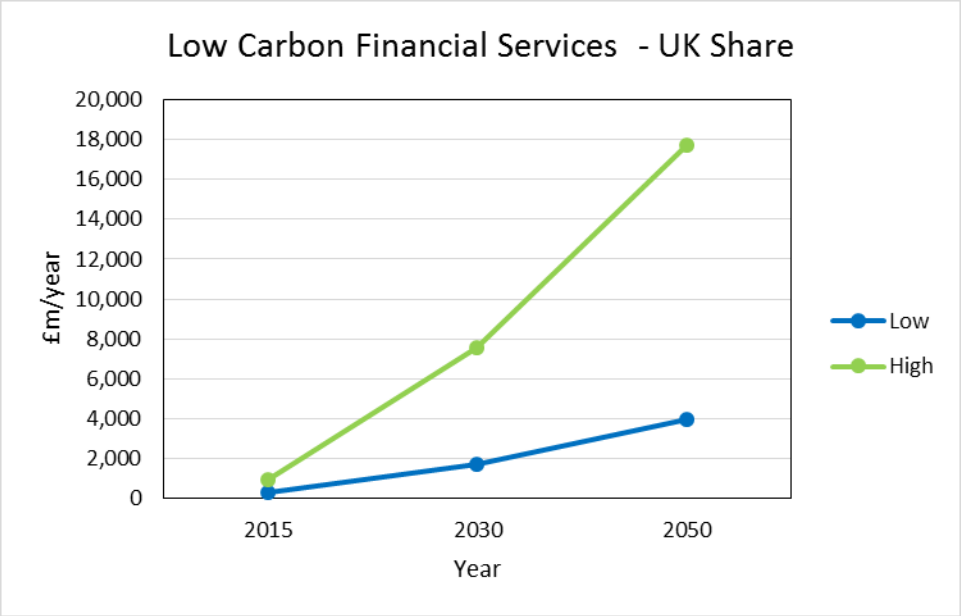
4.3.3 Low carbon financial services

Estimates of the opportunity for UK business for selected opportunities assessed in the financial services sector are given in Figure 13**Error! Reference source not found.**. These identified a potential global market size of between £1.7 bn and £7.5 bn per year in 2030 and £4 bn and £17 bn per year in 2050, with a CAGR of 12 to 15% can be expected between 2015 and 2030 and 4 % between 2030 and 2050.

The assessment of potential UK share of the global market for low carbon financial services, is based on obtaining the same percentage of the global export market as is currently obtained in sectors supplying financial and insurance services. It is also based on a UK home market that proportional to the ratio of UK electricity demand to global electricity demand, which is expect to remain around 1.3%.to 2050. This method of allocation results in an average annual investment of between 0.5% and 2% of UK GBP, which is in line with the estimated cost of the UK low carbon transition in the Stern Review[59].

As outlined in section 4.2.3, the assessment only covers the financial services related to raising the capital needed to invest in low carbon technology projects and excludes the capital sums raised.

Figure 13: Estimated UK share of global market for low carbon finance services in 2015, 2030 and 2050



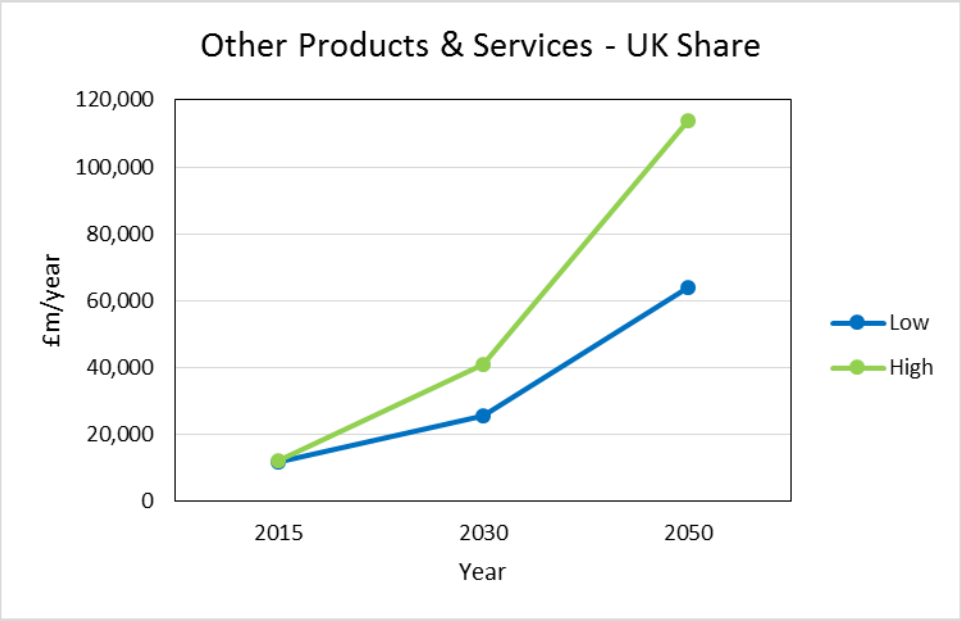
[59] http://webarchive.nationalarchives.gov.uk/20100407011151/http://www.hm-treasury.gov.uk/sternreview_index.htm

4.3.4 Oher Low Carbon Products and Services

Estimates of the opportunity for UK business for selected other products and services are given in Figure 14These identified a potential global market size of between £26 bn and £41 bn per year in 2030 and £64 bn and £110 bn per year in 2050, with a CAGR of 5 to 8% can be expected between 2015 and 2030 and 5% between 2030 and 2050.

The assessment of potential UK share of the global market for selected other low carbon products and services is based on obtaining the same percentage of the global export market as is currently obtained in sectors supplying similar products and using the ratio of UK GDP to global GDP in 2015 to estimate the size of the UK home market. The potential UK market share is the sum of the resulting values.

Figure 14: Estimated UK share of global market for other products and services in 2015, 2030 and 2050



4.4 Projection of overall future market opportunities

Projected UK turnover arising from transition to a low carbon economy grows from £43bn to 126bn in 2015 to £210bn to £600bn by 2030 and £0.5tn to £1.4tn by 2050.

Projected UK employment arising from transition to a low carbon economy grows from 0.2m to 0.4m in 2015 to 1.0m to 2.2m by 2030 and 2.5m to 5.0 by 2050.

To estimate the overall size of the UK low carbon market in 2030 and 2050, we applied the estimates of CAGR derived in section 4.3 to the estimates of the current UK market size produced by ONS and TBR, which were rebased to 2017 prices and used to generate low and high estimates. The results of this analysis are shown in Table 12, which indicate an overall market growth of around 11% pa between 2015 and 2030, and 4% between 2030 and 2050. The method assumes that the products and services assessed in this project are broadly representative of all segments of the market.

Table 12: Projected UK turnover related to the low carbon economy (£2017 Prices)

Low carbon economy (LCE) sector[60]	2015 Turnover (£bn)		2030 Turnover (£bn)		2050 Turnover (£bn)	
	Low	High	Low	High	Low	High
Energy efficient products	20.4	17.5	55.7	47.7	146.4	125.4
Energy from waste and biomass	4.6	27.1	12.4	73.9	32.6	194.3
Low carbon electricity	12.5	34.9	43.7	121.7	75.5	210.4
Low carbon heat	1.2	7.8	3.3	21.4	8.7	56.3
Low carbon services	0.7	4.1	4.5	27.0	10.4	62.5
Low emission vehicles, infrastructure, fuels cells and energy storage	3.9	9.9	94.1	237.0	240.1	604.6
Waste processing and materials recovery	0.0	24.6	Not included	67.1	Not included	176.4
Total	**43.3**	**125.9**	**213.6**	**595.3**	**513.9**	**1,429.7**

To estimate the level of employment generated by UK low carbon market in 2030 and 2050, we applied the estimates of CAGR derived in section 4.3 to the estimates of the current UK employment produced by ONS and TBR, which were used to generate low and high estimates. The results of this analysis are shown in Table 13 which indicate an overall growth in LCE market employment levels of around 11 between 2015 and 2030, and 4% between 2030 and 2050. The method assumes that the products and services assessed in this project are broadly representative of all segments of the market. The growth rates applied to each LCE sector are given in Appendix A4.4,

[60] The sectors in this table have been used by the Office of National Statistics to present the size of the UK low carbon economy. As this report relates to opportunities for the UK low carbon economy, these sectors will be used from this point onwards. A comparison of the sub-sectors included by ONS and by the analyses in this report is in Appendix 2.

