The economics of the Green Investment Bank: costs and benefits, rationale and value for money

Report prepared for The Department for Business, Innovation & Skills

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Executive Summary

The UK Government is committed to achieving the transition to a green economy and delivering long-term sustainable growth. However, this transition requires unprecedented investment over the coming decades, with an estimated investment of up to £200 billion in the energy system alone over the period to 2020 (Ofgem, 2009), and further significant investment in other key green sectors such as transport, waste, water and flood defences. The Government announced the Green Investment Bank (GIB) in the Government's Coalition Agreement in 2010 and committed in the 2011 Budget to fund the GIB with £3 billion over the period to 2015. The GIB will become a key component of the transition to a green economy, complementing other green policies to help accelerate additional investment.

This paper has been developed in the context of work to establish the GIB led by the Department for Business and Skills (BIS). It summarises the results of the workstream on the Economic Rationale for the GIB and draws on work by separate workstreams on product design and the GIB organisation.

The paper seeks to address the following questions for establishing the GIB:

- Of the sectors selected by government as being of policy importance, which have market failures or areas of capital shortage for the GIB to address? If they do exist, critically, how big are they and are they likely to be permanent or transitory?
- Does the GIB as envisioned, with a targeted set of interventions and a £3 billion capitalisation, offer value for money compared to alternative policies?
- What is the likely impact on economic growth in the UK?

The purpose of the work was to answer these questions, and so inform the establishment of a GIB by providing a robust and objective evidence base, through a set of analyses reported here.

Illustrative priority sector assessment and rationale for intervention

Fifteen sectors were identified by the GIB project team in conjunction with other government departments for their importance to the green economy and suitability as possible candidates for financial intervention.

Broadly, most of the sectors examined share a common attribute that creates a challenge for investment: novelty. For many, it is novelty of technology. They vary in their stages of technology development. In some cases though, they are not novel, namely rolling stock, flood defence, photovoltaics and onshore wind, and in other cases they are, for example, carbon capture and storage, wave power and electric vehicle charging infrastructure. Some on the list are so new that they are not yet ready to be deployed commercially, such as marine energy and carbon capture and storage. For other sectors, the novelty is reflected in the business model or commercial arrangements. One example is the Green Deal, where loans are secured against a receivables contract tied to the meter point, and some contract energy management models within non-domestic energy efficiency, again using finance secured against receivables.

At the same time, the UK government is aiming to achieve ambitious targets to decarbonise the economy which means that investment in green sectors needs to be increased more quickly than is likely to happen without government intervention. This speed of adoption is being hampered by a number of sector-related market failures and constraints in the financial markets. Sector-related market failures include externalities, information asymmetries, market power and complements. On the financial market failure side, issues relate to unfamiliarity with the new types of technology and business model risks related to carbon technologies, as well as companies' ability to expand their balance sheets. While players would become accustomed to these risks and scale up investment over time, this would happen at a rate that is too slow given the pace of investment now defined by policy.

The GIB will therefore need to complement and add to the existing policy framework with tailored and targeted financial interventions that help to address market failures, overcome risk aversion, high transaction costs, and the resulting lack of capital. The GIB can be particularly effective by helping to expand the pool of potential investors, improving economics of marginal projects and sharing information to reduce risk perception of the key sectors.

The GIB will need to identify which sectors to focus on. Following a wide, but non-exhaustive, review of different needs across the green economy and a high level assessment of where a GIB intervention would be beneficial, this report highlights in particular three sectors to illustrate the evidence of market failure and the opportunity for GIB intervention, and assess the case for value for money in detail: offshore wind; non-domestic energy efficiency; and, non-Local Authority collected commercial and industrial waste. The sectors were assessed for their potential green impact, the scale of required investment, the potential financing gap and potential market failures and the approach to GIB intervention. The work suggests that there is a case for GIB intervention in all three sectors:

- Offshore wind has the largest expected investment need of the three sectors, totalling around £50 to £130 billion (nominal) between now and 2020, which will be critical to meet government European renewable energy targets. While multiple large scale offshore wind farms have been built, the industry is pushing the technical frontier moving into deeper waters as a result. Therefore, risks are not yet well understood and only a limited number of players are active in the space. Consequently, the scale up in investment is not happening at the pace required by policy. The GIB could intervene to increase the number of new investors and help finance marginal plants that would not otherwise happen without its intervention. A £1 billion investment in offshore wind could produce an additional 1TWh per annum of renewable energy, which is around one per cent of the renewable electricity target in 2020, and reduce emissions by 0.3 $mtCO_2$ pa over the lifetime of the investment.
- Non domestic energy efficiency could be applied across many industrial and commercial businesses. Total investment could amount to £16 billion by 2020. Delivering non domestic energy efficiency is not only one of the solutions to reduce carbon emissions in the UK with the lowest costs, it would also help to improve energy security and long term competitiveness of UK industry. While policies have been put in place to deliver non-domestic energy efficiency, multiple market failures including lack of financing in specific areas prevent investment from happening. The GIB could help by mobilising financing for smaller projects by aggregating investment and by helping to finance larger scale project finance. In non-domestic energy efficiency, the estimated benefits are a reduction in energy demand of 3.5 TWh per annum, and carbon emissions savings of 1.1 $mtCO_2$ pa.
- Non-Local Authority Commercial and industrial waste is a smaller sector in absolute terms, with investment most likely around £1 billion by 2020. While there is no direct target for the commercial and industrial waste sector to meet, the sector can make an important contribution to the

government's target of reducing landfill, generating renewable heat and reducing carbon emissions. There seem to be fewer market failures in this sector given that a large share of landfill is already diverted. However, it appears that there might be some financing issues related to merchant plants as well as new technologies. The GIB could focus on these areas to increase investment in the sector if and where appropriate. A £1 billion waste market (a roughly 50-50 split between EFW and MRF in most scenarios) intervention might generate 0.4 TWh electricity per annum (from energy from waste plant) and reduce emissions by 2.6 mtCO_2pa (mostly from materials recovery facilities).

In summary, the GIB can act as a catalyst to expand the pool of investors and capital available to fund the transition to a green economy. Its interventions should help to improve the mobilisation of new investors for both debt and equity, enhance the pricing of risk in financial markets through increased transparency, and provide investment for marginal projects that would otherwise not have happened.

The GIB's products

The nature of potential GIB products informs the value for money that tax payers are likely to see from the GIB.

In principle, the GIB may participate in projects through the supply of its capital in the form of equity, mezzanine (subordinated) debt, or senior debt. In some cases, it might offer capital on a contingent basis, in which equity is injected when construction costs overrun substantially, freeing up capital set aside by other parties to be used in other projects.

In offshore wind and waste, some utilities may find the idea of co-investment equity attractive if their balance sheet is constrained and if it allows them to expand their project pipeline. In both cases, firms may not find a lender or co-investor elsewhere who is prepared to accept the prevalent commercial risks. In industry and commercial buildings, and in the Green Deal, contract energy managers (also known as energy service companies) may welcome participation from a financial party which can arrange receivable finance on an efficient scale.

Wherever the GIB is investing alongside existing market players, offering similar products, it would do so on pari passu (identical) terms: the market economy investor principle. Where it is offering products that are not available in the market, or are not offered at affordable market prices, it would be providing aid. For example, some forms of credit enhancement might be aid, whereas equity would not be, and debt products might or might not be, depending on whether the terms were similar to those offered by others in the market.

Value for money

For a long time environmental externalities have not been priced properly. Combined with externalities in research and development (addressed, in part through traditional policy instruments) this has resulted in a lack of innovation in low carbon technologies. Many of these externalities have been corrected, but only recently, and the process of urgent reform of the UK's infrastructure has begun. As the UK moves to decarbonise, it finds that the financial markets are still unaccustomed to the risks involved in low carbon technologies, which is in contrast with their familiarity with established technologies. Left to themselves, financial institutions would become accustomed to these risks at a rate that is too slow given the pace of investment now needed.

The economic rationale for GIB intervention in selected sectors is that it can address the under-provision of capital and/or increase the speed of its deployment, thus improving green outcomes. To determine whether the GIB constitutes value for money for tax payers, one has to assess how the GIB interventions compare to other possible policy vehicles. The analysis conducted for this report shows that the GIB can substantially improve green policy outcomes through targeted investment because it can deliver policy objectives more efficiently or equitably than other policies (with less redistribution).

The value for money analysis on the three illustrative sectors is based on a thorough, scenario based approach: it uses scenarios of future policy demand for investment, coupled with sensitivity analysis around the cost of projects, to explore the value for money of investment programmes supported by the GIB. It follows the Green Book approach. The assumptions on alternative policies are: an increase in the level of Feed in Tariff support for new offshore wind projects; an increase in the Landfill Tax for commercial and industrial waste; and, an increase in the Climate Change Levy.

The analysis found that in all three cases, the GIB is more efficient and equitable than the alternative policies and acts as a complement to current policy. It is able to make contributions to policy targets in all three sectors. It has the greatest impact in waste, because of the large size of the GIB relative to the investment need in the sector. In contrast, the GIB's ability to influence the achievement of the renewable energy target is potentially quite limited in the short term, although still helpful, because of the scale of investment needed in comparison to the GIB's balance sheet.

The analysis shows that the consumer will experience greater impacts through product prices from taxation, than through changes in product prices due the value of investments. Hence the redistribution effects are important from a customer perspective.

The value for money analysis also assessed whether the projects the GIB could finance would have a positive or negative net present value for society. It finds that while some of the investments have a positive net present value such as materials recovery facilities for waste and energy efficiency investments, others do not, namely offshore wind and direct combustion energy from waste due to the higher cost of low carbon products (e.g. renewable electricity generation) compared to more traditional products (e.g. fossil fuel electricity generation). These net present value results corroborate existing impact assessments for the current policies in these sectors. What is new is the finding that the GIB, through a targeted investment, can substantially improve the policy outcome even without taking into account a reduction in the cost of finance.

Sector comparison

In addition to the detailed analyses of offshore wind, non-Local Authority collected commercial and industrial waste and non-domestic energy efficiency, the work also examined the remaining 12 sectors that could be an important focus area for the GIB. These include:

- The Green Deal – investments in domestic energy efficiency which would come in play from autumn 2012 and could see a role for the GIB in financing intermediaries to aggregate small loans;

- Nuclear power – a sector with a potentially large investment volume in the range of £20-40 billion by 2020 where the GIB could play a role in the medium term;
- Carbon Capture and Storage (CCS) – a technology still in its infancy and currently mostly grant funded which could see a rise in investment in the £1 to £4 billion range at the end of this decade;
- Photovoltaics – a smaller sector which has been kick-started by the introduction of feed-in tariffs. So far, there has been little evidence of capital constraints in the sector but capital may flow less freely when lower, revised tariffs come into force, and the GIB could potentially play a role in financing aggregators for small scale investments or municipalities;
- Marine – a sector with three distinct technologies, tidal range which is more established and wave and tidal stream which are still in early development; both of which could see increased investment in the second half of the decade and the GIB could play a role similar to that in offshore wind;
- Onshore wind – a sector that has seen rapid growth with a mature technology and where take up is more constrained by planning rather than financing – here there is unlikely to be a role for the GIB;
- Smart meters – which divide into domestic (households) and non-domestic. The revenue arrangements for domestic smart meters are novel and the deployment programme is rapid, suggesting a possible role for the GIB.
- Plug-in vehicle infrastructure – a sector in which most charging points are expected to be installed at home, workplaces and car parks, with on-street charging in areas where cars are kept on the road. There may be a role for the GIB because of the novelty of the market and challenge of coordination of provision with electric vehicle market penetration.
- Rolling stock – a market which is used to private finance and public regulation, with limited technological change and GIB involvement only alongside private investors if there were to be a shortage of capital available.
- Flood defences – mostly provided by public authorities, with little appetite for private investment due to the difficulty of designing a payment vehicle to recover revenues. It is unlikely that there will be a role for the GIB since public authorities can already borrow from the Public Works Loan Board.

A value for money assessment has been applied to all sectors in two steps. In the first step, each is screened for four attributes: complementarity with other government policies; market additionality (including capital mobilisation); timing and investability (with a preference for the period to 2020) and green impact (value of lifetime emissions avoided or other green benefits per unit of GIB capital employed).

Complementarity excludes flood defences, which are almost always publicly funded and there are alternative funding arrangements already in place already. Additionality rules out onshore wind, photovoltaics, rolling stock and possibly nuclear power, where there has been or is indication of future private capital available. On timing, marine energy and carbon capture storage are not yet ready for large-scale investment. On green impact, those with the highest green impact include materials recovery facilities, renewable heat and non-domestic energy efficiency.

The second step was an assessment of investment returns, both in terms of returns to society (net present value per £1 of capital invested), and private returns to the GIB (return on capital employed).
In addition, in depth analysis allowed distributional impacts to be taken into account for offshore wind, waste and non-domestic energy efficiency.

The findings are that not all sectors are worthy of GIB involvement immediately. Non-domestic Smart Meters, materials recovery facilities, non-domestic energy efficiency and the Green Deal offer the greatest returns to society. If green impact is the primary concern, then the portfolio would be weighted in favour of waste (materials recovery facilities) and non-domestic energy efficiency. If returns to the GIB took primacy, then the portfolio would emphasise offshore wind and electric vehicle infrastructure.

Impact on economic growth

To fully understand all possible benefits to establishing a GIB, its potential impact on economic growth was considered. Given the GIB's initial size, analysis suggests that it is unlikely to have a significant impact on economic growth in the UK in the short term, but there might be some benefits in the long term. The origin and scale of benefits depend on the opportunity foregone in terms of any alternative use of the public funding allocated to the GIB, or the risk of a negative effect on growth from increased spending. They also depend upon the allocation of capital across sectors.

The GIB might enhance economic growth in the longer term if its investments offer high investment returns, or generate technology spillovers, or create competition. The first of these is identifiable by a high net present value and benefit-cost ratio, a property which some, but not all of the sector investments examined here possess. Three positive examples are: energy efficiency which improves the supply side productivity of the economy; smart meters which enhance the productivity of the power infrastructure; and, materials recovery facilities which enhance materials resource efficiency. The potential for technology spillovers is difficult to identify but is greatest for the most rapidly innovating sectors. Finally, disruptive technologies which increase innovation in competing technologies might include electric vehicles and their effect on internal combustion engines.

State aid

An examination of the pros and cons of establishing a GIB would not be complete without an examination of the implications for state aid. The European Commission requires evidence that the benefits of the GIB balance the costs of distortions created to competition. It has a methodology for assessing allowable state aid, and it looks for appropriate design of intervention, behaviour-changing incentives and proportionality. The work reported here provides evidence on design rationale, incentives and benefits.

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1 Introduction

A project to explore the economic rationale of the GIB

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The Green Investment Bank was announced in the Government's Coalition Agreement in 2010 and its role was explained further in the update statement made in May 2011 (HM Government, 2011). Its purpose is to support the financing of investment in the transition to a green economy and to complement other green policies. The Government's thesis is that well-targeted financial interventions will help bring about the increased scale of private sector investment which is implied by green policy targets and its vision for a green economy.

This work discusses the reasons for establishing the GIB and assesses whether it offers value for money compared to alternative policies. This discussion and assessment is addressed to a portfolio of green investments and for a handful of financial products which the GIB might offer.

It includes a description of the sectors, a discussion of the rationale for intervention, an assessment of value for money, and introduces the evidence required for a state aid assessment. The information was collated in the period February to July 2011. Case studies of other investment banks can be found in an appendix.

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1.1 Objectives

1.1.1 The origins of the GIB

The Coalition Agreement announced the Government's intention to establish a Green Investment Bank (GIB). The Government has stated that the GIB should focus on investment for the transition to a green economy.

The establishment of a GIB is a recognition that there are market failures and barriers in investment in green assets, which if addressed, help to deliver EU and UK policy objectives. These barriers and failures may include, for example, co-ordination failures, principal-agent problems, bounded rationality, path dependence and issues related to the risk that stems from the industrial application of new technology. The blend of market failures and barriers varies from sector to sector.

The GIB intends to provide well-targeted financial interventions that facilitate market delivery of the scale of investment necessary. In other words, whilst the market failures may arise either in the sector or in the capital markets, the GIB is an instrument that operates in the capital markets, and so will focus on failures that articulate themselves in, or interact with, that realm. It will lever in additional private sector money for projects and recycle funds over time. In this way, it will relieve market failures and barriers and accelerate the UK's transition towards a greener economy.

In establishing a GIB, the key questions revolve around whether these market failures exist, and act in such a way as to create a shortage of capital for green assets. If they do exist, then the question to ask is how big they are and whether they are likely to be permanent or transitory. The purpose of this work is to answer these questions, and to inform the establishment of a GIB: providing a robust and objective evidence base, as well as testing whether the potential interventions that it might make would provide good value for money.

1.2 Scope

1.2.1 **The rationale and value for money of the GIB**

The specification document for this study sets out the scope of the work. There are four phases of work. The first phase requires the identification of market and institutional failures and barriers to investment in green infrastructure and large-scale, late stage green technologies. The extent to which failures and barriers lead to a gap between policy ambition and social and economic need is measured, especially when the gap is the result of a financial barrier. The second phase identifies what drives any gap, how it may be closed and whether the GIB may have a role. The third phase is a broad value for money assessment of the GIB as an institution and for each of its interventions. The final phase considers the impact of the GIB on UK growth and how the GIB could be used to maximise growth.

The quote below from the project specification summarises the objective:

> *‘the overarching outcome of this programme of work is to help Government establish whether the proposed policy to implement a Green Investment Bank demonstrates value for money, and what form, and types of intervention, are likely to deliver greatest value for money’*

1.3 Structure

1.3.1 **Report structure**

This report is presented in seven sections. After the introduction, the second section is a description of the sectors and policy interests across a range of green infrastructure whose delivery is seen as important to the greening of the economy now and over the next two decades.

The third section is an analysis of the potential market and institutional failures that might exist across a range of industrial sectors and green technologies. The analysis is based on an assessment of the available academic literature, analysis conducted by the relevant government departments and evidence collected from interviews with key industry players. This analysis reveals market failures and matches interventions and GIB products to them. Sections two and three cover the scope of work described as phase one and two.

In the fourth section, a quantitative assessment is made of the value for money of GIB interventions in the offshore wind, waste, and energy efficiency sectors. This section describes the approach to this assessment, the treatment of uncertainty and the results. It covers the work specified as phase three.

In the fifth section, the impact of the GIB on UK economic growth is framed by four pillars of growth: Keynesian (growth through demand boost), Pigovian (correction of market failures), Schumpeterian (innovation and "creative destruction") and Georgian (overcoming resource constraints to growth). The concept behind each of these mechanisms of growth is described and potential GIB interventions across a range of sectors are related to each pillar. This section addresses phase four of the scope.

The sixth section gives a brief summary of the state aid rules of particular relevance to the GIB. This is included because the application for state aid approval will draw upon the evidence collected in this research. This section explains how the evidence fits into the approval process and outlines additional evidence which lies outside the scope of this work.

The seventh section draws together conclusions from the whole study.

1.3.2 **Structure of appendices**

A set of appendices accompanies this report. Appendix 1 provides a detailed description of sources and assumptions for the estimates of the magnitude and timing of investment across the sectors, and relates to section 2. Appendix 3 describes the estimation of spare funding capacity on utility balance sheets, which is necessary to understand the capital currently available for power generation investment, in particular offshore wind. Appendix 4 supports section 4.3 by presenting detailed case studies of institutions with remits and functions similar to those of the proposed GIB. Appendix 5 gives a detailed methodology for the value for money modelling conducted for the offshore wind and waste sectors.