Table 13: Projected UK employment related to the low carbon economy

Low carbon economy (LCE) sector[61]	2015 Employment (thousands)		2030 Employment (thousands)		2050 Employment (thousands)	
	Low	High	Low	High	Low	High
Energy efficient products	143	91	389	248	1,023	652
Energy from waste and biomass	10	19	27	52	72	137
Low carbon electricity	47	161	164	562	283	971
Low carbon heat	4	42	10	115	25	301
Low carbon services	15	29	98	187	227	433
Low emission vehicles, infrastructure, fuels cells and energy storage	15	18	359	440	916	1,123
Waste processing and materials recovery	0	89	0	584	0	1,353
Total	**233**	**449**	**1,046**	**2,187**	**2,546**	**4,970**

4.5 Opportunities for UK firms to capture a greater share of future global markets

The estimates of potential UK share of global markets presented in this section are based on the UK's current share of global exports, and hence on the UK's current strengths in manufacturing and services. There is potential to increase this share by building on UK strengths in research and innovation (see Section 3), and by addressing barriers to market entry and to increasing market share (see Section 5).

Comparing our results with previous analysis of the LCEGS market in 2011/12[62], our model forecasts:

- A lower ratio of UK to Global Market Size (2.5% compared with 3.7%)
- A higher proportion of UK turnover that is exported (21.7% compared with 9.5%)

These differences suggest that the UK LCE market is not yet focused on the export market and that there is scope to grow UK exports as the UK invests in the transition to a low carbon economy[63]..

[61] The sectors in this table have been used by the Office of National Statistics to present the size of the UK low carbon economy. As this report relates to opportunities for the UK low carbon economy, these sectors will be used from this point onwards. A comparison of the sub-sectors included by ONS and by the analyses in this report is in Appendix 2.
[62] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/224068/bis-13-p143-low-carbon-and-environmental-goods-and-services-report-2011-12.pdf
[63] The modelling approach probably over estimates the potential for exports, and could be refined by splitting project costs down into the costs of construction, manufactured goods and services and modelling the proportion of turnover exported on each cost element separately.

5 Stakeholder views on opportunities, barriers and potential actions

5.1 Introduction

To provide additional views on the business opportunities of moving to a low carbon economy, 19 interviews were conducted with a total of 23 stakeholders. The stakeholders were from the business, and academic communities as well as from trade associations and devolved administrations. The stakeholders were chosen as being involved in the range of areas addressed in this report. It was not attempted to seek views on every individual technology considered, and the summary of views below should be considered in that light. The views summarised below are as expressed and have not been assessed. They are those of the stakeholders interviewed and do not represent the views of Ricardo Energy & Environment or of the CCC.

The interviews were structured around a number of key areas. After initial feedback on areas of expertise and of collaboration, views were sought on: opportunities for the UK arising from the transition to the low carbon economy – in the area of interest of the interviewee; barriers to exploiting R&D and/or developing these new market opportunities, both in the UK and globally; actions that the interviewee considered the UK Government could take to increase the UK share of the global market in the area of interest; and any other issues.

The stakeholder views are summarised below using the headings for opportunities used in this report. For each group views are summarised on the opportunities, barriers and potential actions to increase market share.

5.2 Low carbon electricity

5.2.1 Opportunities

The UK has a world class oil and gas industry, which is well placed to be active in Carbon Capture and Storage (CCS). UK companies within the existing oil and gas industry supply chains would be well placed to capture value from new CCS plants. The market for solar in the UK remains significant and supply chain opportunities in relation to renewable energy are also possible. For example, manufacturers close to the deployment location of technologies could capture value where their location makes them more competitive, for example turbine tower manufacturers in Scotland may be able to be more competitive due to reduced transport costs. The service sector also offers opportunities for long term jobs e.g. service technicians in localities close to installations.

The UK has strong research and is leading the way in some areas, for example in terms of integrating renewables into the electricity network and smart grids. There is expertise in this area that could be exported as other countries diversify their energy mix.

5.2.2 Barriers

There is uncertainty over CCS, with no Government incentives or clear business case at present. Higher renewable energy penetration could mean a reduced role for CCS, and high capital expenditure means investors would need to be confident in available opportunities.

The unbundled nature of the UK market helps promote competition and drive changes. However there also needs to be clear policy to support this. Overall policy aims to provide low carbon electricity, reduce imports, and lower costs for consumers. However, the lack of clear policy in some technology areas, that could contribute to these overall aims, poses a barrier to the route to market. This, in turn, deters investors. For example, there is a need for a long term policy direction on specific renewables sources, such as on-shore wind, if stable markets and revenues are to be developed. Other renewables have also been adversely affected by policy decisions, for example the Climate Change Levy on solar. Policy uncertainty in other countries, for example following the recent US election, could also provide an adverse signal to investors.

5.2.3 Actions that could be taken to increase share of global market

A vibrant UK market would help to enhance export potential and this could be encouraged by Government providing a clear route to market, through policy. Current funding steams such as through

Innovate UK and the Energy Catayst were commended. Action to address barriers will also assist the UK market – examples of barriers cited include grid connection issues for renewable electricity and access to funding for the whole supply chain. Addressing these would help commercialisation and enable the scaling up of technologies for those ready to focus on delivery and roll out.

A proactive approach is needed to address various issues such as subsidy restrictions and planning barriers. For example, technologies may have developed significantly in recent years since planning consents were awarded. This may mean that latest technologies cannot be deployed due to restrictions on heights, blade sizes etc. which have changed as technology has developed.

5.2.4 Other issues around capturing new market opportunities

Investment in smart grids will help increase connectivity of renewables to the grid as consumers start to think more about where their energy comes from and when to buy it.

The unbundled market in the UK makes it easier for new entrants to get a foothold in the market, however as energy markets develop and non-traditional models are used there is a concern from some that those involved in these alternative models may not have the same level of regulation as traditional suppliers to ensure all are providing value and acting in the interests of the energy system as a whole and the end customers.

Devolved administration views

Opportunities

Opportunities exist to develop the industry e.g. for renewables and nuclear (in one devolved administration area) close to the deployment of such solutions. This includes the development of the right capabilities, technical expertise and knowledge. The alternative is that this will be brought in from overseas, limiting local benefits.

There is an opportunity to demonstrate innovation projects that will benefit the local energy market through grant funding. A scheme in Scotland currently includes 18 capital grant projects and data on economic impacts of accelerating low carbon infrastructure should be available in the next 12-8 months.

Significant opportunities also exist through devolved administration support for energy efficiency, further opportunities will be developed in future through actions identified in the Scottish Government's draft Climate Change Plan, such as through considering how the Energy Savings Opportunity Scheme can be used as a tool beyond compliance, how low carbon technology demonstrators can be encouraged and how to incentivise additional heat recovery opportunities within businesses. The Scottish Government is currently consulting on its draft Energy Strategy, Local Heat & Energy Efficiency Strategies and Regulation of District Heating as well as the Scottish Energy Efficiency Programme.

Specific opportunities exist in Scotland to consider carbon capture and storage linked to North Sea oil and gas infrastructure, whilst the Scottish electricity sector is already looking at distribution networks to provide flexible approaches to active network management and storage. There is a potential to build on this and export knowledge and skills to the wider UK and to Europe. Smart grid technology is likely to be a growth sector given the moves towards active network management at transmission and distribution levels and more local balancing. Specific opportunities also exist in Scotland to maximise the use of renewable electricity generation through the production of hydrogen by electrolysis for entry into future hydrogen markets in a low carbon economy. This hydrogen production method is currently operating in Scotland in Fife and Aberdeen and will come on line soon in the Orkney Islands.

Barriers

The main issue is clarity on what UK Government wants. Is it cheap technologies close to market that will address energy issues, is it solutions which allow UK companies to enter new geographical markets with new products i.e. supply of green hydrogen internationally, or is it the regeneration of skills and capability in particular areas and the development of an industry? It is acknowledged that in some cases the starting base may be low and therefore a realistic view on the value captured locally initially needs to be taken. For some solutions e.g. tidal stream/lagoons, UK Government strategy does not provide a clear steer.

There are also a number of barriers to the development of emerging technologies. Research on the practical application of hydrogen gas as a low-carbon substitute for methane within the current gas grid is required. The transfer of emerging technologies from the academic stage to a commercial stage can be difficult. And emerging technologies need help to find a route to market and to help to de-risk demonstration projects – this may need a wider discussion at UK level. Local innovation technology companies can be over-ambitious and need to consider the use of smaller scale demonstrations in building confidence. Fostering collaboration, due to commercial sensitivities can also be difficult.

A specific issue in Scotland is that the decommissioning of North Sea infrastructure may limit opportunities for demonstration and development of carbon capture and storage (CCS). There is a timeline for decommissioning and a need to consider alignment of this with opportunities for CCS. The symbiotic relationship between a large scale hydrogen network of the future and CCS also needs to be better understood.

Actions that could be taken to increase share of global market

There needs to be clarity in terms of direction from UK Government and then appropriate support mechanisms in line with long term requirements. These could be, for instance, development of industry and of appropriate skills and capabilities. A clear stable long term policy direction will also attract long term investment and boost indigenous capabilities and supply chain evolution.

Government can also help facilitate collaboration in local clusters by providing an independent partner, helping to facilitate knowledge sharing, and providing long term perspectives.

5.3 Low emission vehicles

5.3.1 Opportunities

The UK has opportunities in the electric vehicle battery manufacturing sector, which will be significant as the market for such vehicles increases. There is also a very good academic base related to this, which should be maintained. The right investments now by the UK in vehicle battery manufacturing would set up the industry and manufacturers well for future opportunities in storage in the electricity network and enhance their ability to enter the grid market.

Historically the UK has strengths in manufacturing and designing internal combustion engines (ICE). Ultimately this will need to be replaced, but current research and development opportunities exist within the ICE sector as well as for advanced fuels and electric vehicles. The UK would also be well placed for research and development in areas such as electric machines and power electronics. However actual manufacturing may be more likely in lower costs economies.

Other opportunities were identified in areas such as: charging software; new logistics approaches, such as disruptive logistics, together with the necessary data collection requirements to put this into practice; and inductive (wireless) charging.

5.3.2 Barriers

Within the UK, research and development support is good. However barriers exist in the scaling up of technologies, including; investment gaps; sufficient expertise to exploit research; a conservative culture as opposed to taking risks and accepting some may be failures; and a lack of UK manufacture leadership.

Investment is hard to attract due to high infrastructure requirements and long return periods – investors are usually focused on short payback with limited investment horizons. Political uncertainty and potential policy changes also provide investment uncertainty. Therefore, help to set up manufacturing and incentivise exports through integrated support covering aspects such as infrastructure, land, financial and technical skills may be required.

The lack of a strategic overview of freight transport is a barrier to addressing this important carbon emitter. The lack of data related to how full and heavy freight is also contributes to this.

5.3.3 Actions that could be taken to increase share of global market

Continuing Government support and a long term policy direction is required. Areas of support needed include infrastructure, e.g. charger installations, finance and investment, support to SMEs to help them compete with global leaders, and development of good international standards to ensure the UK is not disadvantaged on the global stage.

Strategic policy is required for freight transport, including appropriate approaches on data collection by industry to enable new approaches to be utilised.

5.4 Energy efficient products

5.4.1 Opportunities

It was highlighted there could be benefits from closer links between material manufacturers and end users to understand how materials are used and incorporated in products and components and make improvements and efficiency savings. As an example, a Magnet Manufacturing Hub was suggested. A similar approach has been used in Japan to link materials through to end user applications. In the UK a water partnership[64] has been set up to come up with ways to improve marketing overseas to improve UK goods sales levels.

There is significant opportunity at the micro and small medium enterprise business level. Such businesses have the opportunity to develop into larger entities. However unless the development of domestic markets can be supported, from which export markets can potentially be developed, there is the risk that companies will look to move abroad to demonstrate and deploy their products.

5.4.2 Barriers

Funding is a major concern following Brexit, especially as significant amounts currently come from European sources for some areas of research and development. European projects enable UK expertise to participate in large integrated projects, providing links across Europe and partnerships to access wider expertise and knowledge and in some cases feedstock for recovery of materials.

The participation of UK academics and industry in European projects also helps to ensure UK interests and issues are represented and taken into account as part of the wider agenda. Following Brexit there is the risk that UK specific aspects may not be considered as fully and the UK will need to consider these itself, which will have funding implications.

Regulation and processes can favour larger entities and not necessarily SMEs. For example regulations and terms and conditions aimed at larger companies in relation to public procurement could be overcome by changes in the domestic market.

Political barriers mean that there is not always the will or prioritisation to help develop and promote areas where the UK has strength, such as developing high tech solutions with export opportunities. Other countries, such as China are moving forward themselves and could leave the UK behind with opportunities missed.

5.4.3 Actions that could be taken to increase share of global market

Government could support new hubs and partnerships to drive efficiencies through material manufacturers and end user applications having a better understanding of each other's needs. There could also be re-engagement on critical materials and security of supply, particularly from a UK specific perspective given current work is predominately EU led.

A strategic view of funding across larger integrated projects is required to ensure UK involvement, as well as greater prioritisation of technology developments and incentivising uptake. Regulations and procurement guidelines can also be reviewed and revised accordingly to ensure public procurement markets are readily accessible to all sizes of companies.

5.4.4 Other issues around capturing new market opportunities

There is a need for whole systems planning, it is not just about the product and solution level inputs but also the supporting infrastructure and outputs it leads to. Examples might be in the areas of smart infrastructure and electric vehicles where it is important to consider and develop the infrastructure

[64] See https://theukwaterpartnership.org/

required as well as developing the core technologies. This overall perspective will enable Government to capture opportunities as they arise. This requires agility in reacting to the market and promoting innovation.

5.5 Other sectors

5.5.1 Opportunities

Opportunities exist in the UKs **food waste processing** to capture food and green waste currently sent to landfill, reducing emissions such as methane, and providing a useable output to use on land as fertiliser as an alternative to artificial fertilisers. This includes the growing media sector, who are using compost to replace all or some of the peat in their products.

The **biofuels** sector also provides UK opportunities if barriers can be overcome both in terms of using first generation biofuels and developments with second generation biofuels, such as waste feedstocks. The UK could have technology and skills advantages in this area, providing real benefits, through the research and development UK companies are doing.

Finance and professional service opportunities are promoted within the UK. For example the City of London's Green Finance Initiative aims to promote London and the UK as a leading global centre for the provision of green financial and professional services[65], in addition to other initiatives such as the Green Investment Bank. The opportunities include raising finance but also the support needed alongside this such as advice on technical, legal, international obligations and secondary market matters.

5.5.2 Barriers

A key barrier for **food waste processing** is that collection in England is not mandated, and financial pressures mean that, while local authorities are keen to collect food waste, it may not always be done. Investment in the infrastructure for treating food waste requires assurances over feedstock availability, while cut backs in incentive schemes mean that the viability of smaller plants has reduced.

For **Biofuels** there is the potential for too much wishful thinking. There needs to be a realistic view on what can be achieved. Inconsistent policy and support for areas that are required but are perhaps not the main focus needs to be addressed to provide stability and investor confidence. Political barriers, feedstock availability and a local willingness to use biofuels are also issues.

In terms of **finance**, barriers relate to the cost of electricity produced by different sources, for example how is low carbon electricity, that is cheaper than electricity from fossil fuels, delivered? This is linked to aspects such as storage, the integration of renewable energy into local grids and the use of smart grids to better balance the supply of and demand for electricity. The price of carbon also needs to be considered. It could be beneficial for the level of a carbon tax to be agreed globally – this could reflect the real cost of 1 tonne of carbon emitted into the atmosphere and hence the cost of avoiding this.

5.5.3 Actions that could be taken to increase share of global market

For **food waste processing**, Government could mandate the collection of food waste in England. There could also be more done in terms of diverting more food that is still fit for human consumption through its collection and redistribution to those who need food through schemes such as Fairshare.

Government could provide consistent support on **biofuels**, and stick with decisions the closer biofuels get to reaching market in order to provide stability. Work could also be done to remove political barriers, for example on the food vs. fuel debate, with appropriate messaging for the public and decision making based on the problem and available solutions, rather than allowing politics to deflect decisions.

While the UK is leading the way in terms of the Climate Change Act, this may be an expensive way of addressing emissions – are there smarter ways of **financing** or investing in ways to reduce greenhouse gas emissions, perhaps at an integrated global level. Alongside carbon savings, the benefits of investments in secondary markets, such as developmental prosperity and improvements in people's lives are also important factors.

[65] http://greenfinanceinitiative.org/about/who-we-are/

5.5.4 Other issues around capturing new market opportunities

Further opportunities exist with the 'bio-based' economy area, where more can potentially be done with natural materials e.g. algae for energy production, composite materials.

Stakeholder views – some themes

Some themes emerge from across the range of stakeholder interviews

- The UK has a strong academic, industrial and business base in many areas that will grow with transition to a low carbon economy
- Current support for research and innovation is welcomed
- A vibrant UK low carbon sector will provide a base for growing export market share
- This growth will be enhanced by:
    - Long term certainty, to the extent this can be achieved, in the policy and financial context
    - Continuing to consider means to enhance commercialisation of key technologies needed for the low carbon transition
    - A holistic approach considering infrastructure issues at the same time as developing key technologies – for instance in considering developing of a charging infrastructure at the same time as batteries and other aspects of electric vehicles

6 Conclusions on opportunities to increase the UK share of future global markets

During this project, we have examined the potential role that various low carbon technologies could play in reducing global emissions of Greenhouse Gases (GHG) and outlined a timeline for the transition to a global low carbon economy that is consistent with limiting the rise in global temperature to below 2^{o}C.

We have assessed the potential size of the global and UK markets for selected low carbon products and services, and used these to estimate the potential for future growth in the UK low carbon economy manufacturing and service sectors in the periods from 2015 to 2030 and from 2030 to 2050.