2 Description of sectors

A wide range of sectors are important to the greening of the UK economy

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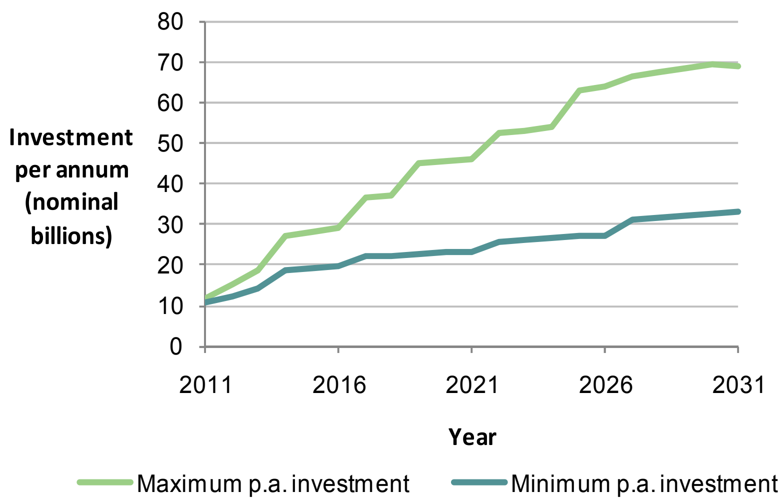
Section Summary

Fifteen sectors were chosen by BIS for consideration, three in detail where an aided intervention was considered likely to be appropriate and the others in brief where commercial investment was more likely to be the focus of the GIB. Further detailed studies of some sectors might be required where aided products could potentially be appropriate in future. The sectors given detailed attention are offshore wind, non-Local Authority collected commercial and industrial waste, and non-domestic energy efficiency. These sectors are subject to a detailed value-for-money assessment in Section 4. Offshore wind has the largest investment programme, of around £50 to £130 billion (nominal) by 2020. Non-domestic energy efficiency is a medium scale opportunity, of up to around £16 billion, and waste is relatively smaller, at around £1 billion. Of the other 12 sectors, nuclear power and carbon capture and storage (CCS) are both potentially large sectors, nuclear power being between £35 and 90 billion of capital investment and CCS between £25 and 36 billion over the next 20 years. Marine energy and photovoltaics each might require up to £15 billion and other sectors are expected to be a small number of billion pounds each.

For other sectors, the novelty appears in the business model or commercial arrangements. This is seen in the Green Deal, where loans are secured against a receivables contract tied to the meter point, and some contract energy management models within non-domestic energy efficiency, again using finance secured against receivables.

The sectors analysed may require a total of £185 – 295 billion of capital expenditure to 2020 to meet targets/ policy ambitions, as shown in Figure 1. The estimate is quite wide as there is uncertainty in long-term economic growth and in the mix of assets which will be deployed to green the economy.

Figure 1. **Green sectors may require £20 billion p.a. or more investment for the next two decades, with the requirement rising to £50 billion in some scenarios**



Source: Vivid Economics analysis of various sources, see appendix 1for more detail

2.1 Overview of investment estimates

A summary of estimates of investments needed to meet policy ambitions in each type of technology is given in Table 1 below. These are taken from UK government scenarios. Appendix 1 gives more detail on how these estimates were calculated and gives a breakdown of estimates by each scenario. The greatest amount of investment is expected in offshore wind, nuclear and carbon capture and storage. Photovoltaics and marine energy are the medium-sized sectors and the rest are much smaller.

Table 1. **Range of estimates for investments in £billion (2011-2012 prices)**

£bn	2011-13	2014-16	2017-21	2022-26	2027-31	Total
Offshore wind	4.8-11	4.9-24	8.1-67	4.9-81	0-81	22.7-264
Non-Local Authority commercial and industrial waste	0.39	0.40	0.40	0	0	1.2
Non-domestic energy efficiency	0.16-0.66	0.24-1.0	0.31-1.3	0	0	0.71-3.0
Renewable heat	0.60	0.50	0.80	0.80	0.80	3.5
Low carbon projects within the Green Deal	Not available					
Nuclear	0	0-8.7	14-26	14-47	14-70	42-152
Photovoltaics	3.0-4.2	2.9-4.3	4.8-8.2	4.8-9.8	4.8-9.8	20-36
Tidal range	0-0	0.8-4.7	0-8.7	1.1-10.1	0-10.1	1.9-34
Tidal stream and wave	0-0	0-0	0-1.6	0-2.2	0-2.9	
Carbon capture and storage	0.4	2.9	1.1-3.2	6.3-16	16-23	26-45
Onshore wind	Not available					
Smart meters	0	5.7	5.7	0	0	11.4
Electrical vehicle infrastructure	0.12	0.12-0.18	0.37-0.53	0.55-1.1	0.82-2.1	2.0-4.0
Rolling stock	4.3	1.5	0	0	0	5.8
Flood defences	1.5	1.5	2.6	2.6	2.6	10.8
Total	**33-42**	**39-74**	**67-155**	**59-197**	**62-226**	**260-693**

Source: Vivid Economics analysis of various sources – see appendix 1 for more detail. Totals may not add up due to rounding.

The subsections that follow describe each sector in turn, covering the current and future market size, technologies, supply chain, benefits generated and a brief description of the current policy interventions.

2.2 Offshore wind

2.2.1 **Current and future size**

As of May 2010 there were 14 operational sites with a combined capacity of 1GW and 4 under construction with a combined capacity of 1.5 GW. There have been 6 further sites approved but not built with a combined capacity of 2.6 GW, and there are 43.7 GW worth of sites under consideration including applications anticipated but not yet submitted (DECC, 2010).

Scenarios of the electricity that may be needed from offshore wind for the UK to comply with the EU Renewable Energy Directive in 2020 have been created for this report. The scenarios consider how much energy may be demanded in 2020 and what proportion of this offshore wind may contribute. This gives low, medium and high scenarios of electricity from offshore wind. The scenarios are fully described in Section 5.2.3 and in appendix 5.

For the low scenario, the prospective generation by offshore wind in 2020 is 33 TWh, which, based on modelling conducted for this report, would require an installed capacity of 13 GW and a capital expenditure of £50 billion by 2020 (nominal). In the medium scenario, offshore wind makes a contribution of 50 TWh and requires an installed capacity of 22 GW and a capital expenditure of £90 billion by 2020 (nominal).

In the high case, however, the offshore wind industry might be constrained in meeting its contribution due to a lack of investment worthy projects. This constraint limits the contribution of offshore wind to 58 TWh from an installed capacity of 23 GW and a capital expenditure of £100 billion. If there were no concerns regarding the investment worthiness of projects, then the high case requires 87 TWh from an installed capacity of 32 GW, requiring a capital expenditure of £130 billion by 2020 (nominal).

2.2.2 **Technologies**

Offshore wind turbines, the towers, foundations and cabling are variants on the same products which have been used onshore over many years. They are larger in scale than onshore plant and built to withstand the harsh conditions of the marine environment. Reliability has a higher premium in offshore turbines because of the difficulty and cost of access for repairs and maintenance, and because of the greater transmission distances, some of the network technology is different from that used onshore. The basic pattern of the turbines has become established, but aspects of designs to allow greater scale and improve performance are being tried out, so there is substantial innovation in the sector.

2.2.3 **Supply chain**

Globally, there are 10 main players in wind turbine manufacturing (both onshore and offshore), shown below by market share in descending order:

- Vestas of Denmark (14.3 per cent market share globally in 2011);
- Sinovel of China (10.7 per cent);
- GE (9.3 per cent);
- Goldwind of China (9.2 per cent);
- Enercon of Germany (7 per cent);

- the Suzlon Group of India (6.7 per cent);
- Dongfang of China (6.5 per cent);
- Gamesa of Spain (6.4 per cent);
- Siemens of Germany (5.7 per cent); and
- United Power, of China (4.1 per cent).

Other manufacturers cover 20 per cent of the wind turbine market (REN21 2011). A sub-set of these manufacturers supply turbines for use offshore. With regards to the UK market specifically, 40 per cent of total wind turbine capacity is supplied by Siemens (RenewableUK 2011h).

Britain does not have currently a large scale wind turbine manufacturer, and correspondingly export opportunities in onshore wind manufacturing are limited. Nevertheless, UK Trade & Investment highlights trade opportunities in 'wind turbine design; project management; training; and the manufacture of specialist components, such as control and condition monitoring systems' (UKTI 2010a).

2.2.4 **Benefits**

Offshore wind is predicted to become a major contributor of renewable energy in the UK. The scenarios of its contribution are described in detail in sections 4.2.3 and 4.4.3. It also makes a significant contribution to carbon dioxide reduction targets, again discussed in detail later, see Figure 22.

2.2.5 **Current interventions**

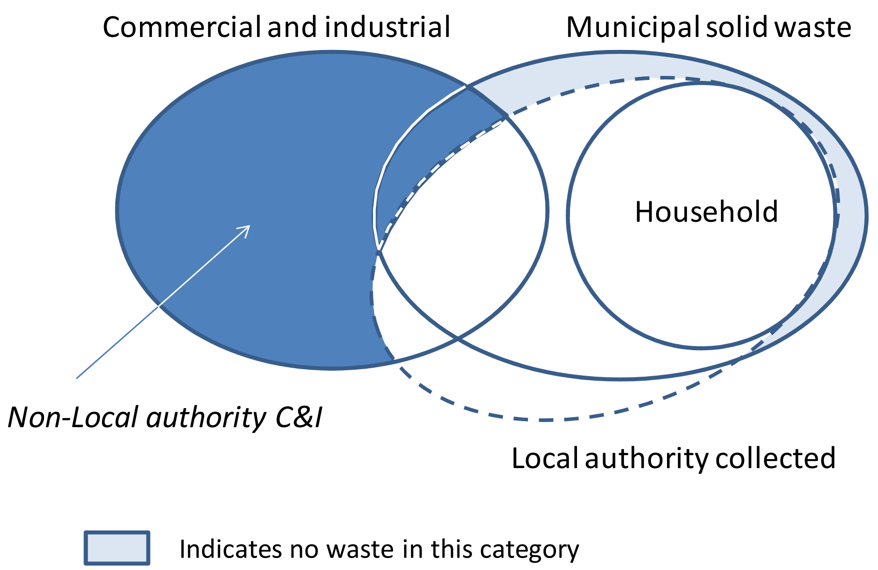
The main direct policy lever in the offshore wind market is currently the Renewables Obligation. This instrument requires each electricity supplier to source a proportion of electricity from certified renewable sources. Offshore wind power generators earn 2 Renewable Obligation Certificates (ROCs) per MWh compared to 1 ROC/MWh for other forms of green generation and as few as 0.25/MWh for landfill gas generation (Statutory Instruments, 2009). The ROC price is taken to be £40.70 in 2012/13 (the 2011/12 figure plus retail price inflation of 5 per cent), so offshore wind receives a production subsidy of more than £80/MWh. These support arrangements will change in the future. The Energy Market Reform announced in June 2011 will replace, for new plants, the Renewables Obligation with feed in tariffs.

Alongside market failures and regulatory uncertainty, which are described in more detail in section 3, there are three possible constraints on the building of offshore wind farms. The first is the build rate. This is a function of a number of factors including the supply chain, planning consent, working capital and management capacity. The second is the set of investable projects which pay a sufficient return on capital. Last is the quantity of investor capital available.

2.3 Non-Local Authority commercial and industrial waste

The definition of municipal waste was changed in 2010, expanding its scope to take in some commercial and industrial waste. The new definition of non-municipal waste now covers 24.6 million tonnes and only contains waste *not* collected by Local Authorities. Time series under the new definition are not available in the public domain, so the trends and management methods are approximated by data under the old definition of non-municipal waste described above. The relationship between these components is shown in Figure 2.

Figure 2. **Diagram showing the relationship between non-Local Authority C&I other waste streams**



Note: waste that is neither municipal solid waste nor commercial and industrial waste is a third category, construction and demolition waste

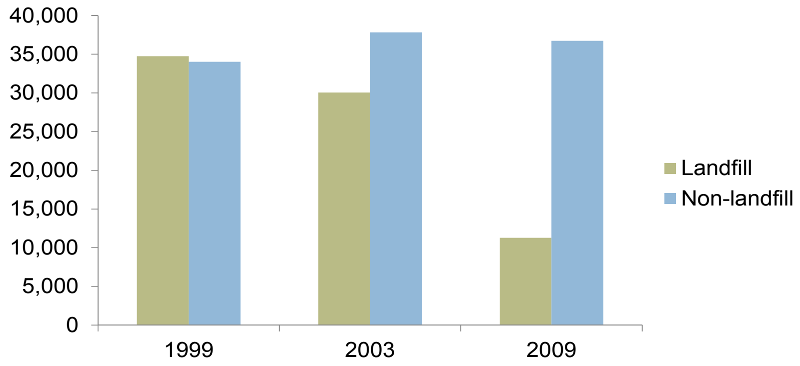
Source: Vivid Economics

The amount of commercial and industrial (C&I) waste in England has fallen by 21 million tonnes in the period from 1998/99 to 2008/09, to its current level of 48 million tonnes, as shown by Figure 3. The industrial sector accounted for 24.1 million tonnes and the commercial sector 23.8 million tonnes (Defra, 2011a and Defra, 2010). This decline in C&I waste is equivalent to a compound annual growth rate of -5.5 per cent between 2003 and 2009.

The majority of non-municipal C&I waste in the UK is diverted away from landfill. The amount of landfill C&I waste has fallen from 32.1 million tonnes in 1998/99 to just 11.3 million tonnes in 2009. In 2009, this put the proportion of C&I waste to landfill at 24 per cent, a significant decline from 41 per cent in 2002/03 and 47 per cent in 1998/99.

The proportion of recycled waste, some of which is sorted in Materials Recovery Facilities (MRF), increased from 39 per cent in 1998/99 to 45 per cent in 2002/03. In 2009 a further 4 per cent of commercial and industrial waste was composted or re-used. A smaller portion, approximately 1.0 million tonnes, or 2.1 per cent, is treated at Energy from Waste (EFW) plants (Defra 2010). The remaining waste is treated by other processes. Recycling rates have increased significantly from 30 per cent in 1998/99 and 33 per cent in 2002/03 to 49 per cent in 2008/09, figures which include composting in those years.

Figure 3. **Total C&I waste arising (000 tonnes per annum) and use of landfill has fallen sharply since 2003**



Notes: this data is for England only, for the years 1989/90, 2002/03 and 2009

Source: Defra data, Vivid Economics calculations

There are possible constraints on the volume of C&I waste that can be diverted from landfill to EFW and MRF, principally the capacity of these waste treatment assets and demand for municipal solid waste (MSW) processing from local authorities, for the processing capacity that is principally contracted to municipal authorities.

There is significant uncertainty about the scale of investment needed in the waste sector, however our analysis suggests that in the highest scenario of diversion required investment to 2020 around £2.6 billion, but in a medium scenario the requirement may be half this amount, at £1 billion. In the lowest scenario of demand the capital requirement in waste is negligible. Full details of our analysis of the waste sector can be found in section 5 and appendix 5.

2.3.1 Technologies

Energy from waste covers a range of technologies including more established combustion or incineration, anaerobic digestion, as well as less tested, advanced conversion technologies such as advanced gasification and pyrolysis, which are capable of producing a wider range of energy outputs and materials. The government has provided financial support for advanced conversion technology demonstration projects, and is reviewing the consenting arrangements for advanced technologies.

2.3.2 Benefits

The overarching policy objective is to move waste management up the 'waste hierarchy', where in order of declining preference, the choice is between prevention, preparing for reuse, recycling, other recovery and disposal. Much of the infrastructure investment concerns the shift from disposal (landfill) up the hierarchy to recycling and recovery. Recycling and energy from waste reduces CO_2 emissions, reduces aquatic and air pollution from landfill and in the latter case contributes towards renewable energy targets. Further details of these contributions can be found in sub-section 4.5.4.

2.3.3 **Current interventions**

Waste policy in the UK in recent years has been focussed on diverting waste away from landfill and the flagship policy is the Landfill Tax. In addition, the EU ETS, renewable energy target and the Renewables Obligation incentivise low carbon power generation. Targets for waste to landfill do not currently apply to non-Local Authority collected commercial and industrial waste.

Two principal factors drive demand for non-Local Authority commercial and industrial waste landfill use; first, the amount of waste; and second, the relative cost of landfill compared to other technologies, such as MRF and subsequent processing, and EFW. The Landfill Tax has an influence on both of these factors by increasing the relative cost of landfill and the absolute cost of waste disposal.

The standard rate of Landfill Tax for active waste in 2010/11 was £48/tonne, although the 2010 Budget increased this by £8/tonne from 1 April 2011. The Landfill Tax will increase by £8/tonne each year until April 2014, when the tax rate for standard-rated wastes will be at least £80/tonne for the 2014/15 financial year and until 2020. There is no discussion of the tax rate after 2020 in the recent waste policy review (Defra, 2011a). The government has announced its intention to publish a UK Bioenergy Strategy later in 2011, including a focus on measures to support long-term sustainable waste fuel supplies.

Additional incentives for investment in EFW are provided by policies influencing the relative price of electricity generated from fossil sources and that generated by the combustion of waste and waste gases. A quarter of one Renewable Obligation Certificate (ROCs) is provided for 1MWh of renewable electricity generated by landfill gas, whilst 1 ROC is awarded for each MWh of renewable EFW with combined heat and power. Renewable electricity generated through advanced conversion technologies such as gasification and pyrolysis or anaerobic digestion receives 2 ROCs per MWh. A relative price incentive is also provided to EFW through the EU ETS which places an explicit price on carbon produced by electricity generation; EUAs, emissions allowances, currently trade at a price of around EUR 17.

The government has also provided financial support for advanced conversion technology demonstration projects, and is reviewing the consenting arrangements for advanced technologies.

Defra concludes that because the targets for reducing waste to landfill apply to municipal waste, much of the activity and innovation has not been addressed to managing C&I waste. Nevertheless, a success of the Landfill Tax is that the C&I sector has achieved a higher recycling rate than households. There are opportunities for further improvement, by extending the provision of recyclables for SMEs, for example, and by encouraging separation of food waste so that it can be sent to anaerobic digestion.

2.4 Non-domestic energy efficiency

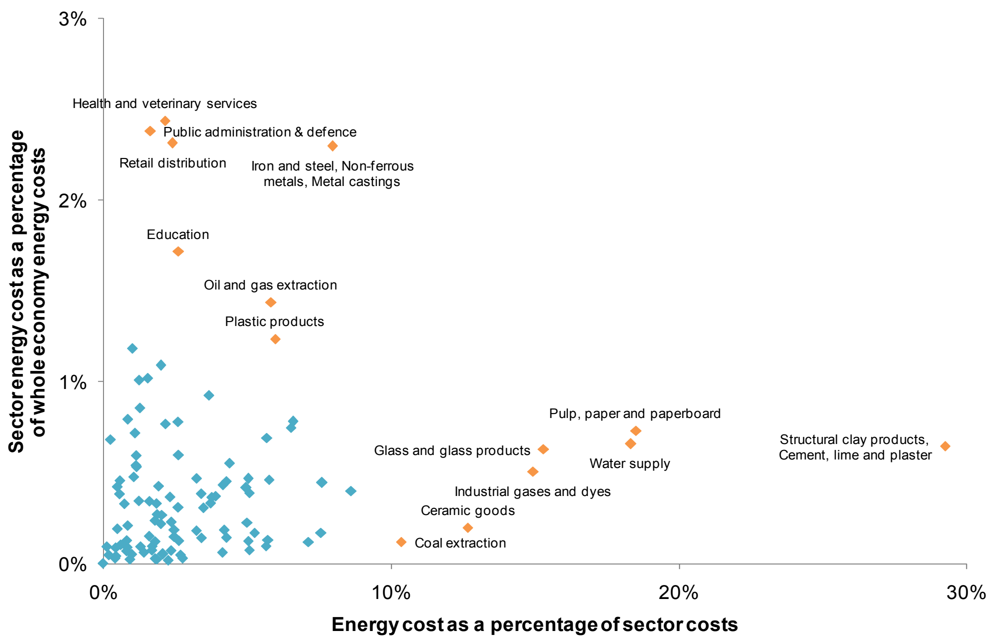
There is more graphical material presented in this sub-section to show the great diversity of size of opportunities, technologies, benefits and intervention, which is a distinguishing feature of this sector.