Our analysis suggests that the low carbon economy will grow from around 2% of UK Total Output in 2015 to up to around 8% by 2030, and around 13% by 2050[66]. The projected compound annual growth rate for the low carbon economy is 11% per annum between 2015 to 2030, and 4% per annum between 2030 and 2050, which is substantially higher than the OECD's projection of average UK GDP growth of 2.3% per annum between 2015 and 2050[67]

However realising this potential growth rate depends on maintaining and improving on the UK's competitive position in the global low carbon technology market, and investing in the development of new products and services across a wide range of technologies and applications. In terms of immediate priorities for investment, we have identified some high growth technologies that will be needed to deliver the commitments made in the Paris Agreement, including:

- Electric Vehicles
- Transport telematics
- Off-shore wind
- Solar PV.
- Smart Grids
- Energy storage

[66] Assuming that UK total output grows on average by 2.3% per year.
[67] https://data.oecd.org/gdp/gdp-long-term-forecast.htm

- Biofuels

We have also identified some technologies that will be need to be fully deployed by 2050:

- Advanced materials and manufacturing, including design for reuse and waste recovery.
- Low carbon chemical processes using bioprocessing, catalysts and membrane technology

In addition, there are significant opportunities for the UK services sector to establish itself as a financial hub for green finance and gain a sizable share of the financial services associated with the estimated capital investment of between $1.5 and $6 trillion per annum needed to deliver the global low carbon economy.

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Appendices

Appendix 1: Methodology for estimating current market value for UK manufacturers of low carbon goods and services

Appendix 2: Comparison of sectors and technologies considered

Appendix 3: Data sources and assumptions for estimating the size of future global markets associated with the low carbon economy

Appendix 4: Summary data from current analysis

Appendix 1 - Methodology for estimating current market value for UK manufacturers of low carbon goods and services

This method note is presented in two parts.

Part A describes the method used to develop up to date estimates of the low carbon economy, excluding climate change adaptation. This method has been designed to allow CCC to generate further estimates in the future.

Part B describes the method used to estimate the market value associated with climate change adaptation, which has not been included in previous assessments of the low carbon economy.

Part A: Method used to estimate the current market value for UK manufacturers of low carbon goods and services

This note sets out the key decisions taken and approaches adopted in:

- Developing up to date estimates of the low carbon economy.
- Preparing a method to allow CCC to generate further estimates in the future.

The aim of the project has been to provide estimates that are consistent with those prepared previously and which would be recognised as being 'of the correct order' by experts operating within the low carbon domain.

The philosophy underpinning the work has been to rely on data already in the public domain or which are readily available from commercial sources.

The challenge in defining and quantifying the low carbon economy arises from the fact that its activities and products are not well served by the current method of industrial classification, the Standard Industrial Coding system. Thus alternative methods are required.

A1A.1 Definition

The work has focused on two main areas:

1. A generally accepted notion of the low carbon economy based on the creation of recognised end products and services.
2. A group of activities and, often intermediary, products that are increasingly being considered as being part of the move to a low carbon economy.

The generally accepted definition of the low carbon economy comprises:

- Renewable electricity generation
- Renewable heat
- Energy efficient products
- Alternative fuels
- Low emission vehicles
- Energy storage
- Low carbon services and finance

This has been the focus of activity aimed at generating up to date estimates of the low carbon economy.

In addition to this, efforts have been applied to acquiring quantitative data on:

- The circular economy
- Low carbon management
- Adapting to climate change
- Low carbon manufacturing
- Materials and product substitution

As these areas are less well defined, dispersed and often incorporated into supply chains, access to quantitative data has proven challenging.

A1A.2 Available estimates of the size of the low carbon economy

It was decided that efforts to generate a current estimate of the low carbon economy and to prepare a model that would allow the CCC to produce its own figures in the future, could best be achieved by focusing on prior work and published statistics.

A review of the literature identified:

1. The Low Carbon and Renewable Energy Economy survey undertake by ONS.
2. The Size and performance of the low carbon economy report, published by BIS/DECC in 2015 and prepared by TBR.
3. A range of sector based data published by trade associations and based on surveys of their members.
4. Statistics prepared by Innovas/K-Matrix.

Each of the methods is considered below:

The ONS estimates are based on a survey sample of approximately 14,000 taken from across the UK and includes all sectors, except those unlikely to be involved in the low carbon economy, e.g. public administration, human health etc. were excluded. The sample was stratified by industry, employment and UK country. The survey has run twice and data are available for 2014 and 2015 (preliminary aggregated data only). There is some doubt regarding the future of the survey.

The BIS/DECC commissioned work utilises a different approach to the ONS survey. The method for the BIS work is based around a database of 11,500 companies known to operate in the low carbon economy based on a review of websites, membership of trade organisations or inclusion in schemes such as the microgeneration certification scheme. A telephone survey was used to establish the extent to which the businesses operated in each sector. The data published are for 2013. The database was derived from IDBR and TBR's own data on an approximately equal basis. TBR's data are readily available and can be used to provide estimates into the future.

A number of trade associations, e.g. Nuclear Industry Association (NIA) and RenewableUK (RUK) undertake surveys of their members and publish these on a regular basis. The Renewable Energy Association (REA) indicates that its estimates are provided by Innovas/K-Matrix. The Innovas/K-Matrix data are derived using a proprietary model based on a range of input materials. The exact nature of the model is not available.

A1A.3 Data methods and sources

A more detailed assessment of the three open methods is provided below. This seeks to offer the strengths and weaknesses of each and its suitability for incorporation into a model for use by CCC.

ONS Low Carbon and Renewable Energy Economy

Since 2015, ONS has run a survey to establish the size of the low carbon economy. Whilst yet to be classified as official statistics, they are provided by government, so are regarded as a de facto standard. The survey covers the 'generally accepted definition' of the low carbon economy. The cost of the 2014 and 2015 surveys was borne by several government departments and the devolved administrations. Funding for the survey into the future is unclear.

Strengths	Weaknesses
Governed by ONS rules – seen as reliable.	Governed by ONS rules – limits disclosure and hence usefulness.
Provided by ONS – considered to be robust.	Not overly granular, some data suppressed. This limits the usefulness of the data.
Used by government, so in general use and 'numbers' will be recognised.	Time lag between the survey and publication, circa 18-24 months.
Method open and available for scrutiny.	Uncertainty over the future of the survey.

As 'near to' official statistics, these data provide an ideal basis for any future estimates. In fact, if the survey continues to be published there may not be a need for alternative estimates.

The initial results of the 2015 survey were published on 26/12/2016. However, this did not include sector level data and only covered direct employment. The latter are scheduled for publication at the end of Q1, 2017.

BIS Size and performance of the low carbon economy 2015 (TBR)

This work was commissioned by BIS/DECC/Defra and undertaken by TBR in advance of the ONS survey being run. ONS sat on a peer review board and there are significant similarities in the sector definitions used. The method used was published in the report published by BIS.

Strengths	Weaknesses
Scrutinised method – peer reviewed.	Limited survey sample (630) underpinning the analysis.
Granular – not subject to ONS suppression rules.	Database requires updating.
Can be updated – to some extent.	
Supported by a database of businesses, so an audit trail is available.	

The method used is significantly different to the ONS survey, so provides an alternative approach. Updating is possible by importing up to date company data into the database[68]. Over time the database will need to be refreshed to take account of new entrants into the sector and those which have ceased operations in low carbon . This work will require access to similar sources to those used previously, e.g. trade directories, certification schemes as well as financial data from IDBR, Companies House and Dun & Bradstreet. A follow up survey to establish the extent to which firms operate across the various low carbon sectors will also have to be undertaken.

Both the ONS and BIS approaches allowed for businesses to operate in multiple low carbon sectors. However, the differences in approach could magnify any sampling errors.

Trade Associations – survey based only

Some of the trade associations undertake survey work to assess performance and change over time. The surveys tend to focus on trade associations' members, so coverage may be limited, and with some activities receiving greater attention than others.

Strengths	Weaknesses
Sector specific.	Not all low carbon sectors covered.
Some sectors provide detailed data on location (nuclear).	Some surveys cover members only.
Operated by sector specialists, so potentially more insightful than those run by 3rd parties.	
Issues over objectivity.	

The trade association data may run the risk of 'optimism bias', so present potentially inflated results.

[68] Up to date data are available for approximately half of the records. Costs will apply.

A1A.4 Comparisons

The results of the comparative analysis are set out in the following table.

Clearly, some differences were to be expected. The principal causes of divergence include:

- Lack of consistency within the definition of sectors.
- Misalignment of sector groups, i.e. the sectors within the groups are not exactly the same.
- The scope of the sectors in terms of how much of the supply chain is included in direct activity, and where/how boundaries are drawn.
- The methods used for assessing indirect employment.
- The metrics used, e.g. employment count versus full time equivalents (FTE).

ONS 2015 Sector	ONS Employment (direct and indirect) 2014	Updated BIS 2015 employment	Commentary
Alternative fuels	*	*	
Bioenergy	*	52,100	TBR sector is “Energy generation from waste and biomass”, “Biomass equipment” and Alternative fuels”
Carbon capture and storage	*	4,200	ONS data appear to be suppressed.
Energy efficient lighting	31,000	14,600	The availability and prevalence of low energy lighting has increased since the BIS work was published, so this may under report the sector. Defining the boundary to include/exclude lighting types and installation is challenging.
Energy monitoring, saving or control systems	33,000	12,100	The BIS survey asked businesses to self identify as providers of products and services. As many of these products are contained within larger products, e.g. software, controls, componentry, inconsistency in definition is the most likely cause of the differences. The BIS work sought to ‘pre-identify’ companies and hence may under report for this large and very diverse sector.
Fuels cells and energy storage	1,000	*	Included in low emission vehicles in BIS work.
Hydropower	2,500	7,300	This sector is characterised by large and small schemes. Many of the smaller schemes operate as subsidiary activities, so may have been excluded from the ONS survey based on SIC codes.
Low carbon financial and advisory services	20,000	28,600	A very diverse sector so differences were expected.
Low emission vehicles and infrastructure	25,000	18,400	The ONS definition expressly includes storage, so may have captured some businesses not included in the BIS work.
Nuclear	37,500	60,400	The ONS survey excludes decommissioning and reprocessing of fuel, which is included in the BIS data.
Offshore wind	11,500	13,000	The stated definitions were similar so the differences are likely to result from sampling and alternative methods used.
Onshore wind	13,000	19,700	The stated definitions were similar so the differences are likely to result from sampling and alternative methods used.
Other energy efficient products	216,500	144,300	As per energy monitoring, the diversity of the sector along with the methods used are the likely causes of the discrepancies. TBR/BIS analysis includes: energy-efficient doors and windows, insulation, recycling – recovery and reprocessing of materials from waste; and sustainable architecture.
Other renewable electricity	*	7,300	Geothermal and marine

ONS 2015 Sector	ONS Employment (direct and indirect) 2014	Updated BIS 2015 employment	Commentary
Renewable combined heat and power	3,500	*	
Renewable heat	9,000	36,200	The stated definitions were similar so the differences are likely to result from sampling and alternative methods used. TBR/BIS group includes: heat networks, heat pumps, solar thermal and heat recovery and ventilation.
Solar photovoltaic	19,000	31,300	The stated definitions were similar so the differences are likely to result from sampling and alternative methods used.
Total	**447,500**	**449,400**	

Source: ONS and TBR/OrtusER

ONS have published initial figures for employment for 2015. These are only available for direct employment in groups of sectors and not yet for individual sectors. Ortus have modelled the sector data to gain total (direct plus indirect) employment data for 2015, using the same multipliers applied by ONS for the 2014 numbers. This allows comparisons to be made between the ONS and BIS data for 2015. Differences are considered to be largely due to differences in the definitions of the sector groups and in the methods used to determine employment numbers.

ONS Group	ONS Employment (direct and indirect)		Updated BIS 2015 employment
	2014	2015	
Energy efficient products	280,500	257,000	202,000
Energy from waste and biomass	22,000	19,100	30,200
Low carbon electricity	86,000	99,800	139,400
Low carbon heat	12,500	6,500	30,800
Low carbon services	20,000	23,700	28,600
Low emission vehicles, infrastructure, fuels cells and energy storage	26,000	35,500	18,400
Total	**447,500**	**441,600**	**449,400**

Source: ONS and TBR/OrtusER

Part B: Method used to estimate the current market value for UK companies associated with climate change adaptation

A1B.1 Summary

Neither the BIS 2015 report, or the ONS Low Carbon and Renewable Energy Economy Survey included the climate change adaptation sector. As such, we have devised a method to define and value the adaptation sector.

As there were no existing estimates for the sector work had to be undertaken de novo, so the data must be considered less robust than those presented above. The numbers were derived using a mix of key words to identify firms operating in the sector along with coefficients to estimate the degree of engagement of those firms known to operate the area, but not identified through the keywords. Examples of the latter include the large engineering consultancies. The results are set out in the table below.

The data are gauged to be of the correct order of magnitude when compared to government's stated spend of £170m in one year on flood defences and mitigation[69].

Table A1B.Summary: Initial estimate of the UK adaptation sector, 2015

Group	Employment (n)	Turnover (£000)	GVA (£000)
Building adaptation	520	96,700	30,200
Business mitigation and management	40	6,000	2,900
Climate event planning and response	570	69,300	19,600
Flood mitigation and management	3,140	252,600	85,900
Public realm adaptation	1,990	393,900	154,400
Engineering related scientific and technical consulting activities	1,340	187,300	95,600
Other engineering activities	730	102,200	55,100
Other research and experimental development on natural sciences and engineering	1,530	235,600	78,700
Total	9,860	1,343,600	522,400

Source: TBR/OrtusER 2017

It should be noted that to some extent the adaptation sector will already be incorporated into the existing low carbon economy. Thus the data set out in the table above cannot be simply added to the numbers in Table 6 to Table 8 in the main text.

A1B.2 Defining the adaptation sector

The research team undertook desk research to collate the range of activities, technologies and systems that form the adaptation sector. Through this process, a number of firms known to engaged in these activities were also investigated.

This desk research identified five thematic groups within the adaptation sector, along with keywords to describe the activities. These groups and keywords are:

[69] Autumn Statement 2016.

Table A1B.1: Keyword groups and sectors

Group	Keyword sectors
Building adaptation	Air Conditioning, Mechanical Ventilation, Ventilation Systems
Business mitigation and management	Business Continuity, Resilience, Risk Management
Climate event planning and response	Catastrophe, Disaster Management, Disaster Recovery, Emergency Management, Emergency Planning, Emergency Response, Reinsurance, Storm
Flood mitigation and management	Flood, Flood Barrier, Flood Defence, Flood Protection, Flood Resilience, Flood Risk, Flooding
Public realm adaptation	Adaptation, Climate Change, Climate Risk, Coastal Management, Extreme Heat, Green Infrastructure, Heat wave, Heatwave, Reservoir Engineering, Sea Level, Solar Films, Solar Shading, Sustainable Drainage, Thermal Management, Urban Design, Water Engineering, Weather

Source: TBR 2017

A number of firms known to be active in the sector were not identified by keywords, as climate change adaptation represents only a small proportion of their work. Thus additional steps needed to be taken to include the impact of these businesses. This involved two steps; first of all, establishing suitable SIC codes that would capture all these businesses, and secondly, estimating the proportion of their work that could be deemed as being for the adaptation sector.

Establishing which SIC sectors to use was carried out by identifying the ones used by firms which were known to be active in the adaptation sector.

These sectors were then included in the adaptation definition, as follows:

Table A1B.2: SIC sectors

SIC sector
Engineering related scientific and technical consulting activities
Other engineering activities
Other research & experimental development on natural sciences & engineering

A1B.3 Building the dataset

A total of 22,444 TCR records have been identified (following cleaning and checking):

1. 3,309 in the keyword sector data extract
2. Of which 2,748 are located in air conditioning and ventilation
3. 18,935 are in the 'SIC based' data extract (viz engineering related)
4. Of which 11,510 are located in Engineering related scientific and technical consulting activities
5. Several hundred records were common in both data extracts. These were kept in the key word dataset.

Due to the large number of firms appearing in the SIC-based search, coefficients have been applied to estimate the extent of their activity that can be allocated to the adaptation sector. Three coefficients[70] were identified for each keyword sector and SiC sector..

[70] The coefficients were based on judgement after reviewing websites and related data and comparisons with other activities. For example, government planned to invest £170m in flood mitigation in the year following the Autumn Statement, 2016.

Table A1B.3: Coefficients

Keyword sector	Low coefficient	Medium coefficient	High coefficient
Risk Management	0.01	0.03	0.05
Reinsurance	0.01	0.03	0.05
Air Conditioning	0.02	0.05	0.07
Ventilation Systems	0.02	0.05	0.07
SIC sector			
Engineering related scientific and technical consulting activities	0.02	0.05	0.07
Other engineering activities	0.02	0.05	0.07
Other research & experimental development on natural sciences & engineering	0.02	0.05	0.07

Source: TBR 2017

A1B.4 Adaptation analysis

Employment, turnover and GVA have been calculated for each keyword sector and each SIC sector using the coefficients.

The employment, turnover and GVA calculated for each keyword sector has been aggregated into the relevant keyword group.