2.4.1 Current and future size

UK industry consumes 20 per cent of total UK energy (DECC, 2010a) and is responsible for 30 per cent of UK greenhouse gas emissions (under UNFCCC National Communications definition and excluding process emissions) (DECC 2009 and 2011, Table 3c). The potential for greater industrial energy efficiency is thought to be large (DECC, 2010), despite strong historical improvements in industrial energy efficiency, but the details are quite uncertain (SKM Enviros, 2010), especially the response of take-up measures to policy and the amount of capital associated with improvements.

Energy use by UK industry has fallen over time, decreasing by 20 per cent between 1990 and 2008 (DECC, 2010a). The decrease in energy use is the net result of changes in energy efficiency and output, as both demand and industry structure change. Higher real output resulted in an increased energy use of 10 per cent from 1990 to 2008, which was offset by a 30 per cent increase in energy efficiency on average in each sector over the same period (DECC, 2010a), with a wide variation in improvement across sectors. This evidence suggests that energy efficiency measures may have been widely taken up in the UK, at least in some sectors, whether autonomously or in response to policy.

Figure 4. **Public services and retail are the sectors using the most energy in the UK, but energy has a higher cost share in industrial sectors**



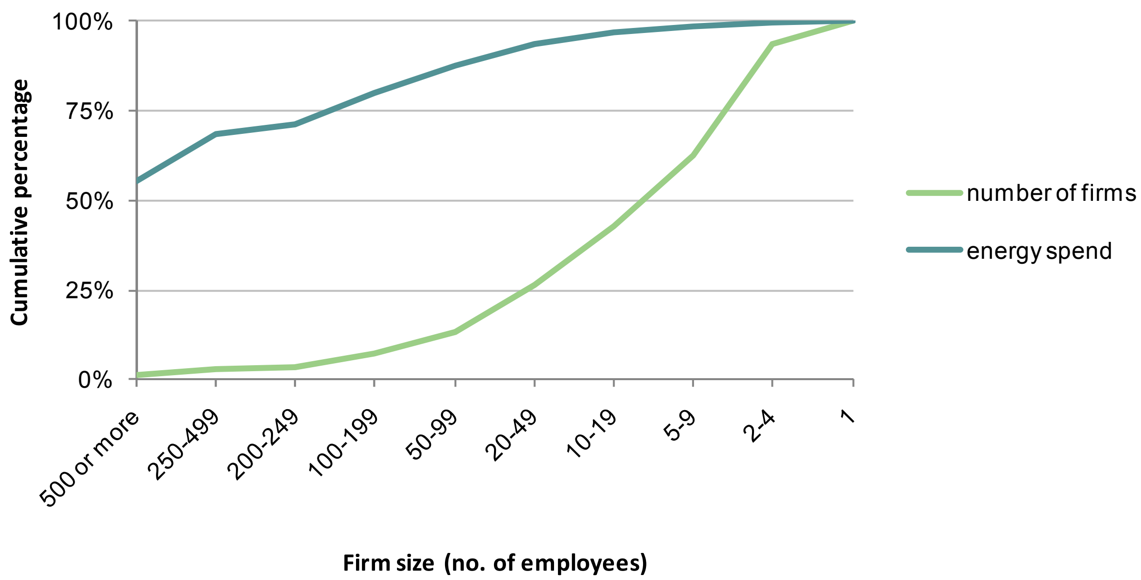
Note: Energy in the form of gas and electricity use; note that DECC use Annual Business Inquiry data for similar analysis

Source: ONS, 2010. Supply & Use tables 2004-2008, 2008 data, Vivid Economics analysis

Industrial energy use in the UK is concentrated in a handful of energy-intensive sectors. Retail and public services are also significant energy users but, for them, energy is a small part of total expenditures. The distribution of energy use across non-domestic sectors and the cost of this energy as a percentage of each sector's costs are shown in Figure 4.

In energy-intensive sectors, energy use is concentrated in the largest firms, as illustrated in Figure 5. This suggests that much of the opportunity for improvements in industrial energy efficiency may be concentrated in a small number of large firms, which may well have the resources to address energy efficiency, and may be more efficient than smaller firms as a result. AEA Technology (2010) corroborates this, finding that emissions could be reduced cost-effectively by 10 $MtCO_2$ by 2030 in the UK's six most carbon intensive sectors, through a relatively small number of large measures, with capital costs of several millions of pounds (AEAT, 2010). Nevertheless, a Carbon Trust study suggests that the greatest potential for improvement in CO_2 efficiency, and therefore energy efficiency, is to be found among smaller firms, as Figure 21 shows. The capital cost of these efficiency measures is low, in the thousands, or tens of thousands, of pounds (Carbon Trust, unpublished).

Figure 5. **Industrial energy use is concentrated in large firms; with 70 per cent of energy consumed by firms of more than 200 employees in a sample of energy-intensive industries**



Notes: Data is for energy intensive industrial sectors for which energy use and firm size data could be matched without disclosive data; the sectors are paper, chemicals, rubber and plastics, and, metals (Standard Industrial Classification (2003) codes 21, 24, 25, 26 & 27)

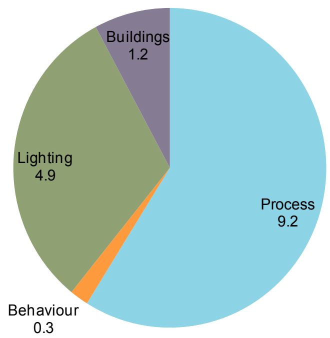
Source: ONS, 2010, 'Supply & Use tables 2004-2008', 2008 data, & BIS, 2008, 'SME statistics for the UK and Regions 2008' & Vivid Economics analysis

The UK non-domestic energy efficiency (NDEE) opportunity is considered to require capital of around £15.5 billion of investment until 2020 (McKinsey, 2011); with over 90 per cent of this opportunity cost effective.

Studies of selected sectors identify up to £3 billion of investment up to 2020 (ENUSIM model and AEAT 2010) [1].

Energy efficiency in buildings offers an investment opportunity of £1.2 billion (McKinsey, 2011, and Carbon Trust, 2010). In addition, McKinsey identify £4.9 billion could be invested in lighting energy efficiency. Process related energy efficiency requires investment of £9.2 billion to 2020. The remaining balance of £0.3 billion relates to behavioural measures. This information is shown in Figure 6. The realistic potential for investment in SME's has been identified as £0.5 billion in process energy efficiency and £0.5 billion in buildings (Carbon Trust, personal communication).

Figure 6. **McKinsey estimates of capital investment of the UK NDEE opportunity to 2020 (£ billions)**



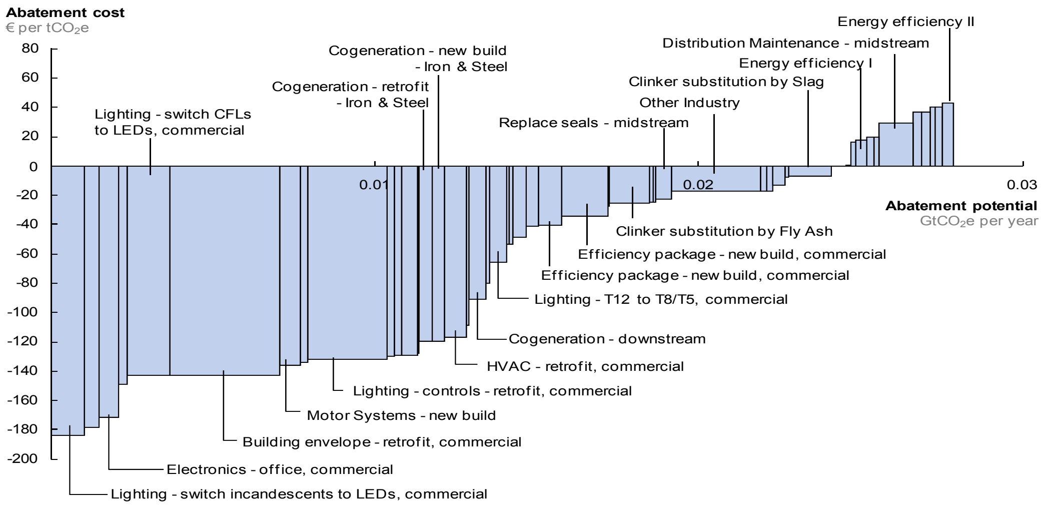
Source: McKinsey, GHG Abatement Cost Curve v2.1

2.4.2 **Technologies**

The range of technologies involved is shown in Figure 7. Lighting and building retrofits are two of the largest contributors of emissions reductions.

[1] This figure is derived from Appendix 1 of AEA (2010), taking the core basic scenario and realistic potential

Figure 7. **Non-domestic energy efficiency could provide an opportunity to abate 28 $MtCO_2$ by 2020**



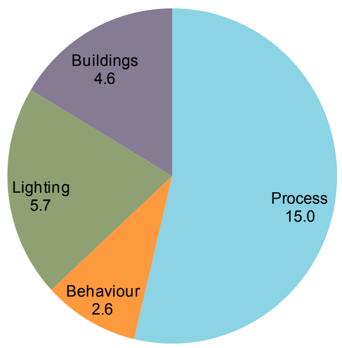
Notes: the curve presents an estimate of the maximum potential of all technical GHG abatement measures below €80 per tCO_2 if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play. Curve is the societal cost curve beyond 2020 for non-residential buildings and industry, including petroleum & gas, iron & steel, chemicals and other industry

Source: McKinsey, GHG Abatement Cost Curve v2.1

2.4.3 Benefits

The potential cost-effective reduction of emissions has been estimated at between 3 and 16 $MtCO_2$pa in 2020 in a study of six large sectors (SKM Enviros, 2010). McKinsey estimates a technical potential of 28 $MtCO_2$ per annum in 2020 across all non-domestic energy efficiency opportunities, Figure 8.

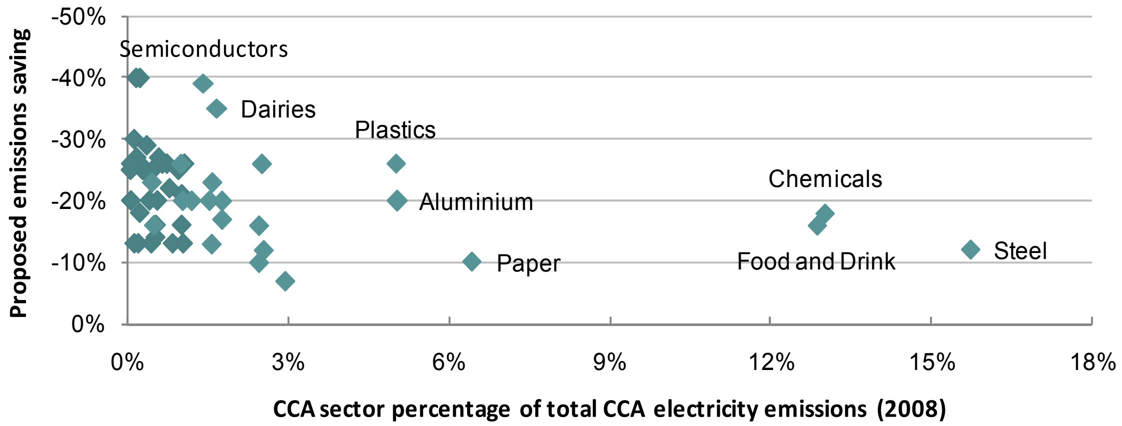
Figure 8. **McKinsey estimates of UK NDEE opportunity in 2020 ($MtCO_2$ p.a.)**



Source: McKinsey, GHG Abatement Cost Curve v2.1

As an additional piece of evidence, the reductions required under Climate Change Agreements are a guide to what may be possible across sectors. Figure 9 shows that emissions reductions of between 10 and 40 per cent might be achieved, although the potential for reductions appears to be more limited for the sectors consuming a larger share of electricity input.

Figure 9. **Emissions reductions potentials considered feasible for CCA sectors range from 10 to 40 per cent, but more electricity intensive sectors are thought to have lower efficiency potentials**

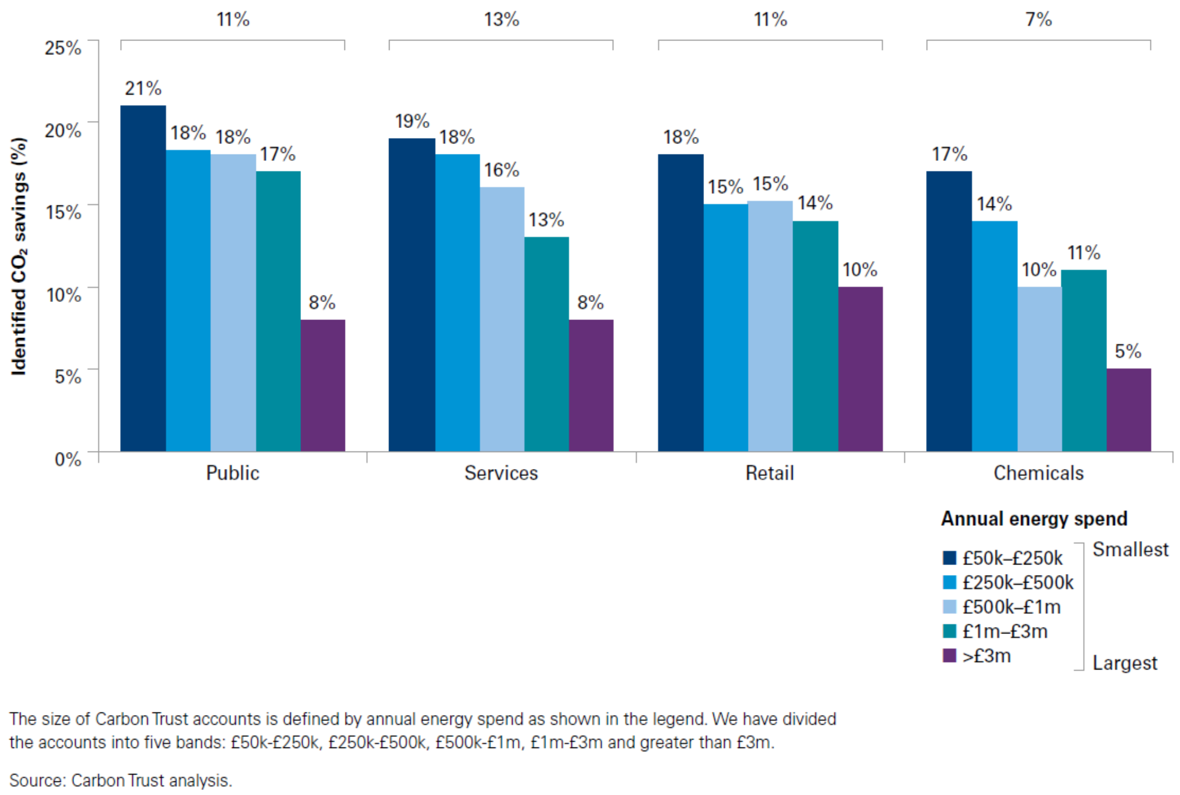


Note: data is for proposed emissions savings requirements, which are currently under negotiation

Source: DECC & Vivid Economics analysis

The Carbon Trust's work has recommended energy savings to clients of between 10 and 20 per cent across a range of non-domestic sectors, as shown in Figure 10.

Figure 10. **Identified savings in percentage terms in the public, services retail, and chemicals sectors by organisation size, from ex ante recommendations identified by the Carbon Trust in 2006/7**

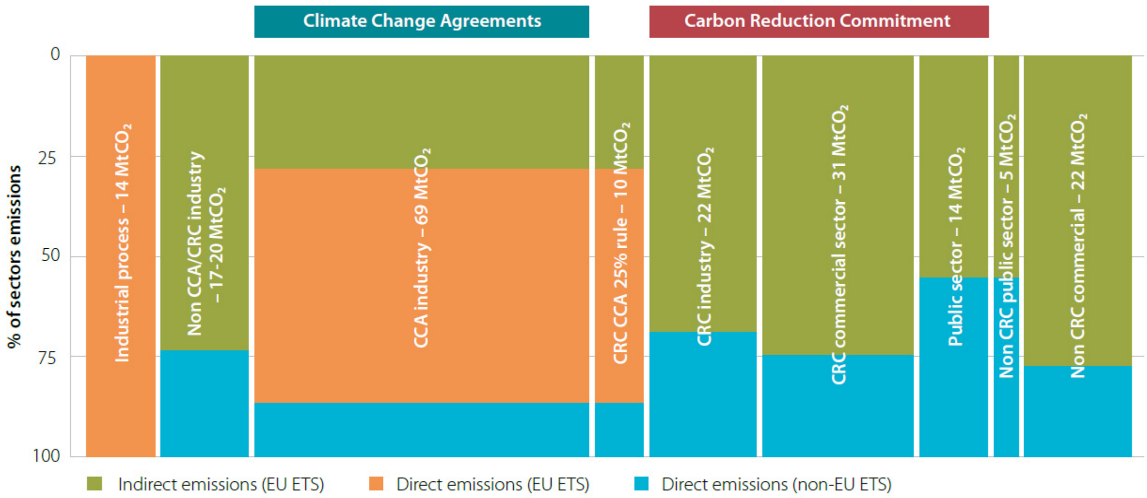


Source: Carbon Trust, unpublished

2.4.4 Current interventions

A number of policies cover industrial energy use and emissions. The key policies are the European Union Emissions Trading Scheme (EU ETS), Climate Change Agreements (CCAs) and the Climate Change Levy (CCL). The EU ETS increases the cost of electricity for all users and the cost of process emissions within the EU ETS. CCAs provide sectors with up to an 80 per cent discount on the CCL if they improve energy efficiency by a negotiated level. The CCL is a tax on electricity and fuel use and is currently equivalent to about 6 per cent on median industrial electricity prices and 7 per cent on median industrial gas prices (HMRC 2011 and DECC 2010a). The CRC Energy Efficiency Scheme may impose a cost of £12 per tCO_2 on organisations with an electricity bill of around £0.5 million per annum or more. The Carbon Trust provides advisory services to firms although the level of public subsidy for these advisory services is currently under review and may be reduced. Figure 11 provides an overview of the policies covering industrial energy use and emissions. Enhanced Capital Allowances are not shown in Figure 11.

Figure 11. **UK industrial energy use and emissions are covered by a number of policies that primarily increase the cost of energy or emissions**



Source: NAEI (2010); SKM Enviros (2010); DECC (2010); CCC calculations.
Notes: Each segment represents different parts of non-residential buildings and industry emissions , related policy coverage (EU ETS, CCA, and CRC) and proportions of direct/indirect emissions in each segment (shown by y axis). Each segment's width represents the size of its emissions. Estimates are based on CCC calculations and are approximate.

Approximations are due to uncertainty around the level of CRC coverage , the CCA 25% exclusion CRC rule and inconsistent data sources for EU ETS and CCAs.

Some commercial sectors and public sector organisations have CCAs or are captured under the EU ETS but for simplicity these have not been displayed but are small.

All sectors are covered by CCL/RHI/ FITs/ Products policy/Carbon Trust support services/F-Gas directive/ECAs.

Source: Committee on Climate Change, 2010, 'The CRC Energy Efficiency Scheme – advice to Government'

2.5 Renewable heat

2.5.1 Current and future size

Heating accounts for just under half of the UK's energy demand, most of which is produced using gas. It represents around half of the UK's CO_2 emissions and more than three quarters of all non-transport energy use, (BERR 2008a, DECC 2010a).

The projection of renewable heat's contribution in 2010 is 13.0 TWh (DECC 2011). This is 1.8 per cent of the total heat demanded in the UK, (DECC 2011g). The government is aiming to increase the share to 12% by 2020. The RHI tariffs published in March 2011 are expected to deliver 11 per cent of heat from renewable sources in 2020: a saving of 1 $MtCO_2$ in the first carbon budget period (2008-2012), 15 $MtCO_2$ in the second carbon budget period (2013-2017) and 52 $MtCO_2$ in the third budget period (2018-2022), (DECC 2011b). The additional 1% of heat from renewable sources by 2020 is expected to be met by tariffs for additional technologies introduced in Phase II of the RHI.

Due to the range of technologies which can be used to produce renewable heat and the relatively small scale of many of these technologies (for example ground source heat pumps being considered large when over 100kWth), it will be likely that a large number of firms, particularly SMEs, will be able to supply and install these technologies. In June 2011 2,600 installation companies were registered under the Microgeneration Certification Scheme, of which over 2,500 are able to carry out heat installations.

The introduction of the Renewable Heat Incentive is expected to lead to increased interest in renewable heat from larger businesses. Everest (a double glazing company), for example, has expanded its business into solar heating.

Notable firms which have already put schemes into operation include the Adams brewery in Suffolk, which has built an anaerobic digestion facility, producing biomethane to be fed into the grid. This facility has a capacity of 12,500 tonnes of waste per annum and it is planned to double in size over the next year. It is estimated that by diverting food waste from landfill, the facility will save nearly 60,000 tonnes of CO_2e and inject 600,000 cubic meters of biomethane into the gas grid each year, (DECC 2011).

Dalkia has built a £40million biomass combined heat and power plant at Chilton near Durham. The 18MW new plant has been designed to be fuelled on locally sourced waste wood and, when completed, the plant will generate renewable electricity and heat (DECC 2011c).

BV Dairy in Dorset has installed a £2.3million innovative anaerobic digestion (AD) combined heat and power plant. This uses 50,000 tonnes a year of liquid waste from their dairy and food processing plant to generate renewable heat and electricity. The biogas from the AD plant is fed to a 190kWe combined heat and power engine which generates 2.1 GWh of electricity and 1.7 GWh of heat per year. Some of the heat is used to keep the digester at the correct temperature and the rest is used in the manufacturing operation to replace heat that was previously generated by oil burning boilers. With these measures, BV Dairy will cut its carbon footprint by about 60%, reducing its output of carbon by about 1,200 tonnes per year (DECC 2011c).

A report commissioned by DECC on the availability of feedstocks suggests that most biomass will be sourced within the UK, but this supply may not grow as fast demand for it, so that by 2020 a majority will be sourced overseas, (AEAT 2011). This is because considerable investment in collection, processing, logistics, transport and storage would be needed in order to expand UK supply. The AEA report states that imported solid bio-feedstocks could be in the region of around 1,000 – 5,000 PJ by 2020, rising to 5,300 – 8,900 PJ by 2030.

Cost estimates were prepared for the RHI policy assessment. Total capital expenditure to 2020 is estimated to be £9.9 billion (undiscounted). The emissions savings are 2.6 $MtCO_2$/year by 2015 and 11.9 $MtCO_2$/year by 2020.

2.5.2 Technologies

There is a wide array of technologies which produce heat from renewable sources, for a variety of uses. The most common uses are space and water heating, and industrial processes of various kinds. The types of renewable heat supported by the Renewable Heat Incentive (RHI) include: biomass, where wood pellets, wood chips or municipal waste is burnt in a boiler; ground and water source heat pumps, where naturally occurring heat is extracted; solar thermal (up to 200 kW); small-scale biogas combustion (up to 200 kW) and, biomethane, where biomethane is produced and fed into the gas grid, (DECC 2011). Ground source heat and geothermal technologies are supported under the ground source heat pump tariff.

Biomass boilers generate heat through the burning of organic matter, primarily wood. The wood generally comes in pellet or chip form but can also be supplied as logs. The heat is used to produce hot water or steam (DECC 2011).

There are several different types of heat pump; ground source, air source, and water source. They are electrically driven heat exchangers which extract renewable solar heat from the air, ground or water. 'The heat pump extracts low level heat from outside and upgrades the temperature so that it is warm enough to heat space and water, (DECC 2011). Ground source heat collectors may be buried in two different orientations, horizontal or vertical, depending upon land availability and conditions. A horizontal ground source heat pump may cost around £900/kW to install whereas a vertical one may cost £1,480/kW (AEAT 2011a).

Deep geothermal systems use heat stored deep underground, normally several hundred meters below the surface. Cold water is pumped down boreholes and hot water or steam returns. These systems tend to be relatively large due to the cost of drilling the borehole and are most suited to community heating (DECC 2011).

Solar thermal technologies use a roof or ground mounted collector (liquid filled flat plates or evacuated tube solar collectors) which use the heat from the sun to warm a liquid, usually water (DECC 2011a).

Biogas may be used in two ways to produce renewable heat. It may either be used where it is generated or processed and fed into the grid (DECC 2011).

2.5.3 Supply chain

The renewable heat supply chain involves research and development, manufacturing, renewable fuel production and supply, equipment installation and maintenance (DECC 2011). The growth of the supply chain is crucial to achieving government targets of 12 per cent penetration. Climate Change Committee (2011, chapter 3, p. 130) estimates that with low supply chain growth only 7 per cent of heat will be produced from renewables by 2020. AEA (2010) and NERA and AEA (2009) identify at least two renewable heat sectors where the supply chain is incomplete: sawmill residues and biogas from anaerobic respiration.

However, as the renewable heat supply chain expands, it may have adverse effects on biodiversity, carbon stock, and air pollution. The government, following European Commission recommendations, has already introduced sustainability reporting requirements for bioenergy, including a minimum of 60 per cent greenhouse gas emission saving for electricity generation and restriction on sourcing raw material of areas, such as primary forests.

2.5.4 Benefits

Renewable heat will help the UK to meet its renewable energy target as well as its decarbonisation objectives for the building and industrial sectors. The scheme will save an estimated 44 $MtCO_2$ by 2020, of which 8 $MtCO_2$is in the traded sector and 36 $MtCO_2$ in the non-traded sector.

There is a reduction in air quality from the burning of biomass where it replaces gas or electricity, but there can be a benefit where biomass combustion replaces heating oil or coal. Air quality is a more important issue in urban areas where air quality is generally worse and population density is higher, (DECC 2011)

2.5.5 Current interventions

The Renewable Heat Incentive aims to 'encourage the installation of renewable heating equipment and generation of renewable heat in order to meet the UK's share of the EU 2020 renewable energy target', (DECC 2011). Phase one of the Renewable Heat Incentive will only provide support for non-domestic installations. From 2012, it will increase in scope to support households as well. In the interim, the Government will run a short-term scheme, the Renewable Heat Premium Payment Scheme. This will provide one-off grants to help householders with the up-front cost of installing renewable heat technologies and will be focused on properties that are heated without gas. Participants in the Premium Payment scheme will also be eligible for support under the longer term scheme, as will any other installation that has installed an eligible technology after the 15th July 2009, providing they meet the eligibility criteria of the full scheme.

Biomass boilers which are larger than 1MW will have to provide evidence that their feedstock is sourced from sustainable woodland, and DECC has also said that it will keep under review whether agricultural land in food production is being displaced by the growing of biomass, so that if it is, steps will be taken to prevent it, (DECC 2011). Furthermore, if it appears that high grade timber is being diverted into heat use, and it is shown to have less advantageous greenhouse gas benefits perspective or causes concerns about deforestation, measures will be introduced to prevent it.

In addition to the RHI, there are three other government interventions in renewable heat:

- CRC Energy Efficiency Scheme (CRC): described earlier.

- Zero carbon new non-domestic buildings: all new non-domestic buildings will be 'zero carbon' from 2019, with the public sector leading the way from 2018, driven by changes to Part L of the Building Regulations (DECC 2011).
- EU ETS (for large scale industrial process)

The Renewable Heat Incentive and CRC are targeted exclusively at the non-domestic sector. The amount of financial support varies by technology to take account of the different costs likely to be incurred. The Renewable Heat Incentive tariff levels available to non-domestic applicants are set out in Table 2.

Table 2. **Tariff levels for biomass heat under the Renewable Heat Incentive, p/kWh**

Scenario	Description	Size	Tariff, p/kWh
Small biomass	Solid biomass, municipal solid waste (inc. CHP)	<200 kWth	Tier 1: 7.9 Tier 2: 2.0
Medium biomass	Solid biomass, municipal solid waste (inc. CHP)	200-1,000 kWth	Tier 1: 4.9 Tier 2: 2.0
Large biomass	Solid biomass, municipal solid waste (inc. CHP)	>1,000 kWth	2.7
Small ground source	Ground source heat pumps; water source heat pumps; deep geothermal	<100 kWth	4.5
Large ground source	Ground source heat pumps; water source heat pumps; deep geothermal	>100 kWth	3.2
Solar thermal	Solar thermal	< 200 kWth	8.5
Biomethane	Biomethane injection and biogas combustion, except from landfill gas	Biomethane all scales, biogas combustion < 200 kWth	6.8

Source: Source: Renewable Heat Incentive Regulations 2011

2.6 Low carbon projects within the Green Deal

2.6.1 **Current and future size**

2.6.1.1 Introduction

The Green Deal is a framework that will enable private firms to offer consumers energy efficiency improvements to homes, community spaces and businesses at no upfront cost, and recoup payments through a charge, paid in instalments, via the consumer's electricity bill (DECC, 2011d, p.5). The Energy Bill 2010-11 provided the primary legislation that enables the Green Deal to be enacted as an item of secondary legislation. Secondary legislation is expected to be laid before Parliament in early 2012 and the first Green Deals are expected to appear in autumn 2012 (DECC, 2011d, box 2). Green Deal will be subject to approval by the European Commission under Article 107 of the Treaty on the Functioning of the European Union (TFEU) on the general prohibition of state aid.

The Green Deal is expected to have 'much greater impacts in the domestic sector than in the non-domestic sector' (DECC, 2011e, p. 22). In scenarios of the Green Deal, the domestic sector will provide around 80 per cent of non-traded CO_2 savings and around 60 per cent of traded CO_2 savings (DECC, 2011e, tables 2 & 3)[2].

The expected prominence of the domestic sector in the Green Deal, as well as the focus of policy to date on this sector, in addition to the consideration of non-domestic energy efficiency in section 3.6, requires this section to concentrate on the nature of the domestic energy efficiency market and how the Green Deal is expected to affect it.

2.6.1.2 Current domestic energy efficiency

The domestic sector consumed 32 per cent of total UK final energy consumption in 2010. Domestic energy use was 19 per cent higher in 2010 than in 1990, the increase driven in part by a 17 per cent increase in the number of UK households and a 9 per cent increase in the UK population since 1990. Despite these demographic pressures on energy use, the energy consumption per unit of household disposable income has reduced by 23 per cent since 1990. There have been large improvements in the energy efficiency of some appliances. For example, most types of freezers have become 50 per cent more energy efficient since 1990. There have also been improvements in insulation and heating efficiency, without which it is estimated that energy consumption may have been twice as high as its current level (ONS & DECC, 2011).

Nearly 70 per cent of domestic energy is from gas, meaning that the majority of the 142.2 $MtCO_{2e}$ of residential combustion emissions in 2009 were non-traded (DECC, 2011f). Heating is the main use of energy in the domestic sector, with 61 per cent of energy used for space heating and 18 per cent used for water heating (ONS & DECC, 2011).

[2] Figures in this report are based on the most recent published information on the Green Deal. Further publications are expected in autumn 2011.

Given the importance of heating in domestic energy use, improving insulation has been the primary focus of energy efficiency policy. Insulation can be fitted to lofts, cavity walls or solid walls. There are 26.6 million homes in Great Britain, of which 23.3 million have lofts, 18.7 million have cavity walls and 7.9 million have solid walls. 58 per cent of homes with lofts have been insulated. 58 per cent of houses with cavity walls have been insulated. In contrast, 1 per cent of homes with solid walls have had solid wall insulation fitted (DECC, 2011g).

There have been improvements in energy efficiency beyond insulation. The Carbon Emissions Reduction Target (CERT), which is described in more detail in section 2.6.4, requires energy suppliers to deliver energy efficiency measures to households. Since CERT's inception on April 1st 2008 the program has delivered, in addition to insulation, over 300 million compact fluorescent lamps (CFLs), 2.29 million real time energy use displays and 6,500 heat pumps, as well as switching the fuel type of 73,000 households and providing home energy use advice to almost 30,000 households (Ofgem, 2011).

2.6.1.3 Domestic energy efficiency under the Green Deal

The current proposals for the Green Deal suggest that measures from the following category could be installed under the scheme:

- heating, ventilation and air conditioning, e.g. condensing boilers and under-floor heating;
- building fabric, e.g. insulation and draught proofing;
- lighting, including fittings and controls;
- water heating, including innovative hot water systems and efficient taps and showers;
- microgeneration, e.g. ground and air source heat pumps and micro-CHP.

The latest impact assessment for the Green Deal, DECC (2011e), has focused on insulation, with substantial levels of installation intended, as Table 3 illustrates. However, proposals recognise that opportunities to access households may be limited to one visit, and therefore packages of measures should be installed during a visit.

The Green Deal is expected to abate 3.3 – 4.9 $MtCO_{2e}$ from the non-traded sector by 2020 and to avoid the purchase of EU allowances for 0.6 – 1.0 $MtCO_{2e}$ from the traded sector by 2020 (DECC, 2011e, table 2). Detail on the aggregate energy savings of the program are not provided in the latest impact assessment, (DECC, 2011e), but insulation is expected to save 4 – 10.5 MWh/household/year, depending on the type installed.

Table 3. **The Green Deal may increase solid wall insulation by 20 times the current level, while insulating many of the remaining lofts and cavity walls**

Measure	Low scenario	High scenario	Maximum feasible potential
Lofts	2.3	3.4	4.5
Cavity wall	0.5	2.3	4.0
Solid wall	1.8	2.2	3.1
Glazing	0.7	1.0	1.4
Party wall	0.5	0.7	0.9
Insulated doors	1.3	1.9	2.5

Source: DECC (2011e), Table 1

2.6.2 Technologies

2.6.2.1 The Net Present Value of measures

All measures installed under the Green Deal must meet the 'Golden Rule', which is that the periodic charge should not exceed the expected savings for that period, as section 2.6.4explains in more detail. This implies that all measures should have a positive Net Present Value (NPV) at a discount rate equivalent to the cost of finance and excluding social benefits, such as the value of non-traded emissions abated. For measures that have a negative NPV, such as solid wall insulation, it is expected that the Energy Company Obligation (ECO) will provide a subsidy such that the NPV for the household is positive. Table 4 describes the costs and NPVs of a selected range of measures. Overall, the net present value of the Green Deal is estimated to be £6.4 – £10.9 billion (DECC, 2011e, table 2).

The value of energy efficiency to households lies primarily in the value of energy savings. However households also 'take comfort' from lower energy bills, which means that they consume a greater quantity of energy in response to an increase in their budgets, which arises because of the original energy saving. This rebound effect is assumed to be 15 per cent of energy saved (DECC, 2011e, p. 108). Although offsetting 15 per cent of expected carbon savings, this additional comfort taken is a benefit to the household, valued at the increased expenditure on energy.

In addition to energy saving, comfort taken and the value of emissions savings, improvements in energy efficiency also have the benefit of improving air quality and the security of energy supply.

Table 4. **The Green Deal may increase solid wall insulation by 20 times the current level, while insulating many of the remaining lofts and cavity walls**

Measure	Cost	NPV
Cavity wall insulation (easy)	£380	£3,500
Cavity wall insulation (hard)	£1,600	£2,100
Loft insulation (professional installation)	£280	£370
External solid wall insulation	£7,600	- £2,700
Internal solid wall insulation	£5,000	- £1,000
Electric central heating	£1,000	- £5,000
Gas central heating	£2,300	£720
Boiler replacement	£2,500	£1,500

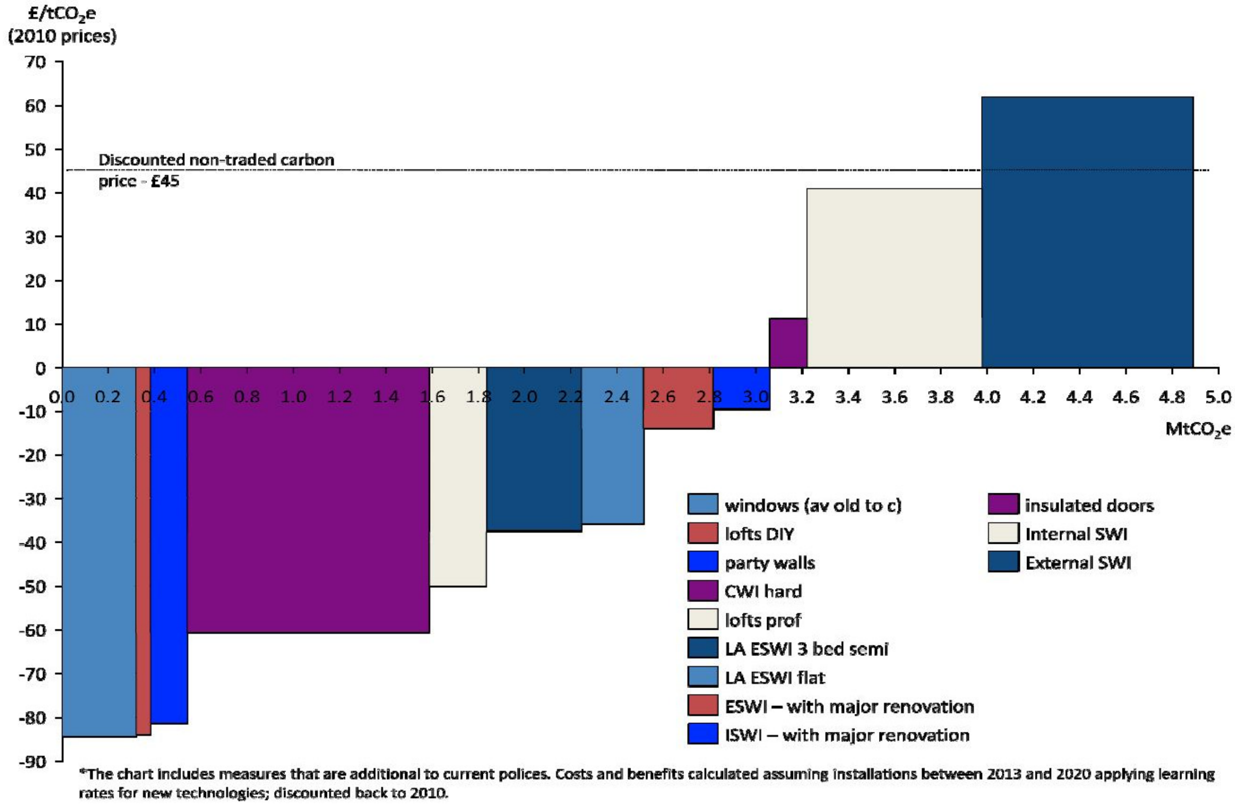
Notes: figures are rounded to two significant figures

Source: DECC (2011e), table A6.1

2.6.2.2 Marginal abatement cost curve

A total of 4.9 $MtCO_2$ of emissions savings in 2020 have been identified as feasible in the high scenario of the Green Deal (assuming 70 per cent of maximum feasible potential installations are carried out). This would reduce domestic sector emissions by approximately 4 per cent. Of the savings identified, 83 per cent are non-traded emissions and just over 60 per cent of these non-traded emissions have a marginal abatement cost less than zero. Given that the discounted non-traded carbon price is £45 (base year 2010, assumptions made by DECC, 2011e) the Green Deal offers cost-effective abatement in a sector with a high carbon price. The marginal abatement cost curve for Green Deal related savings of non-traded emissions is presented in Figure 12.

Figure 12. **Most domestic energy efficiency measures other than solid wall insulation have negative marginal abatement costs for non-traded emissions in 2020**



Source *DECC (2011e), figure 1*

2.6.3 Supply chain & finance

2.6.3.1 Supply chain

A strong supply chain, particularly of accredited installers, is likely to be a key to the success of the Green Deal, with a similar scheme in Australia failing due to concerns over the quality of installation and fraud (DECC, 2011e, box B1). DECC estimates that by 2015 the supply chain of the Green Deal could support up to 100,000 gross jobs (DECC, 2011d, p. 2). There is an ongoing consultation to design the regulatory framework in which Green Deal suppliers and installers will operate. In terms of the supply of materials it is reasonable to assume, especially for cavity wall and loft insulation, that supply chains are established and able to cope with demand from the Green Deal as the UK has had active energy efficiency programs since 2002. The solid wall insulation market is still relatively small and may expand rapidly.