The three tables below present the data for scenarios based on the use of low, medium or high coefficients:

Table A1B.4: Low coefficient scenario

Group	Employment (n)	Turnover (£000)	GVA (£000)
Building adaptation	522	96,691	30,245
Business mitigation and management	41	5,968	2,872
Climate event planning and response	568	69,262	19,626
Flood mitigation and management	3,136	252,576	85,947
Public realm adaptation	1,989	393,931	154,423
SIC Sector			
Engineering related scientific and technical consulting activities	1,341	187,273	95,640
Other engineering activities	732	102,175	55,056
Other research and experimental development on natural sciences and engineering	1,531	235,607	78,669
Total	**9,861**	**1,343,482**	**522,478**

Source: TBR 2017

Table A1B.5: Medium coefficient scenario

Group	Employment (n)	Turnover (£000)	GVA (£000)
Building adaptation	1,304	241,604	75,574
Business mitigation and management	50	8,265	4,048
Climate event planning and response	593	94,591	27,013
Flood mitigation and management	3,136	252,576	85,947
Public realm adaptation	1,989	393,931	154,423
SIC Sector			
Engineering related scientific and technical consulting activities	3,353	468,184	239,101
Other engineering activities	1,831	255,437	137,640
Other research and experimental development on natural sciences and engineering	3,828	589,017	196,673
Total	**16,084**	**2,303,604**	**920,419**

Source: TBR 2017

Table A1B.6: High coefficient scenario

Group	Employment (n)	Turnover (£000)	GVA (£000)
Building adaptation	1,826	338,213	105,794
Business mitigation and management	58	10,562	5,224
Climate event planning and response	619	119,920	34,400
Flood mitigation and management	3,136	252,576	85,947
Public realm adaptation	1,989	393,931	154,423
SIC Sector			
Engineering related scientific and technical consulting activities	4,694	655,457	334,742
Other engineering activities	2,563	357,612	192,696
Other research and experimental development on natural sciences and engineering	5,359	824,623	275,342
Total	**20,244**	**2,952,894**	**1,188,568**

Source: TBR 2017

A1B.5 Overall LCE estimate

The medium coefficient scenario totals for the adaptation sector have been added to the previous estimates for the overall low carbon and renewable energy economy. The results are shown below in Table A1.7.

Table A1B.7: Total LCE including adaptation (medium coefficient scenario)

	TBR total employment	TBR total turnover (£billions)	TBR GVA (£billions)
TBR LCE 2016	449,411	122.64	41.93
TBR Adaptation	16,084	2.30	0.92
TBR Total	**465,495**	**124.94**	**42.85**
Adaptation as a percent of total LCE	3.5%	1.9%	2.1%

Source: TBR 2017

The totals compared to the ONS Low Carbon and Renewable Energy Economy Survey estimates are shown in the two tables below.

Table A1B.8: LCE TBR vs ONS employment comparisons

Sector Group	ONS 2014	TBR 2015
Energy efficient products	155,500	90,882
Energy from waste and biomass	11,500	19,032
Low carbon electricity	40,500	161,242
Low carbon heat	7,000	41,977
Low carbon services	13,000	28,610
Low emission vehicles, infrastructure, fuels cells and energy storage	11,000	18,387
Waste processing and materials recovery	Not included	89,281
Adaptation (medium scenario)	Not included	16,084
Total	**238,500**	**465,495**

Source: TBR 2017

Table A1B.9: LCE TBR vs ONS turnover comparisons

Sector Group	ONS 2014	TBR 2015
Energy efficient products	24.17	17.02
Energy from waste and biomass	2.45	26.35
Low carbon electricity	10.27	34.04
Low carbon heat	37.82	7.63
Low carbon services	1.96	4.02
Low emission vehicles, infrastructure, fuels cells and energy storage	6.76	9.64
Waste processing and materials recovery	Not included	23.94
Adaptation (medium scenario)	Not included	2.30
Total	**83.42**	**124.94**

Source: TBR 2017

Note: margins of error in the ONS data are as follows.

Sector group	Variance
Low carbon electricity	> 10% and < 20%
Low carbon heat	> 20% and < 30%
Energy from waste & biomass	> 10% and < 20%
Energy efficient products	< 10%
Low carbon services	> 20% and < 30%
Low emission vehicles	> 10% and < 20%

Appendix 2 – Comparison of sectors and technologies considered

Three analyses have been used in the current work:

- Analysis by the Office of National Statistics of the size of the UK low carbon economy
- Analysis by TBR Ltd of the size of the UK low carbon economy
- Current analysis of the size and growth potential for opportunities arising from transition to a low carbon economy

The first two analyses are intended to be comprehensive. The analysis of future opportunities covers:

- All sectors for low carbon electricity apart from hydropower and nuclear
- Low emission vehicles
- Low carbon finance and insurance, but not other low carbon analysis services
- Selected other low carbon opportunities
- Broad estimate for adaptation
- Broad estimate for the low carbon economy

Alignment of the areas covered by these analyses is given in Table A2.1

Table A2.1: Alignment of the low carbon economy sectors considered by ONS, TBR and IEA and the technologies and areas considered in the current work

ONR Group	ONS Sector	TBR sector	IEA group	Technology/ measure, current work	Area, current work	Sector grouping used for assessing % UK share of global market	Group for graph in Section 4
Low carbon electricity	Offshore wind	Offshore Wind	Power	Onshore wind		Machinery / Electrical Products	Low carbon electricity
Low carbon electricity	Onshore wind	Onshore Wind	Power	Offshore wind		Machinery / Electrical Products	Low carbon electricity
Low carbon electricity	Solar photovoltaic	Solar PV	Power	Solar Photovoltaic (PV)		Machinery / Electrical Products	Low carbon electricity
Low carbon electricity	Hydropower	Hydroelectric energy	Power				
Low carbon electricity	Other renewable electricity	Marine	Power	Marine energy		Machinery / Electrical Products	Low carbon electricity
Low carbon electricity	Carbon capture and storage	Carbon capture and storage	Power	Carbon capture and storage		Machinery / Electrical Products	Low carbon electricity
Low carbon electricity	Nuclear	Nuclear energy	Power				
Low carbon electricity			Power	Energy storage (Power)		Machinery / Electrical Products	Low carbon electricity
Low carbon heat	Renewable heat	Geothermal heat	Residential				
Low carbon heat		Solar thermal	Residential				
Low carbon heat	Renewable combined heat and power	Heat networks	Residential				
Low carbon heat		Heat pumps	Residential				
Energy from waste and biomass	Bioenergy	Energy generation from waste and biomass	Industry				
Energy from waste and biomass		Biomass equipment	Industry				
Energy from waste and biomass	Alternative fuels	Alternative fuels	Industry	Alternative fuels	Biofuels	Chemicals / Related Industries	Other low carbon products and services
Energy efficient products	Energy efficient lighting	Energy-efficient lighting	Residential				
Energy efficient products	Other energy efficient products	Energy-efficient windows and doors	Residential				

ONR Group	ONS Sector	TBR sector	IEA group	Technology/ measure, current work	Area, current work	Sector grouping used for assessing % UK share of global market	Group for graph in Section 4
Energy efficient products		Heat recovery and ventilation	Residential				
Energy efficient products		Insulation	Residential	Insulation	Advanced Insulation	Construction	Other low carbon products and services
Energy efficient products		Sustainable architecture	Residential				
Energy efficient products			Power	Materials and Product Substitution	Alternative Batteries	Machinery / Electrical Products	Other low carbon products and services
Energy efficient products			Transport	Materials and Product Substitution	Alternative Magnets	Metals / Metal Products	Other low carbon products and services
Energy efficient products			Industry	Materials and Product Substitution	Bioprocessing	Chemicals / Related Industries	Other low carbon products and services
Energy efficient products			Industry	Materials and Product Substitution	Catalysts	Chemicals / Related Industries	Other low carbon products and services
Energy efficient products			Industry	Materials and Product Substitution	Membranes	Chemicals / Related Industries	Other low carbon products and services
Energy efficient products	Energy monitoring, saving or control systems	Energy controls and control systems	Residential	Energy controls and control systems	Smart grids	Computer and information services	Other low carbon products and services
Low carbon services	Low carbon financial and advisory services	Low carbon finance	Services	Low carbon finance	Green Finance	Financial services	Low carbon financial services
Low carbon services			Services	Low carbon finance	Performance/lifetime insurance	Insurance	Low carbon financial services
Low carbon services		Low carbon advisory services	Services				
Low emission vehicles, infrastructure, fuels cells and energy storage	Low emission vehicles and infrastructure	Low emission vehicles	Transport	Low emission vehicles	Transmission / Engines	Transport Equipment	(Not included as already in figures for vehicles)
Low emission vehicles, infrastructure, fuels cells and energy storage	Fuels cells and energy storage		Transport	Low emission vehicles	Charging Solutions	Transport Equipment	Low emission vehicles
Low emission vehicles, infrastructure, fuels cells and energy storage			Transport	Low emission vehicles	Fuel Cell Electric Vehicles	Transport Equipment	Low emission vehicles

ONR Group	ONS Sector	TBR sector	IEA group	Technology/ measure, current work	Area, current work	Sector grouping used for assessing % UK share of global market	Group for graph in Section 4
Low emission vehicles, infrastructure, fuels cells and energy storage			Transport	Low emission vehicles	Electric Vehicles	Transport Equipment	Low emission vehicles
Low emission vehicles, infrastructure, fuels cells and energy storage			Transport	Low emission vehicles	Hybrid electric vehicles	Transport Equipment	Low emission vehicles
Low emission vehicles, infrastructure, fuels cells and energy storage				Low emission vehicles	Logistics / Telematics	Transport Equipment	Low emission vehicles
		Waste processing and materials recovery		Recycling of materials from waste	Lithium Batteries	Machinery / Electrical Products	Other low carbon products and services
		Adaptation		Adaptation		Construction	Box on adaptation
				Circular Economy		Machinery / Electrical Products	Box on circular economy

Appendix 3 - Data sources and assumptions for estimating the size of future global markets associated with the low carbon economy

See xls file “CCC Global Market Size Estimates_v01-17”

Appendix 4 – Summary data from current analysis

[From "CCC Global Market Size Estimates_v01-17.xls"]

Table A4.1: Estimates of global market size for technologies and areas considered.