2.6.3.2 Finance

A cornerstone of the Green Deal is that it can offer to finance fully the capital cost of measures. The structure of the financial product for the consumer is relatively clear, although policy is still in the proposal stage. A charge will be attached to the electricity supply point of a house that receives a Green Deal package and the charge will be collected as part of the electricity bill until all costs, including finance costs are recovered.

It may be possible to achieve a low cost of capital for Green Deal loans as the charge will be collected through the electricity bill and these bills have a low rate of default. It is assumed that the default rate on Green Deal charges will be equal to the current cost of default on domestic energy payments, which is estimated to be around 1.5 per cent of gross revenue. This translates to annual costs to the Green Deal of £20 million per year. Half of this amount assumed to be the write-off of bad debt and the other half is incurred through administration (DECC, 2011e, p. 25). The energy supply market is regulated to ensure that mechanisms such as Pre-Payment Meters (PPM) can be utilised to instigate the reclamation of debt while a customer is still receiving energy which helps to reduce default risk.

2.6.4 Current intervention

The Energy Company Obligation (ECO) is planned to become the overarching policy for domestic energy efficiency in 2012 (DECC, 2011e, p. 47). It will replace the Carbon Emissions Reduction Target (CERT), which is an obligation on large domestic energy suppliers to deliver measures that will provide overall lifetime CO_2 savings of 293 $MtCO_2$ by December 2012, the Community Energy Saving Program (CESP), which improves energy efficiency in low income communities and is funded by energy suppliers and electricity generators, and Warm Front, a grant program funded by Government for heating and insulation for low-income households. The Green Deal will provide a supportive financing framework for the first time. There are also building regulations that limit the carbon intensity of new buildings and may, by 2016, require all new homes to be ‘zero-carbon’ (DCLG, 2011).

2.7 Nuclear

Greater detail is provided for nuclear power because of the complexities of the supply chain, the range of scenarios of future size, and the importance of the sector in terms of capital investment and carbon dioxide savings.

2.7.1 Current and future size

There are currently 18 nuclear power reactors in operation in the UK, located in 10 plants with a total net capacity of approximately 11 GW (WNA 2011). In 2008, nuclear energy supplied approximately 18 per cent of all electricity generated, or 69 TWh (DECC 2010f). According to existing decommissioning schedules, all existing nuclear power plants are due to shut down by 2035 (DECC 2010).

According to DECC, the UK nuclear industry currently employs around 44,000 workers (DECC 2011h). Independent research cited by DECC and BIS (BIS and DECC 2009) estimates that the civil nuclear manufacturing supply chain in Britain had a total turnover of £3.6bn and employed 33,000 people in 2008. British Energy (since 2009 part of EDF Energy), the operator of 15 of the 18 active nuclear reactors, had a turnover of £2.8bn in fiscal year 2008 (British Energy 2008).

In the UK there are two operators involved in the existing fleet, and three consortia planning to build new plants. Decommissioning is handled by a non-departmental public body, which also owns the sites being operated by one of the two operators of the existing fleet, and the enrichment fuel cycle is handled by two companies, one of which (Westinghouse) is also a nuclear reactor vendor company. However, two new consortia are planning to enter the British market with the construction of nuclear plants (NIA 2011).

The two operators of the existing fleet are British Energy and Magnox North Limited. British Energy, owned by EDF (80 per cent) and Centrica (20 per cent), operates 8 plants comprising 15 reactors, producing approximately 96 per cent of all British nuclear electricity (British Energy 2008). British Energy also plans to install 6.4 GW of new capacity at Hinkley Point and Sizewell (DECC 2011i). Magnox North Limited, a state-owned body also responsible for the decommissioning of old nuclear power plants, operates two plants comprising three reactors, producing 4 per cent of British nuclear electricity (NDA 2010). The sites are owned by the NDA, a state-owned body also responsible for the decommissioning of old nuclear power plant, who contract out the delivery of site programmes through management and operation contracts with licensed operators,

Industry has announced plans to build 16GW of new nuclear plants in total. A joint venture between EDF and Centrica has announced plans to build 4 EPRs (6.4GW) at Hinkley Point and Sizewell. Horizon Nuclear Power, a joint venture between RWE and E.ON, and NuGeneration, a consortium of GDF SUEZ, Iberdrola, and Scottish and Southern Energy, also intend to enter the UK market. Horizon plans to construct ‘at least 6 GW of new nuclear capacity at Wylfa and Oldbury’, while NuGeneration ‘has set out plans to build up to 3.6 GW of new nuclear capacity at Sellafield’ (DECC 2011h).

The two reactor vendors bidding for new nuclear power plants in the UK are French state-owned AREVA, and Japanese-owned Westinghouse Electric Company (Toshiba of Japan holds 77% of Westinghouse). AREVA is selling the European Pressurised Water Reactor (EPR) design, one of which is being built in each of Finland and France, with two further reactors under construction in China (AREVA 2011a). Westinghouse is offering the AP1000, four reactors of which are currently being constructed in China (Westinghouse 2011). EDF has decided that their choice of reactor will be the EPR whereas the other two consortia have yet to make their technology selection.

The enrichment fuel cycle is handled by Westinghouse and URENCO. URENCO is headquartered in Marlow, Buckinghamshire, and supplies enriched uranium to 11 countries worldwide (URENCO 2011).

The UK has no domestic reactor design vendor. However, a number of UK companies across the nuclear supply chain may be able to profit from growing global demand for nuclear energy. UK Trade and Investment (UK Trade and Investment 2010) highlights opportunities in new build nuclear for Rolls-Royce (world leader in safety-critical instrumentation and control systems), AMEC (involved in design, construction, licensing and operation of nuclear plants), and Sheffield Forgemasters (world leader in the provision of high quality heavy forged and cast steel products). Further opportunities exist in the fuel cycle, where URENCO has a 27 per cent market share (URENCO 2011), as well as in plant maintenance (Doosan Babcock, pioneering non-destructive examination techniques to test piping and welding).

Table 5. **Trajectories for nuclear power capacity from DECC's 2050 Pathways**

Scenario	Description	2010	2020	2030	2040	2050
Level 1	Baseline scenario. It is assumed that government action stalls, and that the lack of clarity over planning prevents new capacity from being built	10.0	3.6	1.2	0	0
Level 2	Government and public actions proceed as envisaged in the 2008 white paper, and a build rate of 1.2 GW p.a. is achieved	10.0	6.8	16.4	27.2	39.2
Level 3	Quick and effective implementation of government facilitative actions and clear signals over a carbon price allow a build rate of 3 GW p.a. to be achieved by 2025	10.0	6.8	31.4	60.2	90.2
Level 4	A build rate of 3 GW p.a. between 2020 and 2025, ramping up to 5 GW p.a. after 2025. This would require active government intervention, and may be constrained by international competition for scarce nuclear expertise and resources	10	9.8	47.4	96.2	146.2

Note: Installed capacity figures in GW

Source: DECC 2010 and Vivid Economics

Unlike the construction of past nuclear power plants, the new nuclear programme is to be planned, financed, constructed and operated by the private sector. Government policy can be stated as follows: 'The UK Government is committed to enabling energy companies to build new nuclear power stations to contribute to the UK's energy security and climate change goals, *provided that they receive no public subsidy specific to* *the industry*' (DECC 2011k, italics Vivid Economics).Therefore all forecasts are subject to the commercial decision-making of the major utilities and reactor vendors involved.

The most detailed long-range forecast of nuclear power capacity is given in DECC's 2050 Pathways Analysis (DECC 2010b). The publication analyses four possible pathways, shown in Table 5 below, with the lowest (level 1) envisaging no nuclear new build and zero nuclear capacity by 2050, and the highest (level 4) projecting 5 GW of new capacity p.a. from 2025 onwards, leading to a total of 146 GW of nuclear capacity by 2050. For comparison, current nuclear capacity is around 11 GW.

The financial resource associated with these four pathways is given in Table 6 below. The total investment up to 2050 ranges from zero (for no new build) to £151 billion (for level 4, corresponding to 5 GW p.a. from 2025 onward), given in £2009. These figures use the central capital cost estimate from DECC's capital cost assumptions (DECC 2010).

Table 6. **Investment projections for nuclear power capacity based on DECC's 2050 Pathways**

			Capital cost by decade (£bn)			
	Total capacity added 2010-2050 (GW)	**Total capital costs (£bn)**	**2011-2020**	**2021-2030**	**2031-2040**	**2041-2050**
Level 1	0	0	0	0	0	0
Level 2	40.4	105	11.8	31.6	30.8	30.6
Level 3	93.2	241	15.0	72.5	76.9	76.5
Level 4	151	391	24.7	110	128	128

Note: Assumption about capital costs are taken from DECC 2010, central case

Source: DECC 2010a and Vivid Economics

2.7.2 Technologies

There are three different nuclear fission technologies currently in operation in the UK. The oldest technology still in use is the Generation I Magnox reactor. Two power plants of this type are currently operated by the state-owned Nuclear Decommissioning Authority (NDA), due to shut down by 2012 (DECC 2010). The mainstay of the UK nuclear fleet are seven Generation II advanced gas-cooled reactors (AGRs), operated by British Energy. With the exception of Hinkley and Hunterston, both operational since 1976, these entered commercial service in the late 1980s (WNA 2011) and are due to shut down between 2018 and 2023. This type of technology was used exclusively in Britain, with France and the US relying mostly on Generation II pressurised-water reactors (PWR). This is the third type of technology, which is currently in operation at the Sizewell-B plant, which was connected to the grid in 1995.

Two new Generation III+ nuclear technologies, the Westinghouse AP1000 and the AREVA UK EPR are currently undergoing Generic Design Assessment (GDA). Details of these two technologies are given in Table 7 below.

Table 7. **Current reactor designs**

Technology	Vendor	Description	Units under construction
AP1000	Westinghouse Electric Company	A generation III+ pressurised-water reactor (PWR), the AP1000 is an evolutionary design based on the AP600. Westinghouse claims 'an accelerated construction period of approximately 36 months', as well as approximately 1200 MW net capacity, 18 month fuel cycles and 60 year design life. Unlike previous PWR reactors, most of its safety systems are passive, i.e. they do not require electricity to function. This makes it more resilient to accidental power outages, such as those affecting the Fukushima reactors in 2011.	Four units under construction – Hayang 1 (China) – Hayang 2 (China) – Sanmen 1 (China) – Sanmen 2 (China)
UK EPR	AREVA	The EPR reactor is a generation III+ PWR, with a net capacity of 1,650 MW. It is based on French and German PWR technology and designed for 60 years' service life with a fuel cycle of up to 24 months. It utilises both active and passive safety features, with a total of four layers of redundancy.	Three units under construction – Olkiluoto 3 (Finland) – Flamanville (France) – Taishan (China)

Sources: Westinghouse 2011, AREVA 2011a and 2011b, IEA 2010 and Vivid Economics

The IEA describes nuclear power as a 'mature, commercialised technology' (IEA 2010). Current development efforts focus on producing 'standardised designs that can be built with a minimum of adaptations' (IEA 2010), in order to reduce costs as much as possible. While some innovation is likely to occur, 'established technologies are expected to still dominate nuclear capacity in 2050' (IEA 2010). The focus of innovation in nuclear energy is therefore placed on improving existing designs, enhancing production processes, and improving safety measures.

Process innovation is fostered by the Nuclear Advanced Manufacturing Research Centre (Nuclear AMRC), opened in November 2010. A collaboration between the University of Sheffield and the Dalton Nuclear Institute at the University of Manchester, the Nuclear AMRC is dedicated to enhancing capabilities and competitiveness in the manufacturing processes involved in current nuclear technology. It 'helps British manufacturing companies [to] compete for nuclear contracts worldwide' (Nuclear AMRC 2011). Funding has come from BIS (£15m) and the regional development agency (RDA) Yorkshire Forward (£7m). BIS and the Northwest Development Agency invested a further £8m to expand the nuclear research laboratory at the Dalton Nuclear Institute (Nuclear AMRC 2011). However, RDAs are in the process of closing their operations in accordance with government policies. This could potentially restrict the funding for similar projects.

The UK is not heavily involved in international efforts to develop the next generation of nuclear power. Long-term innovation is concentrated in the Generation IV International Forum (GIF), an R&D collaboration aiming to select and develop six nuclear energy systems for further development. The UK is a member of GIF, but it has not signed the 2010 Framework Agreement setting out the nuclear R&D agenda. Consequently the UK is not currently involved in any of the R&D projects conducted by GIF (GIF 2011).

Further innovation may be expected downstream from nuclear power plants, in the nuclear waste processing and management sector. Thus the 2008 white paper states that 'the NDA will review alternative waste management options and, if deemed necessary, will undertake further research into those options' (BERR 2008b)

2.7.3 **Supply chain**

According to DECC, 'the renaissance of nuclear power both in the UK and globally, coupled with the wider move to a low-carbon economy, provides major opportunities for the nuclear supply chain and skilled employment.' (DECC 2011j). The construction of 16 GW of new nuclear plants by 2025, which DECC says is in line with current industry plans, may create up to 30,000 new jobs in the supply chain of this sector (DECC 2011j). The elements of the nuclear supply chain include civil engineering, mechanical equipment, electrical equipment, heating, ventilation and air conditioning (HVAC), and the elements of the nuclear island, see NAMTEC 2009 for a full list.

A 2008 report by the Nuclear Industry Association (NIA 2008) highlights the opportunities for British industry contained in a nuclear new build programme. A large proportion of the supply chain associated with capital-intensive nuclear plants may go to UK companies: 'UK industry could supply 70 to 80 per cent of a new build programme' (NIA 2008). Nevertheless, 'it is still recognised that some of the key components, e.g. very large forgings, reactor pressure vessels, turbo/generators, currently cannot be produced by UK companies' (NIA 2008).

A variety of UK and international firms could be involved in the supply chain for the construction of new nuclear plants. According to the Manufacturing Advisory Service, these companies include (but are not limited to) Alstom, Siemens, Balfour Beatty, Costain, Parsons Brinkerhoff, Sir Robert McAlpine, AMEC, BAE Systems, Doosan Babcock Energy Systems, and Rolls Royce (MAS 2011a). There are also likely to be opportunities for a number of Small and Medium Enterprises to join the supply chain as lower tier suppliers to the main contractors or directly to the developers.

However, global competition for nuclear capabilities may lead to a shortage of nuclear personnel in the supply chain. Reactor physicists for example 'are both ageing and in short supply, here and around the world' (BERR 2008b). This is echoed by the Manufacturing Advisory Service, pointing out that 'there are significant issues associated with the availability of skilled workers across the whole supply chain, and [that] there will be strong competition from overseas new build programmes for nuclear skills' (MAS 2011b). The UK government is aware of this situation, and has set up a Nuclear Technology Education Consortium, receiving £1 million from the Engineering and Physical Sciences Research Council, and a further £1.6 million from industry (BERR 2008b). The Government is also working with the industry and the sector skills council (Cogent) to identify and address the key risks to availability of appropriately skilled and experienced labour.

2.7.4 **Benefits**

Nuclear power is a reliable, low-cost and low-carbon source of energy. A programme of nuclear new build can be part of the transition to a low-carbon economy, and increase energy security. According to the Committee on Climate Change, 'nuclear power currently appears to be the most cost-effective of the low-carbon technologies, and should form part of the mix' (Committee on Climate Change 2011).

According to the 2008 White Paper on nuclear energy, energy security consists of 'capacity, diversity, and a reliable supply chain' (BERR 2008b). Nuclear, as a proven technology, is capable of substantial capacity increases: DECC's two central cases (level 2 and level 3) in the Pathway 2050 analysis show a four- to nine-fold increase in nuclear capacity by 2050 as compared to 2010. Diversity requires a balanced portfolio of both peak load and base load capacity. As one of the few low-carbon baseload technologies, nuclear is crucial to delivering both diversity and decarbonisation: 'without new nuclear […] it seems likely that a significant proportion of the new capacity built to meet baseload demand for energy will come from additional fossil fuel power stations' (BERR 2008b). Finally, nuclear energy is supported by reliable fuel supply. Pressure points could potentially arise in the general supply chain though if demand for nuclear plants increases simultaneously in various countries and numbers of skilled personnel are not increased. One particular issue could arise with respect to large forgings where the number of companies operating in this domain is small. Nevertheless, according to BERR, 'nuclear fuel supply is a stable and mature industry'. This is echoed by the Committee on Climate Change, pointing out that nuclear power 'uses finite, though widely available, fuel' (Committee on Climate Change, 2011).

Besides being a reliable source of energy, nuclear is also widely perceived to be a low-cost option. The Committee on Climate Change, in its recent Renewable Energy Review, states that 'recent estimates indicate that its [nuclear] costs (including those for decommissioning and waste) are among the lowest of the low-carbon options' (Committee on Climate Change, 2011, p. 46). This is supported by reports from Mott MacDonald (Mott MacDonald 2010, commissioned by DECC), and Parsons Brinckerhoff. Mott MacDonald point out that 'by 2020, nuclear is projected to […] be the least cost zero carbon generation option among the main technologies' (Mott MacDonald 2010). Parsons Brinckerhoff give the levelised costs for nuclear as 5-9 pence per kWh, lower than onshore wind (7-11 pence), CCGT (5-11 pence), and biomass (6-12 pence) (PB 2010). A recent report by Parsons Brinckerhoff confirms this, giving the levelised costs of nuclear energy as 7.16 pence per kWh for first of a kind plant, falling to 6.72 pence per kWh for next of a kind plant (PB 2011). This compares favourably with CCGT (7.66-8.84 pence per kWh), CCGT with CCS (9.48-10.48 pence per kWh), and coal with CCS (9.41-10.83 pence per kWh).

Lastly, nuclear is also a low carbon source of electricity. The nuclear energy White Paper gives the lifecycle CO_2 emission intensity of nuclear power, 'including CO2 emitted during construction, operation and decommissioning of the power station, mining, and transport of fuel, and disposal of waste' (BERR 2008b) as 7 - 22 gCO_2/kWh. This compares very favourably with fossil baseload technologies, given as 385 gCO_2/kWh (gas) and 755 gCO_2/kWh (coal) in the White Paper. Nuclear energy is also estimated to be less carbon intensive than other low-carbon technologies: a report by the Parliamentary Office of Science and Technology reports that

> *'the majority of estimates [for nuclear new build power plants] fall below 26 gCO_2eq/kWh […] For current UK conditions, recent but unpublished research from the University of Manchester estimates a footprint of 6.4 gCO_2eq/kWh for a new build plant. Non-peer reviewed estimates produced by AEA Technology for existing UK plants are 5.5 gCO_2eq/kWh for Sizewell B and 7 gCO_2eq/kWh for Torness' (POST 2011).*

This compares to lifecycle emissions of 'below 50 gCO_2/kWh' for renewable technologies, according to (Committee on Climate Change, 2011).

2.7.5 **Current interventions**

Current UK government policy is to allow energy companies to construct new nuclear plants 'provided they are subject to the normal planning process for major projects and receive no public subsidy' (DECC 2011h). It is also making carbon price support available to new nuclear power plants.

DECC is taking four actions to facilitate commercial investment in new nuclear plants. These are:

- deciding in a timely fashion which sites are potentially suitable for new nuclear plants by 2025;
- completing the EU-required regulatory justification;
- firming up waste and decommissioning financing arrangements; and
- completing the Generic Design Assessment. (DECC 2011i)

Besides these actions, the UK government is proposing to take on full responsibility for the disposal of radioactive waste for a fixed price. The Price 'will be set at a level consistent with the Government's policy that operators of new nuclear power stations should meet their full share of waste management costs'. The aim is that 'new nuclear operators should be provided with certainty over the maximum Final Price they will be expected to pay the government for the provision of a waste disposal service' (DECC 2010c). The government therefore takes on the risk of cost overruns in the disposal of radioactive waste, but 'the Final Price should […] include a risk premium to compensate the taxpayer for taking on the risk of subsequent cost escalation'. The process of assuming liability and taking title 'will be subject to ensuring compliance with EU State Aid law' (DECC 2010c).