ID	Grouping	Technology / Measure	Area	2015 Global £m/year (low)	2015 Global £m/year (high)	2030 Global £m/year (low)	2030 Global £m/year (high)	2050 Global £m/year (low)	2050 Global £m/year (high)
1	Low carbon electricity	Onshore wind		59,000	59,000	77,000	82,000	120,000	150,000
2	Low carbon electricity	Offshore wind		3,200	3,200	16,000	17,000	38,000	48,000
5	Low carbon electricity	Marine energy		0	0	4,400	4,700	81,000	100,000
6	Low carbon electricity	Solar Photovoltaic (PV)		63,000	63,000	70,000	74,000	170,000	220,000
7	Low carbon electricity	Carbon capture and storage		1,200	1,200	86,000	170,000	150,000	360,000
8	Low carbon heat	Energy storage (Power)		0	0	11,000	12,000	17,000	21,000
13	Waste processing, energy from waste and biomass	Recycling of materials from waste	Lithium Batteries	120	120	3,400	3,400	12,000	12,000
15	Waste processing, energy from waste and biomass	Alternative fuels	Biofuels	160,000	180,000	400,000	470,000	1,200,000	1,400,000
20	Energy efficiency products	Insulation	Advanced Insulation	110,000	110,000	110,000	110,000	86,000	86,000
24	Energy efficiency products	Energy controls and control systems	Smart grids	72,000	72,000	320,000	450,000	360,000	500,000
29	Low carbon services	Low carbon finance	Green Finance	11,000	32,000	60,000	260,000	96,000	430,000
30	Low carbon services	Low carbon finance	Performance/lif etime insurance	850	2,600	6,300	19,000	10,000	31,000
32	Other low carbon	Low emission vehicles	Transmission	3,000	3,000	110,000	110,000	390,000	390,000
33	Other low carbon	Low emission vehicles	Charging Solutions	7,300	15,000	220,000	450,000	700,000	1,400,000

ID	Grouping	Technology / Measure	Area	2015 Global £m/year (low)	2015 Global £m/year (high)	2030 Global £m/year (low)	2030 Global £m/year (high)	2050 Global £m/year (low)	2050 Global £m/year (high)
34	Other low carbon	Low emission vehicles	Fuel Cell Electric Vehicles	0	0	65,000	140,000	340,000	560,000
35	Other low carbon	Low emission vehicles	Battery Electric Vehicles	6,800	6,800	190,000	190,000	1,100,000	1,100,000
36	Other low carbon	Low emission vehicles	Hybrid electric vehicles	14,000	14,000	540,000	480,000	1,300,000	1,200,000
37	Other low carbon	Low emission vehicles	Logistics / Telematics	5,300	5,300	31,000	700,000	160,000	3,300,000
38	Other low carbon	Adaptation		50,000	65,000	120,000	270,000	270,000	440,000
39	Other low carbon	Circular Economy		0	0	800,000	1,600,000	1,400,000	2,700,000
43	Other low carbon	Materials and Product Substitution	Alternative Batteries	0	0	6,900	7,300	20,000	26,000
44	Other low carbon	Materials and Product Substitution	Alternative Magnets	6,900	6,900	260,000	270,000	910,000	920,000
46	Other low carbon	Materials and Product Substitution	Bioprocessing	87,000	87,000	200,000	490,000	790,000	1,900,000
47	Other low carbon	Materials and Product Substitution	Catalysts	16,000	20,000	27,000	34,000	49,000	62,000
48	Other low carbon	Materials and Product Substitution	Membranes	16,000	18,000	68,000	93,000	350,000	570,000
	Total			**692,670**	**764,120**	**3,802,000**	**6,508,600**	**10,119,000**	**17,926,000**

Table A4.2: Estimates of UK home market size for technologies and areas considered.

ID	Grouping	Technology / Measure	Area	2015 UK Home Market £m (low)	2015 UK Home Market £m (high)	2030 UK Home Market £m (low)	2030 UK Home Market £m (high)	2050 UK Home Market £m (low)	2050 UK Home Market £m (high)
1	Low carbon electricity	Onshore wind		900	900	1,400	1,800	1,200	1,600
2	Low carbon electricity	Offshore wind		970	970	2,900	3,700	2,600	3,300
5	Low carbon electricity	Marine energy		0	0	110	150	530	670
6	Low carbon electricity	Solar Photovoltaic (PV)		430	430	1,300	1,600	2,000	2,500
7	Low carbon electricity	Carbon capture and storage		0	0	2,800	1,600	7,900	5,500
8	Low carbon heat	Energy storage (Power)		0	0	640	820	350	430
13	Waste processing, energy from waste and biomass	Recycling of materials from waste	Lithium Batteries	8	8	390	490	410	520
15	Waste processing, energy from waste and biomass	Alternative fuels	Biofuels	310	360	500	580	160	180
20	Energy efficiency products	Insulation	Advanced Insulation	3,700	3,700	3,400	3,400	2,400	2,400
24	Energy efficiency products	Energy controls and control systems	Smart grids	940	940	4,200	5,900	4,700	6,500
29	Low carbon services	Low carbon finance	Green Finance	130	400	700	3,000	1,200	5,400
30	Low carbon services	Low carbon finance	Performance/lifetime insurance	11	32	74	220	1,200	5,400
32	Other low carbon	Low emission vehicles	Transmission	210	210	3,400	4,800	7,300	8,200
33	Other low carbon	Low emission vehicles	Charging Solutions	460	940	7,400	20,000	14,000	32,000
34	Other low carbon	Low emission vehicles	Fuel Cell Electric Vehicles	0	0	0	6,800	6,800	14,000
35	Other low carbon	Low emission vehicles	Battery Electric Vehicles	530	530	10,000	17,000	34,000	40,000
36	Other low carbon	Low emission vehicles	Hybrid electric vehicles	960	960	14,000	11,000	11,000	5,700

ID	Grouping	Technology / Measure	Area	2015 UK Home Market £m (low)	2015 UK Home Market £m (high)	2030 UK Home Market £m (low)	2030 UK Home Market £m (high)	2050 UK Home Market £m (low)	2050 UK Home Market £m (high)
37	Other low carbon	Low emission vehicles	Logistics / Telematics	140	170	600	13,000	2,200	46,000
38	Other low carbon	Adaptation		510	640	810	1,000	1,400	1,700
39	Other low carbon	Circular Economy		0	0	24,000	48,000	38,000	76,000
43	Other low carbon	Materials and Product Substitution	Alternative Batteries	0	0	390	490	410	520
44	Other low carbon	Materials and Product Substitution	Alternative Magnets	490	490	110	150	270	320
46	Other low carbon	Materials and Product Substitution	Bioprocessing	2,900	2,900	6,100	15,000	22,000	52,000
47	Other low carbon	Materials and Product Substitution	Catalysts	510	640	810	1,000	1,400	1,700
48	Other low carbon	Materials and Product Substitution	Membranes	510	600	2,000	2,800	9,600	16,000
	Total			**14,619**	**15,820**	**88,034**	**163,130**	**173,030**	**328,290**

Table A4.3: Estimates of UK market share of global market (home market + exports) for technologies and areas considered.