The Government also funds compensation payments above a certain cap for damage caused to third parties as a result of a nuclear accident. The Paris and Brussels Conventions require that liability for third party damage as a result of a nuclear accident is channelled to nuclear operators and for these liabilities to be fully insured. Under the current Conventions operator liability is capped, beyond which further claims are paid through public funds. Currently the operator is liable for the first £140m and above this up to c£300m claims are to be met through public funds. The Conventions were revised in 2004 and upgraded the regime substantially, including raising the total compensation amount from c£300m to €1500m. Of this total a minimum of €700m must be for the operator to pay with Government funding claims between €700m and €1,200m. The remaining €300m, i.e. up to €1,500m, is covered by contributions from parties to the Brussels Conventions. In the public consultation on this, published on 24 January 2011, Government proposed that it would transfer the €500m which it would have to pay to the operator making the operator liability level €1,200m. These amendments have yet to come into force.

2.8 Photovoltaics

2.8.1 **Current and future size**

Overall, PV is the main form of micro-generation in the UK by number of installations (Ofgem, 2011a) but makes a relatively small contribution to overall renewable electricity generation (DECC, 2010d). This is likely to be the pattern for the next several decades.

Approximately 114 MW of solar PV was installed in the UK as of the end of June 2011 (DECC, 2011m). This is 0.13 per cent of UK generating capacity in 2009 (DECC, 2010d). The majority of UK PV is micro-generation, which is generation from units with a capacity of less than 50 kW (HMG, 2004). Of PV supported by the Feed-in Tariff (FiT), 108.8 MW of installed capacity was from units of less than 10 kW as of the end of June 2011, of which 89.5 MW was from units of less than 4 kW. This compares to 4.7 MW of installed capacity from units of more than 10 kW (DECC, 2011m). Prior to the FiT, 13 MW of capacity had been supported by the Renewables Obligation (RO) (Ofgem, 2011b). The vast majority of PV supported by the RO has now transferred to the FiT (National Grid, 2011). Almost all capacity is grid-connected and distributed (DECC, 2011).

The rate of growth in capacity has been very high since the introduction of the FiT in April 2010, rising to current levels of 114 MW from just 27 MW at the end of 2009 (DECC, 2011m). However the UK is a small PV market in the global context, with just 0.2 per cent of cumulative installed capacity in 2010, and its growth is part of a wider, rapid, increase in PV deployment, with the UK contributing just 0.3 per cent of capacity installed in 2010 (BP, 2011), despite record growth.

A K-Matrix report for BIS in 2011 estimated that in 2009 – 2010 the UK PV industry generated revenue of £5.0 billion and employed over 39,000 people across 2,085 companies (K-Matrix, 2011). The data presented here falls within an inclusive definition including both supply chain activities (components and assemblies) and value chain activities (R&D, supply and training). Hence, the figures can differ quite significantly from those reported by other sources. For further details of the methodology please see Chapter two in the Low Carbon and Environmental Goods and Services (LCEGS) sector report 2009/10.

The K-Matrix employment estimate may be based on a wide definition and other estimates of employment are lower. The IEA report that solar PV provided 1,171 direct labour places in research, development, manufacturing and deployment in 2009, based on a submission from DECC (IEA, 2010a). Ernst & Young report that there were 2,400 Micro-generation Certification Scheme (MCS) accredited solar PV installers as of June 2011 (Ernst & Young, 2011). Greenpeace and the European Photovoltaic Industry Association estimate that 30 full-time equivalent (FTE) jobs are created for each MW of PV manufactured and installed (Greenpeace and EPIA, 2011), which would suggest that the UK solar PV industry employs approximately 3,400 FTEs.

Estimates of market value for UK PV are scarcer but a DECC submission to the IEA Photovoltaic Power Systems Programme (IEA, 2009) estimates that the ‘value of PV business’ was £243 million in 2008.

The future of solar PV in the UK is sensitive at present to the level of subsidy offered. The FiT is currently under review and it has been recommended that the FiT for PV over 50 kW be reduced (DECC, 2011n). Installation of large PV units had been more numerous and more profitable than expected. Any further construction of these large units would consume a large proportion of the remaining budget while not contributing to a core aim of the FiT of increasing household distributed micro-generation (DECC, 2011n).

Estimates of UK PV capacity by 2020 vary. DECC estimates that 2.7 GW of solar PV capacity will be installed in the National Renewable Energy Action Plan (DECC, 2011o). The National Grid estimates 1.5 GW may be installed, a downward revision made post-consultation from 3.5 GW (National Grid, 2011). Arup, in its report for DECC, estimate that 4.9 – 5.7 GW could be installed by 2020 (Arup, 2011).

The PV market can be usefully separated into 'upstream' and 'downstream'. The upstream involves the processing of raw materials, such as high-grade silicon, and the manufacture of PV modules and inverters. The downstream concerns the installation and finance of PV.

The UK has relatively small involvement in the PV upstream, a competitive global market (see section 2.8.3). UK upstream capacity includes two plants that manufacture PV units: Crystalox Limited and Sharp's Wrexham plant. These have a combined production capacity of 570 MW, which was over 90 per cent of UK production capacity in 2009 (IEA, 2009). Romag also manufactures in the UK.

Downstream activity is, by its nature, a largely domestic business. It is thought to account for around half of the value created in the solar PV market (EPIA, 2011). There is little public information on the market structure of this downstream market. Gathering information on this segment of the value chain has been recognised as difficult (Greenpeace & EPIA, 2011). The majority of PV units installed in the UK, by volume and electrical capacity, are small and have been retro-fitted to domestic houses. It appears that this installation is undertaken by a large number of small and medium sized enterprises (SME's) as evidenced by the 2,400 MCS accredited solar PV installers.

Public information on the finance arrangements in the downstream is also scarce. Some reports describe that while funds exist or were planned, the fast track review for the FiT has increased risk to such an extent that some funds have paused (UNEP SEFI, 2011). Private communication with DECC has confirmed that the finance mechanisms have changed in light of the review, with a shift from funds to bank finance for aggregator firms, which install units across many households and collect the FiT revenue.

Overall the solar PV market appears to be competitive in all segments of the value chain and has responded effectively to the fourfold increase in installed capacity in the UK in the last year. The market, both the global upstream and domestic downstream, seems driven by policy support and the only break on its growth seems to be policy risk.

The UK was responsible for 2 per cent of solar PV exports by value in 2009[3], which makes it the 10th largest global exporter. However the UK's high rank belies a highly concentrated export market, with the top nine

[3] UN COMTRADE with HS code 854140 (Vossenaar, 2009)

exporting countries responsible for 80 per cent of global exports, making the UK a small exporter relative to market leaders. The EU is the destination for nearly 95 per cent of UK exports. The UK has had positive net exports for solar PV since 2000 and the ratio of exports to imports has increased from 0.9 in 2000 to 2.3 in 2009.

2.8.2 Technologies

PV generates electricity from the electric field that is created when sunlight passes between layers of a semiconductor. PV cells are constructed either from wafers of crystalline silicon or from thin films manufactured from a variety of materials. Crystalline silicon technologies accounted for 85-90 per cent of global output in 2008, and thin film accounted for 10-15 per cent. Thin film is a more recent technology and tends to be cheaper but less efficient than crystalline silicon technology (IEA, 2010a). It may have advantages in some applications. PV may be connected to the grid, where it may be distributed, i.e. many small units across many sites, or centralised, or PV can stand-alone from the grid.

PV technology is rapidly advancing (NREL, 2009). Costs are estimated to have fallen by 60 per cent since mid-2008 and are expected to fall in the future (UNEP SEFI, 2011). Recent estimates suggest that PV levelised costs are 20.2 – 38 p/kWh for 2010 and 13.6 – 25 p/kWh by 2020 (Arup, 2011), while the latest public available private sector estimates are 23 – 27 p/kWh for 2011 and 12 – 15 p/kWh by 2020 (Ernst & Young, 2011). For comparison, the FiT available for installations registered between now and the end of March 2012 is between 30.7 – 43.3 p/kWh, depending on size (Ofgem, 2011a).

2.8.3 Supply chain

The solar PV supply chain is becoming increasingly multinational and vertically-integrated (IEA, 2010a), sophisticated (REN21, 2010) and competitive (UNEP SEFI, 2011). The UK, having no PV manufacturing firms in the global top 15 (REN21, 2010) and a low percentage of global exports, has little influence in manufacturing.

A 2009 Innovas report, in the same series as the 2010 report, estimated that 65 per cent of the market value in the UK was generated by firms whose main business was solar PV, with the remaining 35 per cent from firms in the ‘supply-chain’, which supply components or services to PV and other markets (Innovas, 2009). The same report also estimated that 37 per cent of the market value came from manufacturing, implying that UK PV economic activity is focused primarily on services such as installation.

The Committee on Climate Change claims that to ‘reach the level of solar PV deployment set out in DECC’s National Renewable Energy Action Plan (2.7 GW by 2020), the UK will need to develop a robust supply chain’. Analysis from Pöyry is described, but unreferenced, which suggests that ‘as long as there is sufficient labour to install new panels, deployment of 2.2 GW per year on average through the 2020s would be feasible’ (Committee on Climate Change, 2011).

The UK ranks 7th in patents for solar PV between 1980 – 2007 but is responsible for just 2.4 per cent of total patents in that period (Dechezlepêtre and Martin, 2010). Japan, USA, Germany and South Korea dominate solar PV innovation, with 84 per cent of total patents. In 2008 total public funding in the UK for solar PV research and development was £24.7 million (IEA, 2009), which was approximately 10 per cent of public funding for the 12 countries in the IEA Photovoltaic Power Systems Programme (IEA, 2010a). Research makes an important contribution to reductions in cost, as does economies of scale in manufacture and learning by doing in installation. The majority of global investment in solar research and development is privately funded (UNEP SEFI, 2011). The Committee on Climate Change are of the opinion that the 'significant effort globally to reduce solar PV costs' means that there is 'limited scope for the UK to influence the pace of cost reduction' (Committee on Climate Change, 2011).

2.8.4 Current intervention

As with many other renewable energy technologies, PV deployment currently only occurs due to government support (Element Energy, 2009a), presently through a Feed-in Tariff (FiT) or participation in the Renewables Obligation. Although most PV is installed under a FiT, large scale PV may become competitive with the support of two Renewable Obligation Certificates (ROCs), by 2013 – 14 (Ernst & Young, 2011). It is also considered unlikely that the UK will be a major player in the global market (Committee on Climate Change, 2010, 2011).

The FiT and Renewable Obligation are currently under review, including the role of Venture Capital Trusts and FiTs. Other programs, e.g. Low Carbon Buildings Programme and the Community Sustainable Energy program (capital grants) have been closed. Other support programs, the enterprise investment scheme and the venture capital trust scheme are under review.

2.9 Marine renewables

2.9.1 Current and future size

Marine energy sector includes:

- wave power, which is generated by harnessing the energy produced as the wind passes the sea surface;
- tidal stream (shallow and deep) power uses the energy of water flows;
- tidal range (barrage) power extracts the energy produced by the changes in the height of the tide (Arup, 2011).

Wave and tidal stream technologies are at an early development stage. According to the latest figures by DECC RESTATS, there is 4.6MW installed capacity of wave energy with another 24.5MW awaiting or under construction in the UK. There is 5.2MW of tidal stream capacity as well as a 0.1MW shallow tidal stream prototype. Tidal range is a significantly more mature technology. There is a 240MW facility (Rance) in France and a 254MW facility (Sihwa) is under construction in South Korea. UK has the world's second largest tidal range (nine metres), located in the Severn Estuary in Wales, which could produce as much as 17TWh/year. However, there are no plans to develop the site fully at the moment and there are no operational tidal range power stations in the UK.

There are a number of firms involved in the development of marine technologies in the UK, including Aquamarine Power Ltd, Pelamis Wave Power Ltd, OpenHydro Site Development Ltd, Atlantis Resources Corporation Pte Ltd, Neptune Renewable Energy Ltd and Marine Current Turbines Ltd. Although many of them are small enterprises, they are backed by significant institutional players from financial intermediation, energy utilities or engineering procurement and construction services (EPCS) sectors. The utilities involved include Scottish and Southern Energy, Scottish Power (Iberdrola), E.ON, Npower, Statkraft, EDF and International Power. The large technology suppliers include ABB, BAE Systems, Rolls Royce and Siemens. Together, this collection of firms possesses considerable financial strength and technical capability and thus the ability to develop marine resources strategically around the UK and to sell products across Europe and beyond.

The UK has a strong position in this nascent market of wave and tidal stream energy. DECC, in its Marine Energy Action Plan (now superseded by the UK Marine Energy Programme policy initiative), concludes that 'The UK is classed as the world leader in the development of marine renewable energy technologies' (DECC, 2010e, p. 14). It goes on to say that 'The UK has engineering and manufacturing expertise in the complex systems required for the power conversion systems, which are high value and can be exported globally.' Given this promising starting point, it can be argued that the UK's balance of trade will benefit significantly from marine energy, so long as it maintains its present competitive position.

There is a wide range in the estimates of how much marine energy may be deployed, reflecting the considerable uncertainties there are, and it is too early even to say which technology may end up being the most important. Below is a series of estimates of how much capacity will be installed by certain dates under three scenarios. **Error! Reference source not found.** shows wave power installations and Table 9 tidal stream installations. The estimates span a four-fold range in 2035 and a seven-fold range in 2050, and it is expected that there will be more installed capacity of wave than tidal stream power. Arup (2011) offers somewhat more conservative estimates in the longer term: wave power capacity of 186MW-279MW by 2020 and 500MW-2,520MW by 2030; tidal stream capacity of 241MW-406MW by 2020 and 500MW-2,160 MW by 2030. The high scenario of Carbon Trust (2011a) is on the other hand more ambitious and projects 1GW of wave and tidal stream combined by 2020 and 18.5GW of wave and 9GW of tidal stream by 2050. DECC estimates that 2GW of marine energy capacity could be deployed by 2020 and up to 30GW by 2050 (DECC Wave And Tidal Energy UK website, accessed 16 September).

In 2010 there were 33 companies in the UK wave and tidal sector, which employed only 500 people and had sales of £82m (K-Matrix, 2011). Exports in the sector totalled £8.12m and imports £5.08m. K-Matrix (2011) anticipates fast expansion with annual sales growing at an average 6.2 per cent in 2011-2016. RenewableUK expects the UK to hold 22 per cent of the global export market in 2020 and 14 per cent in 2035. RenewableUK sets out the future potential size and economic contribution of the marine sector to the UK economy. It anticipates turnover of £3.7 billion by 2020 creating gross value added of around £0.5 billion, with 10,000 people employed in the sector. These figures are intended to give a sense of the scale of activity rather than the net economic impact of the sector on the UK economy. According to the analysis, the UK retains an 80 per cent share of the supply chain for deployment in UK waters and around a fifth of global supply in 2020, a figure which gradually declines as overseas competitors gain strength. The headline findings are reproduced in Table 10. Carbon Trust (2011a) estimates that the sector can create 68,000 jobs and add £15bn to the UK GDP in the period between 2010 and 2050.

Table 8. **Cumulative capacity of wave power generation deployed in the UK, MW**

Scenario	2020	2035	2050
High	234	6,000	36,000
Base	156	4,000	24,000
Low	156	1,300	7,000

Note: commercial operation follows two years after deployment

Source: RenewableUK (2011a)

Table 9. **Cumulative capacity of shallow and deep tidal stream power deployed in the UK, MW**

Scenario	Demonstration 2015-18	2020	2035	2050
Shallow High	70	300	2,600	4,100
Shallow Base	40	200	1,100	2,000
Shallow Low	40	180	600	900
Deep High	20	30	1,700	3,200
Deep Base	10	20	1,100	1,400
Deep Low	10	20	500	700

Source: RenewableUK (2011a)

Table 10. **A scenario showing rapid growth of the UK marine energy industry, prepared by RenewableUK**

Variable	Unit	2020	2035	2050
Annual value to UK[1]	£bn	3.7	6.1	5.9
Number of individuals directly employed	Persons	10,000	19,500	19,000
UK share of domestic market	%	80	71	65
UK share of export market	%	22	14	9
Gross Value Added	£m	530	800	770

Note:[1]The source report refers to 'value to the UK' which is the total capital and operating cost (excluding financing costs and interest charges), spend on goods and services provided domestically.

Source: RenewableUK (2010c)

2.9.2 Technologies

Whereas wave and tidal stream technologies are still being developed and tested, tidal range technologies are mature. Wave and tidal stream are quite different from each other in mechanism, resource potential and most favoured locations. A wide range of both sorts of energy technology are being developed and tested. Wave power is particularly divergent in the designs being used, (DECC 2010e). The main technologies are listed in Table 11.

Table 11. **Existing avenues of technological innovation for Wave and Tidal Stream energy**

Wave	Tidal stream
Oscillating water column, a partially submerged structure involving two openings, one to the air and one to the sea, producing a column of air which moves like a piston	**Horizontal axis turbine** works in a similar way to wind turbine, accounting for the bi-directional water flow by changing orientation or by rotating blades in the opposite direction
Overtopping, creates a head of water which is fed to a traditional hydroelectric generator	**Vertical axis turbine** constantly turns in the same direction, whatever the direction of the flow of water
Point absorber, a float on the surface which absorbs energy from waves of all directions through its movements at/near the water surface. The power-take-off system may take a number of forms, depending on the configuration of displacers/reactors	**Oscillating hydrofoil** is attached to an oscillating arm. As the tidal current passes either side of the hydrofoil, it raises or lowers the arm. This drives fluid in a hydraulic system which drives a generator
Attenuator is a long device that floats parallel to the direction of wave travel. The device is hinged so that as the wave passes under, different sections of the device are moved relative to each other and energises a hydraulic power-take-off system	**Venturi effect** can be combined with other technologies, where the device is contained within a duct, concentrating the energy available
Oscillating wave surge converter extracts the energy caused by wave surges and the movement of water. The arm oscillates as a pendulum mounted on a pivoted joint in response to the movement of water in the waves	
Submerged pressure differential typically near shore and attached to the seabed. The motion of the waves causes the sea level to rise and fall above the device which can induce a pressure differential. The varying pressure pumps fluid to generate electricity	

Sources: RenewableUK (2011a) KTN (2011)

The tidal stream and wave technologies have reached a similar stage, where a small number of firms have full-scale prototypes under test at sea and others are preparing for testing. The next step, which is expected to roll out over the next five years, is to build and operate small arrays of the most promising and well-progressed technologies. Once proven at this medium scale, it becomes possible to entertain the construction of multiple large arrays. As the deployment scenarios in the tables above show, this large-scale deployment phase would not begin until just before or after 2020.

The size of the capital funding requirement to complete deployment of prototypes and to build the first arrays has been estimated by RenewableUK at £130m to £250m or £4.2m/MW – £8.4m/MW (RenewableUK, 2010c). A previous estimate by The Carbon Trust identified a higher figure of £432m from the deployment of the first device to the first array, Carbon Trust (2009). Ernst and Young (2010) estimated capital expenditure costs, which are shown in Table 12.

Table 12. **Capital expenditure of marine technologies, £m/MW**

Technology	Pre-demonstration	Demonstration (first 10MW project)	Commercial project
Wave	6-1-8.6	4.1-5.7	2.8-3.9
Tidal stream shallow	7.5-12.4	3.5-5.1	2.7-3.9
Tidal stream deep	7.3-9.9	3-4.1	2.8-4
Tidal range	Technology available	Technology available	2-3.2

Source: Ernst and Young (2010, pp. iii-iv), 2010 prices, base costs at medium resource)

The rate of innovation in the sector is high and Britain has an impressive track record of contribution. Between 1988 and 2007, Britain ranked fourth in the world in registering new patents relating to marine technology. This is the highest position that the UK reached in the international rankings for patents in any renewable technology segment, according to a list produced by the European Patent Office, EPO (2010). Dechezlepêtre and Martin (2010) report that the UK leads the world in marine energy patents in the period 2002 to 2007. It indicates that Britain may be better placed to build market share in the global market for marine renewables than in other forms of renewable energy.

It will be some time before it is clear what the unit costs of the technology will be at scale. Projected levelised costs of marine technologies are shown in Table 13. Levelised costs for all marine technologies, except the tidal range, are expected to fall considerably by 2030.

Table 13. **Levelised costs of marine technologies, £/MW**

Technology	2020	2025	2030
Wave	237	191	147
Tidal stream shallow	227	201	171
Tidal stream deep	190	191	140
Tidal range	275	275	275

Source: Arup (2011, pp. 83-84, medium scenario, pre-demonstration and initial deployment in 2010-2015)

Arup (2011, p. 67) points out that 'investment and R&D is still required to develop commercial technology and the infrastructure to aid deployment.' DECC notes that this is true even for the more mature of the technologies: 'traditional tidal range technologies (barrages in particular) use proven high-head turbine technologies, however, even some applications of lagoon and impoundment structures are yet to be finalised', (HM Government, 2010, p. 9).

2.9.3 **Supply chain**

The UK is well positioned to manufacture, construct offshore and install marine power due to its history of offshore hydrocarbon production and its offshore wind programme. The government has identified a need, in its Marine Energy Action Plan, for 'the sector [to] capitalise on opportunities for marine to learn from and build on synergies related to the skills and supply chain for offshore wind' (HM Government, 2010, p. 35). The current involvement of firms commercially active in offshore wind suggests that the market is building these links quite effectively. Examples include the utilities who own offshore wind projects, technology providers who manufacture wind turbines, and engineering contractors who carry out groundworks, infrastructure and installation.

A challenge in deploying these renewables is to provide access to the electricity grid in remote areas. Arup (2011, p. 71) argues that 'the largest areas of wave and tidal stream resources are located off the Western and Northern Isles of Scotland, where current grid capacity and availability is low. The transmission of large-scale variable generation, the ability of the grid to deal with this supply and the reinforcement of the downstream networks are the key constraints.'

2.9.4 **Benefits**

Marine renewables, if their performance and costs prove suitable, would help the UK to achieve its targets and goals in renewable energy supply and greenhouse gas emissions. They would lower the UK's dependence on fossil and nuclear fuels which have to be imported, and some, such as tidal power, could provide a more predictable source of energy than wind and solar.

The Carbon Trust has estimated that the total practical resource that could be exploited for electricity generation is in the order of 50TWh/yr for wave, and 18TWh/yr for tidal stream. Carbon Trust (2006) and a complementary report by Arup (2011) also presents scenarios of output by technology. The abatement of emissions can be estimated by combining these scenarios with electricity emissions factors. For 2020, the emissions saving opportunity is around 0.5 to 0.8 $MtCO_2$/yr, and for 2030, between 0.7 and 3.3 $MtCO_2$/yr. Table 14 sets out Ernst & Young's scenarios by technology in terms of tonnes of carbon dioxide abated in 2020 and in 2030. Alongside these greenhouse gas benefits, there would be additional air quality benefits from reduced oxides of nitrogen and possibly sulphur, and reduced impacts of fossil fuel extraction, storage and transport.

Table 14. **Abatement by technology and development scenario, based on Ernst & Young, million tCO_2 p.a.**

Technology	Year	Low	Medium	High
Wave	2020	0.2	0.2	0.3
Wave	2030	0.3	1.0	1.5
Tidal Stream	2020	0.3	0.3	0.5
Tidal Stream	2030	0.3	0.9	1.4
Tidal range	2020	-	-	-
Tidal Range	2030	0.1	0.3	0.4

Source: Arup (2011), Ernst & Young (2010), DECC(2011e), Vivid Economics

2.9.5 **Current interventions**

The focus of the current interventions has been on research and development, with public subsidy adding to the venture capital that is being invested to create designs, operate prototypes, reduce costs and improve performance. The technology will continue to depend upon subsidy for a long time, either in the form of capital grants or revenue support, with a likely shift from the former to the latter as capital deployed increases in scale. Eventually, if the technology is successful, it might compete for support with other mainstream renewable technologies such as wind power, and at that point the specific marine energy interventions described below would no longer be needed.

There are currently a large number of existing policy interventions encouraging the growth of the marine sector. The main revenue incentive is the Renewables Obligation. It is under review, and one of the issues that has been raised is whether to up-rate the number of Renewable Obligation Certificates received per MWh generated by marine technologies. RenewableUK has called for the certificate issue rate to be raised to 5 ROCs/MWh from its current level of 2 ROCs/MWh in England and Wales. In Scotland, wave power is entitled to 5 ROCs/MWh and tidal current 3 ROCs/MWh.

There is a pool of capital funding available from the New Entrants Reserve. This amounts to 300 million credits from the EU Emissions Trading Scheme, set aside for supporting eight carbon capture and storage and 34 renewable energy projects.

In addition, DECC is giving out ‘appropriate targeted support [for] generic technology development to ensure continued cost reductions necessary for the sector.’ Part of this support goes to the provision of capital testing facilities at National Renewable Energy Centre (NaREC) and the European Marine Energy Centre (EMEC), and WaveHub, a product testing facility. The Technology Strategy Board has set up a wave and tidal power knowledge transfer network.

There are a number of funding programmes. The Marine Renewables Proving Fund consists of £22.5 million from DECC’s budget which is disbursed by the Carbon Trust and supports six developers. The Marine Renewables Deployment Fund was set up in 2004 with £42 million of capital grants support available for array demonstration projects. The fund was allocated for the previous Government Spending review period which ended at the end of the last financial year. In that period no technology had advanced to a stage where it was able to take advantage of the fund. In July, DECC announced a new £20m fund which will run through the current spending review period and which will support wave and tidal array demonstration. From 2006, the Scottish Government’s Wave and Tidal Energy Support scheme allocated £13m in capital grants and revenue support to technologies demonstrated at the European Marine Energy Centre in Orkney. The scheme is now closed to new applications.

The Crown Estate, the owners of the sea bed out to the 12 nautical mile limit, has also recently engaged in a large scale leasing for projects with a potential of up to 1,600 MW of capacity in the Pentland Firth and Orkney waters. In order to facilitate the exploitation of the leased seabed the Crown Estate have invested £5.6m in an enabling actions fund to help accelerate and de-risk the projects. According to the Crown Estate; ‘the projects are believed to represent the largest planned development of wave and tidal energy worldwide’, Crown Estate (2011a).

2.10 Carbon capture and storage

2.10.1 Current and future size

CCS is not currently a commercially deployed technology so market size tends to be described by the level of government subsidy available and predictions of future requirements in order to meet climate change objectives. The UK Government has committed to support four demonstration projects. The first of these is most advanced and the Government is currently in negotiation with a consortium led by Scottish Power. £1 billion has been set aside to fund the capital cost of this project.

DECC sets out in its 2050 Pathways Analysis an assumption of four full scale demonstration plants in operation by 2018 (DECC 2010). A report by Pöyry (2009) translates this into a figure of 1.7GW of installed capacity. Pöyry shows two 450 MW plants following on, taking capacity to around 2.6GW by 2021.

From this point onwards, a further 7.4GW is installed by 2030 in the low scenario produced in the Pöyry report, and 17.4GW in the high scenario to give an installed capacity of between 10 and 20GW. This later scenario would require the construction of two 1GW plants per year between 2021 and 2023, and two 1.5 GW plants per year between 2024 and 2027, of which Pöyry assesses as 'only just plausible, especially when the 'dash for gas' delivered 2.8GW per year of CCGT capacity at its peak'. The DECC Pathways Analysis also contains a scenario in which no further CCS plants are built after the four demonstration projects.

It is this high level of variability of estimates of future deployment that led the Committee on Climate Change to state that 'CCS technology is promising but highly uncertain, and will remain so until this technology is demonstrated at scale later in the decade', (Committee on Climate Change, 2010a)

The cumulative installed capacity of these plants is illustrated in Table 15. A range of capital cost estimates drawn from DECC's 2050 Pathways Analysis is shown in Table 16 to illustrate the variability in possible costs, which range between £1,400/kW to £2,500/kW.

Table 15. **Cumulative capacity of CCS installed according to scenarios presented by Pöyry**

Scenario	2021	2025	2030
Medium	2.6	4.5	10
High	2.6	6.5	20
Demonstrations only	1.7	1.7	1.7

Source: Pöyry (2009), DECC (2010)

Table 16. **Capital cost assumption from DECC 2050 pathways analysis in £/kW, for CCS applied to coal with ASC and flue-gas desulphurisation**

Scenario	2020	2030	2040
Low	1,500	1,450	1,400
Central	2,050	1,950	1,900
High	2,500	2,500	2,500

Note: Parsons Brinckerhoff (2011)reports higher unit costs than the estimates in this table but only reports first of a kind and next of a kind costs and does not project unit costs forward to specific future dates.

Source: DECC (2010)

Parsons Brinckerhoff (2011) estimates levelised costs for projects starting in 2017 with a 10 per cent 'discount rate'. Its estimate for combined cycle gas turbine fitted with CCS is £95/MWh, and that for coal with CCS is £94/MWh. In comparison, nuclear power is £67/MWh, and CCGT is £88/MWh (including carbon costs).

2.10.2 **Technologies**

CCS consists of three distinct processes which first extract carbon dioxide from a fuel or exhaust gas, then transport it to where it can be stored, and finally pump it into a secure geological storage facility. Each of these processes is already used in industrial processes for a variety of reasons unrelated to carbon abatement strategies. CCS is potentially suitable for any large industrial combustion plants, such as cement or steel works, as well as on combustion power stations. In power stations they are expected to be applied first to coal-fired power stations, then to gas-fired stations.

Of the three processes in CCS the most capital intensive is the capture of CO_2. It may also offer the greatest opportunity for cost reduction through innovation. There are three main capture methods, described in Table 17.

Table 17. **Current approaches to the capture of CO_2**

Technology	Description	Development
Post combustion	CO_2 is extracted from the exhaust gas of a conventional combustion plant. Extraction is usually by means of an amine solvent	Past use supplying CO_2 as a chemical feedstock for industry, for purifying natural gas from the well or for use in carbonated drinks. Pre-commercial pilot projects have been built at Niederaussem in Germany and at Scottish Power's Longannet power station.
Oxyfuel combustion	Fuel is burnt in an oxygen rich environment to give a higher concentration of CO_2, making it easier to extract	The newest capture technology. The technology has moved quickly from small scale 1MW test rigs to a 40MW test rig built in 2009 by Doosan Babcock
Pre combustion	The molecules of the fuel are broken up under high pressures and temperatures to produce a new fuel gas which can be used in a combined cycle gas plant	Technology for the conversion of solid and liquid fuels into a fuel gas, called syngas, for combustion has existed for a long time.

Source: Pöyry (2009)

The scope for innovation in capture is likely to be high due to its novelty in application to large combustion plants. In contrast, the transport of CO_2 is well understood. In 2009, there were 2,400km of pipelines transporting CO_2 to more than 70 EOR projects across the world, (Pöyry 2009).

Like transport, CO_2 has been pumped underground ever since the 1970s in order to enhance hydrocarbon production. Furthermore, CO_2 co-produced with natural gas has stored underground at Sleipner in the North Sea injecting 1 Mt CO_2 pa since 1996. Although this is a much smaller scale than a 1GW power station, it has not leaked and proves the technique in principle. Other small-scale projects have added to the tally of experience.

2.10.3 **Supply chain**

There is a range of firms and academic institutions (Technopolis, 2009) involved in the development of Carbon Capture and Storage technologies. They include major firms with substantial technical and financial resources covering commercial arrangements, finance, exploration, transportation, power generation, and heavy plant manufacture businesses. Together, they have the capability to develop strategic assets not just in the UK and Europe, but across the world.

Some participate in the Carbon Capture and Storage association. Those members with registered interests in storage include CCS TLM, Petrofac (CO_2 DeepStore Ltd), Rhead Group, Schlumberger, and Senergy. Members with particular interests in gas separation include Air Liquide, Air Products and BOC. Other notable members include Rio Tinto, Sasol, Zurich (banking group), Arup, PWC, Norton Rose, Linklaters, Siemens, Tata Steel, Mitsubishi Heavy Industries, BG Group, BP, Chevron, ConocoPhilips, Maersk Tankers, Shell, Statoil, Total, E.ON, Scottish Power, Drax and SSE (CCSA, 2011). University of Edinburgh, Imperial College, and University of Nottingham are among the UK academic institutions, which host dedicated CCS research centres.

The UK is in a strong position in relation to the transport and storage of CO_2 due to its extensive experience in the laying of undersea pipelines and building offshore installations. It is also in a strong position to supply parts of the capture units. The evidence for this is that between 1988 and 2007 it registered the fifth highest number of patents in the world for carbon capture and carbon storage products (EPO 2010). Although a number of leading academic institutions in the UK are engaging in CCS research, the UK is no longer a top three recipient of research funds under the EU Framework Programmes (Technopolis, 2009). On the other hand, many of the plant manufacturers which are based outside the UK are likely to have a strong position in the UK and global market.

The UK may also trade its storage capacity internationally. The nearest demand centre would be the industrial area in the Netherlands and Germany, and it has southern North Sea hydrocarbon fields which are closer than the UK continental shelf.

2.10.4 Benefits

CCS applied to power generation would help the UK to achieve its targets and obligations for greenhouse gas reductions. The DECC consultation document ‘A framework for the development of clean coal’ set out the case for CCS on coal plants in the following terms; ‘The Government believes that new coal power stations in the UK will be important to maintain the diversity and security of our energy supplies. Yet decarbonisation of the power sector will be key to delivering our 2050 climate change targets. So, any credible strategy for tackling climate change must actively set out to address emissions from coal power stations’... ‘CCS technologies offer the potential to substantially reduce emissions from coal power stations and would enable coal to continue contributing to energy security in a low carbon future (DECC 2009).

Table 18. **Annual carbon abatement under different development scenarios in $MtCO_2$**

Scenario	2021	2025	2030
Low	8	14	21.7
High	8	20.2	43.3

Source: Pöyry (2009), DECC (2010), DECC (2011p)

An estimate of the amount of abatement using CCS is 5-8 $MtCO_2$ per annum by 2021, rising to up to 43 $MtCO_2$ per annum in 2030. This reflects the capacity scenarios presented earlier at an illustrative load factor of 90% (the actual figure might be lower) and marginal emissions estimates from DECC for the years 2021, 2025, and 2030 (DECC 2011p). A report by Element Energy on behalf of the Committee on Climate Change estimated that CCS in industry has the potential to abate up to 38$MtCO_2$ per year by 2030 (Committee on Climate Change, 2010a). The report estimates that the cost may be between £30 and

£150/tCO_2. AEA (2010, pp.12-13) found that cost-effective emission abatement potential in high-emitting sectors, such as cement and steel, is roughly halved if CCS opportunities are not available.

2.10.5 **Current interventions**

There are a number of policies and organisations that are in place which support the research, development and demonstration of CCS plants in the UK. In addition the government has set up the Office of Carbon Capture and Storage to 'guide the UK's efforts on CCS both domestically and internationally' (DECC 2011q).

The Government has already committed £1 billion to the funding of the first of four demonstration projects and in the 2011 Budget, reaffirmed its commitment to providing public funding for CCS demonstration plants, although the previously planned CCS Levy will no longer be used to fund it (HM Treasury 2011). There is also European support available for specific projects from the New Entrant Reserve. In May 2011 the government submitted 12 applications from UK projects, seven of which were for CCS projects (DECC 2011r).

Any new coal fired power station must demonstrate CCS on at least 300MW of its capacity. It must also be carbon capture ready (CCR). The CCR requirement is in response to an EU Directive on the Geological Storage of Carbon Dioxide which requires that prior to a combustion plant of over 300MWe receiving planning consent it must carry out a number of assessments on the technical and economic feasibility of capturing, transporting and storing its emissions of CO_2. According to the guidance note issued by DECC in response, consent applicants will be required to demonstrate that: i) sufficient space is available on or near the site to accommodate carbon capture equipment in the future; ii) retrofitting their chosen carbon capture technology is technically feasible, iii) there is a suitable area of deep geological storage offshore for storage of captured CO_2 from the proposed power station; iv) it is technically feasible to transport the captured CO_2 to the proposed storage area; and v) the likelihood that it will be economically feasible within the power station's lifetime, to link it to a full CCS chain, covering retrofitting of capture equipment, transport and storage (DECC 2009).

Other than these specific interventions the CCS will also receive implicit support from the carbon price floor and EU Emissions Trading Scheme. This will give an increasing incentive to build CCS plants, since the penalty for emitting carbon will start at around £16 per tonne of CO_2 in 2013, and will follow a linear path to £30/tCO_2 in 2020, rising to £70/tCO_2 in 2030 (HM Treasury 2011, 2009 prices). The figures will be higher in nominal terms (prices of the day). CCS deployment will also be funded through the EMR in due course.

An important aspect is the network infrastructure. There are substantial economies of scale and coordination benefits inherent in the construction of a brand new pipeline network, both of which may trigger policy intervention in the future. It will be some years from now before it becomes clear whether a national, regional or a collection of bilateral links, is to be built.

2.11 Onshore wind

2.11.1 Current and future size

The large-scale onshore wind industry in England and Wales is reported to have an annual turnover of approximately £120 million (RenewableUK 2010a). Using the number of full time jobs associated with this figure (655), and assuming that the turnover per job is similar in Wales and the rest of Britain, this implies a turnover for the wind industry in the entire UK of approximately £1.1 billion per year[4]. In addition, the market for small wind systems in the UK has reached nearly £30 million, growing by 70 per cent year on year. It is forecast to more than double in 2011, reaching more than £75 million. Of this market, approximately 60 per cent is supplied by UK manufacturing, which earns another £6 million in exporting revenue from the sale of small turbines. The total turnover of onshore wind in the UK may therefore exceed £1.1 billion per year.

In 2008, wind energy produced 7,097 GWh of electricity, constituting 1.8 per cent of the UK's total electricity production (IEA 2011b). By 2010 wind energy electricity production had increased to 10,021 GWh, or 2.6 per cent of the UK's total electricity production (IEA 2011). Of this wind energy total, onshore wind has produced 7,564 GWh (RenewableUK 2011a).

According to the UK Wind Energy Database, a total of 292 onshore wind farms with a capacity of 4,213 MW are currently operational in the UK, with a further 1.3 GW of capacity, spread across 27 projects, under construction. 3.8 GW in 218 projects are approved but not yet built, while 7 GW across 280 projects are in the planning phase (RenewableUK 2011b). This information is shown in Table 19 below.

Table 19. **The status of onshore wind as of September 2011**

Project status	Number of projects	Capacity (MW)
Operational	350	4,252
Awaiting construction	47	1,943
Approved but not built	237	3,166
In planning process	273	6,574

Source: DECC RESTATS

Approximately 6,800 full time employees are currently working in the onshore wind industry in the UK (RenewableUK 2011), around 6,000 of which are employed in the large-scale onshore sector (turbines over 100 kW) and 800 in the small-scale onshore sector (turbines with less than 100 kW capacity). This is a 48

[4] The total number of full time jobs in large-scale onshore wind in the UK is around 6000 (renewable UK 2011 - working for a greener Britain). The Welsh figures imply a turnover of around £183,000 per job, giving a total of £1.1 billion for the UK, if turnover per job is the same across the UK as it is in Wales.

per cent increase from 2007 levels, when employment was around 4,000 full time employees (RenewableUK 2011). These numbers may rise further, as detailed in the forecast section below.

The Committee on Climate Change estimates that wind energy, comprising both on- and off-shore wind, may turn into one of the major sources of electricity in the UK, possibly providing 30 per cent of electricity generation by 2020 (Committee on Climate Change, 2008). DECC's estimate for onshore wind is that 'onshore wind could deliver around 15% of the total' target for renewable energy (DECC 2011u).