ID	Grouping	Technology / Measure	Area	2015 Total UK share £m/year (Low)	2015 Total UK share £m/year (high)	2030 Total UK share £m/year (Low)	2030 Total UK share £m/year (high)	2050 Total UK share £m/year (low)	2050 Total UK share £m/year (high)
1	Low carbon electricity	Onshore wind		1,300	1,300	1,900	2,300	2,000	2,600
2	Low carbon electricity	Offshore wind		980	980	3,000	3,800	2,800	3,600
5	Low carbon electricity	Marine energy		0	0	140	180	1,100	1,300
6	Low carbon electricity	Solar Photovoltaic (PV)		840	840	1,800	2,100	3,100	3,900
7	Low carbon electricity	Carbon capture and storage		8	8	3,300	2,700	8,800	7,800
8	Low carbon heat	Energy storage (Power)		0	0	710	890	460	570
13	Waste processing, energy from waste and biomass	Recycling of materials from waste	Lithium Batteries	9	9	410	510	490	600
15	Waste processing, energy from waste and biomass	Alternative fuels	Biofuels	1,400	1,500	3,100	3,700	8,100	9,400
20	Energy efficiency products	Insulation	Advanced Insulation	3,700	3,700	3,400	3,400	2,400	2,400
24	Energy efficiency products	Energy controls and control systems	Smart grids	1,400	1,400	6,200	8,600	6,900	9,600
29	Low carbon services	Low carbon finance	Green Finance	300	900	1,600	7,100	2,700	12,000
30	Low carbon services	Low carbon finance	Performance/lifetime insurance	21	63	150	440	1,300	5,700
32	Other low carbon	Low emission vehicles	Transmission	250	250	4,900	6,300	13,000	14,000
33	Other low carbon	Low emission vehicles	Charging Solutions	560	1,100	10,000	26,000	24,000	51,000
34	Other low carbon	Low emission vehicles	Fuel Cell Electric Vehicles	0	0	910	8,700	11,000	22,000
35	Other low carbon	Low emission vehicles	Battery Electric Vehicles	620	620	13,000	19,000	49,000	55,000
36	Other low carbon	Low emission vehicles	Hybrid electric vehicles	1,100	1,100	21,000	18,000	29,000	22,000
37	Other low carbon	Low emission vehicles	Logistics / Telematics	210	240	1,000	23,000	4,400	91,000

ID	Grouping	Technology / Measure	Area	2015 Total UK share £m/year (Low)	2015 Total UK share £m/year (high)	2030 Total UK share £m/year (Low)	2030 Total UK share £m/year (high)	2050 Total UK share £m/year (low)	2050 Total UK share £m/year (high)
38	Other low carbon	Adaptation		520	650	830	1,000	1,400	1,800
39	Other low carbon	Circular Economy		0	0	29,000	58,000	47,000	93,000
43	Other low carbon	Materials and Product Substitution	Alternative Batteries	0	0	430	530	540	690
44	Other low carbon	Materials and Product Substitution	Alternative Magnets	520	520	1,500	1,600	5,000	5,100
46	Other low carbon	Materials and Product Substitution	Bioprocessing	3,500	3,500	7,400	18,000	27,000	64,000
47	Other low carbon	Materials and Product Substitution	Catalysts	610	770	980	1,200	1,700	2,100
48	Other low carbon	Materials and Product Substitution	Membranes	610	710	2,400	3,400	12,000	20,000
	Total			**18,458**	**20,160**	**119,060**	**219,290**	**265,190**	**500,930**

Table A4.4: List of 50 Market Segments reviewed.

ID	Grouping	Technology / Measure	Area	Rationale	Priority	Assessed?
1	Low carbon electricity	Onshore wind		Lagging behind other major economies	Low	Yes
2	Low carbon electricity	Offshore wind		Area of emerging UK strength	Medium	Yes
3	Low carbon electricity	Nuclear energy		Outside scope (Fusion, Fission)	Not Relevant	No
4	Low carbon electricity	Hydroelectric energy		Normally sourced from local suppliers	Low	No
5	Low carbon electricity	Marine energy		Area of emerging UK strength	Medium	Yes
6	Low carbon electricity	Solar Photovoltaic (PV)		Competing with lower cost economies	Low	Yes
7	Low carbon electricity	Carbon capture and storage		Lagging behind other major economies but required longer-term and some UK strengths	High	Yes
8	Low carbon electricity	Energy storage (Power)		Area of particular UK strength	High	Yes
9	Low carbon heat	Geothermal heat		Limited market size / home market	Low	No
10	Low carbon heat	Heat pumps		Lagging behind other major economies	Low	No
11	Low carbon heat	Solar thermal		Lagging behind other major economies	Low	No
12	Waste processing, energy from waste and biomass	Heat networks		Normally sourced from local suppliers	Low	No

ID	Grouping	Technology / Measure	Area	Rationale	Priority	Assessed?
13	Waste processing, energy from waste and biomass	Recycling of materials from waste	Lithium Batteries	Area of existing UK strength	Medium	Yes
14	Waste processing, energy from waste and biomass	Energy from waste and biomass		Normally sourced from local suppliers	Low	No
15	Waste processing, energy from waste and biomass	Alternative fuels	Biofuels	Area of emerging UK strength	Medium	Yes
16	Waste processing, energy from waste and biomass	Alternative fuels	Hydrogen	Constrained by resource availability	Low	No
17	Waste processing, energy from waste and biomass	Alternative fuels	Other	Normally sourced from local suppliers	Low	No
18	Waste processing, energy from waste and biomass	Biomass equipment		Lagging behind other major economies	Low	No
19	Energy efficiency products	Energy-efficient lighting		Existing market / technology	Not Relevant	No
20	Energy efficiency products	Insulation	Advanced Insulation	Area of existing UK strength	Medium	Yes
21	Energy efficiency products	Energy-efficient windows and doors		Existing market / technology	Not Relevant	No
22	Energy efficiency products	Heat recovery and ventilation		Existing market / technology	Not Relevant	No
23	Energy efficiency products	Energy controls and control systems	Smart Meters	Existing market / technology	Not Relevant	No
24	Energy efficiency products	Energy controls and control systems	Smart grids	Area of emerging UK strength	Medium	Yes
25	Energy efficiency products	Energy controls and control systems	Energy Management	Covers multiple solutions/technologies	Non-Specific	No

ID	Grouping	Technology / Measure	Area	Rationale	Priority	Assessed?
26	Energy efficiency products	Sustainable architecture and buildings	BIPV	Area of emerging UK strength	Medium	NO
27	Energy efficiency products	Other energy efficient equipment		Existing market / technology	Not Relevant	No
28	Low carbon services	Low carbon advisory		Covers multiple solutions/technologies	Non-Specific	No
29	Low carbon services	Low carbon finance	Green Finance	Area of particular UK strength	High	Yes
30	Low carbon services	Low carbon finance	Performance/lifetime insurance	Area of particular UK strength	High	Yes
31	Low carbon services	Low carbon management		Covers multiple solutions/technologies	Non-Specific	No
32	Other low carbon	Low emission vehicles	Transmission	Area of particular UK strength	High	Yes
33	Other low carbon	Low emission vehicles	Charging Solutions	Area of emerging UK strength	Medium	Yes
34	Other low carbon	Low emission vehicles	Fuel Cell Electric Vehicles	Area of emerging UK strength	Medium	Yes
35	Other low carbon	Low emission vehicles	Battery Electric Vehicles	Area of emerging UK strength	Medium	Yes
36	Other low carbon	Low emission vehicles	Hybrid electric vehicles	Lagging behind other major economies	Low	Yes
37	Other low carbon	Low emission vehicles	Logistics / Telematics	Area of emerging UK strength	Medium	Yes
38	Other low carbon	Adaptation		Early stage of technology development	Non-Specific	Yes
39	Other low carbon	Circular Economy		Early stage of technology development	Non-Specific	Yes

ID	Grouping	Technology / Measure	Area	Rationale	Priority	Assessed?
40	Other low carbon	Low carbon manufacturing	Lean / Agile Manufacturing	Area of particular UK strength	High	No
41	Other low carbon	Low carbon manufacturing	Lightweighting / Dematerisation	Area of particular UK strength	High	No
42	Other low carbon	Low carbon manufacturing	Other	Covers multiple solutions/technologies	Non-Specific	No
43	Other low carbon	Materials and Product Substitution	Alternative Batteries	Area of particular UK strength	High	Yes
44	Other low carbon	Materials and Product Substitution	Alternative Magnets	Constrained by resource availability	Low	Yes
45	Other low carbon	Materials and Product Substitution	Alternative materials (Other)	Competing with lower cost economies	Low	NO
46	Other low carbon	Materials and Product Substitution	Bioprocessing	Area of particular UK strength	High	Yes
47	Other low carbon	Materials and Product Substitution	Catalysts	Area of particular UK strength	High	Yes
48	Other low carbon	Materials and Product Substitution	Membranes	Area of particular UK strength	High	Yes
49	Other low carbon	Materials and Product Substitution	Rare Elements Alternatives	Constrained by resource availability	Low	NO
50	Other low carbon	Materials and Product Substitution	Other	Covers multiple solutions/technologies	Non-Specific	No

A4.5: Compound Annual Growth Rates (CAGR) used in 2030 & 2050 projections

Low carbon economy (LCE) sector[71]	Study Area based on	2015-2030	2030-2050
Energy efficient products	Low carbon other	6.9%	5.0%
Energy from waste and biomass	Low carbon other	6.9%	5.0%
Low carbon electricity	Low carbon electricity	8.7%	2.8%
Low carbon heat	Low carbon other	6.9%	5.0%
Low carbon services	Low carbon services	13.3%	4.3%
Low emission vehicles, infrastructure, fuels cells and energy storage	Low emission vehicles	23.6%	4.8%
Waste processing and materials recovery	Low carbon other	6.9%	5.0%

[71] The sectors in this table have been used by the Office of National Statistics to present the size of the UK low carbon economy. As this report relates to opportunities for the UK low carbon economy, these sectors will be used from this point onwards. A comparison of the sub-sectors included by ONS and by the analyses in this report is in Appendix 2.

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