Employment numbers for the onshore wind industry may rise in the future: in a study commissioned by RenewableUK, employment for the future deployment of onshore wind is modelled (RenewableUK 2011c). At a deployment of 16 GW (below DECC's level 2 forecast, shown in table 2 below, and at the lower end of the feasible maximum capacity range), direct employment may reach 11,900 full time equivalents (FTE), with another 7,100 FTEs in indirect jobs. This would constitute a near doubling in FTEs compared to employment today.

The feasible maximum capacity for onshore wind energy is estimated to lie between 16 (DECC 2010) and 31 GW. Another source puts the figure at 28 GW (Enviros 2005). The Committee on Climate Change estimates the 'practical resource' for onshore wind in the UK at 74 TWh/year. Using a load factor of 27 per cent, given by DECC as the average load factor for 2009 (DECC undated), this would equate to a practical resource of 31 GW of capacity[5]. For comparison, the total capacity of all nuclear plants currently operating in the UK is 11 GW (WNA 2011).

DECC uses four levels of onshore wind deployment in its 2050 Pathways (DECC 2010), ranging in ambition from a phasing out of onshore wind (level 1), to a very high deployment scenario reaching 50 GW of capacity in 2040 (level 4). These are detailed in Table 20 below. In the 2011 UK Renewable Energy Roadmap, the central case prediction for 2020 is a deployment of around 13 GW (DECC 2011c), just below level 2.

[5] 1 GW of capacity operating at a load factor of 100 per cent would produce 8.760 TWh p.a., as there are 8760 hours in a year. At a load factor of 27 per cent, it would take approximately 31 GW of capacity to produce 74 TWh of electricity p.a.

Table 20. **Trajectories for onshore wind installed capacity from DECC's 2050 pathways**

Scenario	Description	Capacity installed (top row) and build rate (bottom row, italics), GW				
		2010	**2020**	**2030**	**2040**	**2050**
Level 1	Lower bound scenario. The average build rate of the last four years, 0.55 GW/year, is maintained up to 2025, but sites are not replanted when turbines are decommissioned, leading to a build rate of zero after 2025.	3.9	9.4	8.3	2.8	0.0
		0.55	*0.55*	*0.0*	*0.0*	*0.0*
Level 2	This level assumes a build rate of 1 GW/year, which is maintained as old sites are replanted when turbines are decommissioned. This, together with projects approved or operating, leads to a total capacity of 20 GW, calculated to deliver 53 TWh of electricity per year at a load factor of 30%.	4.4	14.4	20.0	20.0	20.0
		1.0	*1.0*	*1.0*	*1.0*	*1.0*
Level 3	Requests for planning permission are submitted at the rate of 2.5 GW/year until 2020, with a success rate of 70%. A build rate of 1.6 GW/year is achieved, leading to a total capacity of 32 GW, calculated to deliver 84 TWh p.a. (also assuming a load factor of 30%). This is near the top end of feasible maximum wind capacity estimates in the UK.	4.4	19.6	31.2	32.0	32.0
		1.44	*1.6*	*1.6*	*1.6*	*1.6*
Level 4	A build rate of 2.5 GW/year is achieved by 2020. Assuming an approval rate of 70%, this build rate would require approximately 3.5 GW of submissions for planning approval. A total of 70 GW would need to be submitted, compared to a total of 18 GW that has been submitted up to 2009.	4.4	22.5	43.1	50.0	50.0
		1.52	*2.5*	*2.5*	*2.5*	*2.5*

Note: Recent build rates in Germany (2.1 GW/year) and Spain (1.6 GW/year) indicate that levels 3 and 4 are challenging, but not infeasible.

Source: DECC 2010

According to RenewableUK, the installation costs of onshore wind are between £1,250 and £1,573/kW (RenewableUK 2010b), while Ofgem gives a figure of £1,200/kW (Ofgem 2009). DECC forecasts capital costs (in £2009) to be between £997 and 1,500/kW in 2020, with a central cost estimate of £1,258/kW. This is set to fall slightly to a range of £934 to 1,500/kW in 2040, with a central cost estimate of £1,223/kW (DECC 2010). Using DECCs mid-range estimates, investment in onshore wind energy between 2011 and 2050 may be between £10.4 and 117 billion in undiscounted £2009. A detailed overview of the investment requirements associated with each level of deployment is shown in Table 21 below.

Table 21. **Depending on the level of ambition, total investment in onshore wind may top £100 billion**

	Total capacity added 2011-2050 (GW)	Total capital costs (£bn)	Capital cost by decade (£bn)			
			2011-2020	2021-2030	2031-2040	2041-2050
Level 1	8.3	10.4	6.9	3.5	0	0
Level 2	40.0	49.6	12.6	12.5	12.3	12.2
Level 3	63.4	78.6	19.3	20.0	19.7	19.6
Level 4	94.1	116.6	24.0	31.2	30.7	30.6

Note: Decadal costs may not add up to total due to rounding. Underlying capital costs per kW are linearly extrapolated between DECC's 2020, 2030 and 2040 number

Source: DECC 2010 and Vivid Economics

2.11.2 Technologies

Onshore wind is an established and mature renewable energy technology. According to DECC, 'onshore wind is one of the most established, large scale sources of renewable energy in the UK' (DECC 2010).

Onshore wind turbines usually consist of a three-blade rotor mounted on top of a tall tower, with a gearbox and generator mounted in the nacelle at the top of the tower. The tower can take a height between 25 to 75 meters, with rotor diameters ranging up to 80 meters (RenewableUK 2011e), and a rotation frequency of 10 to 30 revolutions per minute. Commercial large scale turbines range in capacity between a few hundred kilowatts and 2 megawatts. The average capacity of new turbines currently being installed is 2.5 MW (RenewableUK 2011).

In its 2011 update, the Committee on Climate Change reports that 'given maturity, there is limited scope for innovation of ... technology, and therefore only limited further cost reductions are envisaged' (Committee on Climate Change, 2011). However, while innovation in technology is envisaged to be limited, there is innovation in project management and community engagement. The 2011 RenewableUK Annual Report highlights the Community Benefits Protocol, which aims to engage local communities by sharing the financial success of onshore wind in their vicinity, thereby increasing local planning permission approval rates (RenewableUK 2011f).

A UNEP report investigates the international distribution of innovation and patenting, showing that the UK is present in wind energy innovation, though not a leader in this field. Out of a world total of 2,323 patents in wind energy (including both on- and offshore wind) between 1988 and 2007, the UK filed 87, or 3.8 per cent. The innovation leaders according to this metric are Germany (649 patents, or 28 per cent), the US (320, or 14 per cent), and Japan (196, or 8 per cent), with the UK in 6th place behind Spain (UNEP 2010).

2.11.3 **Supply chain**

The UK's onshore wind energy supply chain is currently capable of a build-rate of around 0.85 GW/year of new onshore wind capacity in the UK (Pöyry 2009). If deployment is ramped up in line with level 2, 3, or 4 of the DECC 2050 pathways, annual build would exceed this capacity: level 2 envisages an annual build of 1 GW, level 3 1.6 GW, and level 4 2.5 GW from 2020 onwards. This may create increased investment and jobs in the UK, or result in increased imports from abroad, or both. Thus the manufacturing part of the supply chain is likely to continue to remain outside the UK.

In small-scale wind, defined as wind turbines with a capacity of less than 100 kW, the UK is in a stronger position: RenewableUK states that 'the UK has a globally competitive manufacturing industry for small-scale wind systems', and that in 2009 'more small wind systems were exported by UK manufacturers than were installed in the UK' (RenewableUK 2011). 'Five of the world's top ten small wind companies are based in Britain' (UKTI 2010b), and 56 per cent of UK small wind production is exported (RenewableUK 2011d). However, total trade volume is comparatively small at export revenues of £6.3 million in 2010, corresponding to 0.03% per cent of UK machinery and equipment manufacturing exports (ONS 2011). Though the industry is growing over the medium term, there has been a short term decline in exports: compared to 2007, 2010 exports have increased by 132 per cent; however, compared to 2009, exports have declined by 15 per cent (BWEA 2009 and RenewableUK 2011d).

Two major supply chain companies are Maybey Bridge and Welcon, both producing wind turbine towers. Maybey Bridge, a British company, built a £38 million factory for the production of onshore wind turbines, with a capacity of 300 towers per year, potentially employing up to 240 people (RenewableUK 2010). Welcon, a subsidiary of Danish Skycon group, is investing £35 million in expanding its wind turbine manufacturing plant in Campbelltown, Scotland. The plant is expected to employ 300 people by 2012 (RenewableUK 2010).

2.11.4 **Benefits**

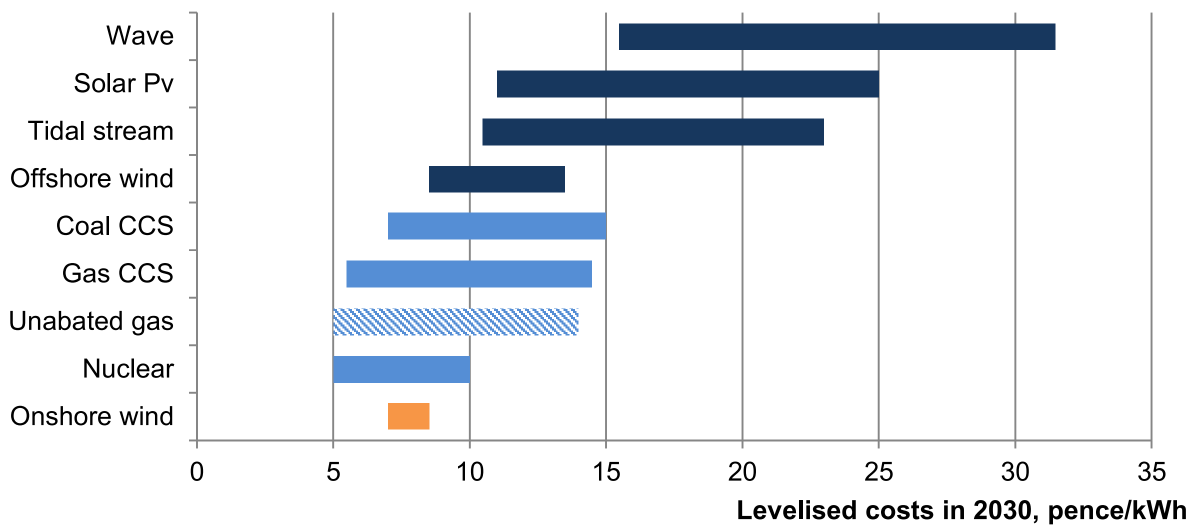
Wind energy is among the most affordable low-carbon energy technologies that are both proven and can be deployed at scale. With life-cycle emissions of 8 to 20 gCO_2/kWh for large scale onshore, and 20 to 46 gCO_2/kWh for small scale, onshore is a very low carbon technology, comparable to nuclear or river hydro, and considerably less emission intensive than solar PV (20 to over 150 gCO_2/kWh) (POST 2011).

According to the Committee on Climate Change 'Onshore wind has a comparable cost to nuclear' and is 'likely to be cost-competitive against new gas CCGT facing a carbon price of £30/tCO_2 in 2020' (Committee on Climate Change, 2011). By 2030 onshore wind is estimated to cost between 7 and 8.5 pence per kWh in levelised costs. This compares favourably with other renewable technologies, such as offshore wind (8.5-13.5 p/kWh), tidal stream (10.5-23.0), solar PV (11.0-25.0 p/kWh) and wave (15.5-31.5 p/kWh). Furthermore, it is competitive with CCS-fitted fossil fuel plants, such as gas CCS (5.5-14.5 p/kWh) or coal

CCS (7.0-15.0 p/kWh) (Committee on Climate Change, 2011). This information is summarised in Figure 13 below.

This analysis is confirmed by DECC's UK renewable energy roadmap, which gives levelised costs for onshore wind in 2020 as 71-122 £/MWh (equivalent to 7.5-12.7 p/kWh), significantly lower than offshore wind (102-176 £/MWh), solar PV (136-250£/MWh), and competitive with gas CCGT (87-91 £/MWh) (DECC 2011c).

Figure 13. **Onshore wind is projected to be the most affordable renewable energy technology in 2030**



Note: In the calculation of these numbers, the Committee on Climate Change assumed a carbon price of £70/tCO_2 in 2030, taken from DECC's carbon price projections

Source Committee on Climate Change (2011) and Vivid Economics

A further benefit of onshore wind energy is that it allows for distributed generation. By reducing the distance between electricity generation and consumption, it can reduce the burden on transmission networks, lowering future investment costs.

2.11.5 Current interventions

The UK government 'is committed to the development of wind energy in the UK' (DECC 2011u). The main government policy instrument is the Renewables Obligations (RO). This requires each electricity supplier to source a given percentage of electricity from certified renewable sources. In 2011-2012, the requirement is 12 RO certificates (ROCs) per 100 MWh supplied in Great Britain, and 5.5 ROCs per 100 MWh in Northern Ireland (Ofgem 2011b). Failure to supply the specified number of ROCs renders an electricity supplier liable for a fine (buyout) of £36.99/MWh, rising annually with inflation (Ofgem 2010). Each MWh of electricity produced from onshore wind energy generates one ROC. For comparison, each MWh produced from offshore wind generates two ROCs, whereas one MWh from landfill gas only generates 0.25 ROCs (DECC 2011v). The fines revenue is recycled to ROC holders.

Starting in 2014, the RO will be phased out and replaced with a feed-in tariff, using a contract for difference model (FIT CfD). A FIT CfD is 'a long-term contract set at a fixed level under which variable payments are made to top-up the level of payment to the generator to the agreed tariff' (DECC 2011b). As a two-way CfD, the generator has to make payments to the consumer/the Treasury whenever the market electricity price rises above the agreed price level. By 2017, the RO scheme will be ended, and the transition to FIT CfD's will be completed. (DECC 2011w). The level of FIT CfD's may be determined by a competitive auction, via tenders, or by government fiat, but no final decision has been made on this issue.

Furthermore the government has established an Office for Renewable Energy Deployment (ORED), charged with 'ensuring that we meet our targets for renewable energy' (DECC 2011x). Part of its remit is to 'unblock barriers to deliver' (DECC 2011x), including issues such as the planning system, the supply chain, and connection to the grid. Actions undertaken include a project to encourage wind turbine manufacturers to locate in the UK and a Community Engagement Protocol.

Actions mentioned in the recently published UK Renewable Energy Roadmap include publishing new RO banding levels for onshore wind by the end of 2011, implementing a smooth transition from the RO to the new electricity market support mechanism, and reforming the planning system, for example by allowing local communities to retain the additional business rates generated from renewable energy projects.

2.12 Smart meters

2.12.1 Current and future size

Smart meters are new types of electronic gas and electricity meters, which collect information about energy use at regular intervals, display energy use and price information to consumers and communicate the information to energy suppliers. The government aims by 2020 for all homes and smaller non-domestic premises in the UK to be equipped with smart meters measuring their gas, electricity and water consumption. This involves the replacement of over 50 million meters, and energy suppliers are responsible for their procurement and installation in homes and small business premises. The bulk supply of smart meters is expected to be ready by the fourth quarter of 2012 and the mass rollout of smart meters is expected to commence in the second quarter of 2014. Further detail is listed in Table 22.

Table 22. **Scenarios for the roll-out of smart meters in the UK**

	Low	Central	High
End 2016	49%	57%	70%
End 2017	66%	77%	90%
End 2018	83%	91%	97%
End 2019	94%	97%	100%
End 2020	98%	100%	100%

Source: DECC/Ofgem (2011, Appendix 1, Table 1)

The government is keen to accelerate the rollout process from the previously published target completion date of 2020. It now intends to require energy suppliers to take all reasonable measures to complete the rollout of smart meters in 2019 or face enforcement action from Ofgem. The government may consider employing interim targets as well.

2.12.2 Technologies

DECC and Ofgem, in consultation with energy suppliers and consumer groups, have listed a range of functionalities that any proposed design of smart meter and related communications equipment must fulfil:

	High level functionality	Electricity	Gas
A	Remote provision of accurate reads/information for defined time periods • delivery of information to customers, suppliers and other designated market organisation	✓	✓
B	Two way communications to the meter system • communications between the meter and energy supplier or other designated market organisation • upload and download data through a link to the wide area network, transfer data at defined periods, remote configuration and diagnostics, software and firmware changes	✓	✓
C	Home area network based on open standards and protocols • provide "real time" information to an in-home display • enable other devices to link to the meter system	✓	✓
D	Support for a range of time of use tariffs • multiple registers within the meter for billing purposes	✓	✓
E	Load management capability to deliver demand side management • ability to remotely control electricity load for more sophisticated control of devices in the home	✓	
F	Remote disablement and enablement of supply • support remote switching between credit and prepayment modes	✓	✓
G	Exported electricity measurement • measure net export	✓	
H	Capacity to communicate with a measurement device within a microgenerator • receive, store, communicate total generation for billing	✓	

Source: DECC (2011y, p. 14)

2.12.3 **Supply chain**

A number of smart metering equipment manufacturers are already in operation and energy suppliers (or third parties to whom suppliers have outsourced their metering operation) will be able to choose which metering equipment they purchase. The technical specification that Government is in the process of developing and is currently consulting on will ensure interoperability between smart metering equipment utilised by different suppliers. The communications services required for the smart metering system will be procured through a competitive tender, determining who will run the data and communications services.

There are over 1,200 UK companies involved in energy management many of which also work in the smart meter sector. The energy management industry generated £2.7bn in sales and £335m in exports in 2009-2010 (K-Matrix, 2011).

2.12.4 **Benefits**

The estimated overall cost of the smart meter programme across the domestic and the small and medium non-domestic sector is around £11.7 billion and its total benefit is estimated to be over £18.7 billion. This delivers a net benefit of £7.1 billion (DECC, 2011y, z).

For a typical household the costs breakdown is the following:

Table 23. **Domestic smart metering costs and savings**

Costs and savings	Gas	Electricity
Display cost	£15	£15
Meter	£56	£44
Wide Area Network	£15	£15
Home Area Network	£3	£1
Installation	£49	£29
Total costs	**£138**	**£104**
Typical annual bill savings	**£13.64**	**£12.07**

Note: Average annual household gas bill (standard credit)in England and Wales was £682 and the average electricity bill was £431 in 2010 (DECC Energy Price Statistics, Table 2.3.2.and Table 2.2.2) . Annual savings are assumed to be 2% for gas (credit) and 2.8% for electricity (credit and PPM).

Source: DECC (2011z) and Vivid Economics calculations

These majority of benefits to consumers stem from reduced energy consumption.

Suppliers will benefit from reduced costs of operation, e.g. through avoided visits to customers' premises, fewer complaints about inaccurate bills and a streamlined supplier switching process. These operational savings are expected to be passed down to consumers.

Networks will, for example, benefit from reduced losses and better informed network enforcement investment decisions, as well as from improvements in their outage management.

Generators are expected to benefit from a shift in consumption from peak to off-peak time periods.

The UK as a whole will benefit from avoided carbon emissions in both the traded and the non-traded sectors. Further unquantified benefits include those arising from enabling a smart energy grid and increased competition in the energy supply market (DECC 2011z).

2.13 Plug-in vehicle recharging infrastructure

2.13.1 **Current and future size**

In its fourth Carbon Budget, the Committee on Climate Change describes a (Medium Abatement) scenario in which there are 60 per cent of all new vehicles in the UK are electric by 2030 (Committee on Climate Change, 2010b, Chapter 4). The infrastructure to charge them will mostly be made up of home and workplace charging points, since the majority of journeys are home-work commuting. There will be a smaller number of public 'fast-charge' points, allowing consumers to recharge away from home or workplace if they wish, as set out in the DfT's *Plug-in vehicle infrastructure strategy* (DfT, 2011).

Electric vehicles could achieve higher market penetration in the UK than in many other countries. The Department for Business Innovation and Skills (BIS) points out that 'The UK demographic (relative population density and distribution amongst large city conurbations) provides an ideal environment for the introduction of plug in hybrid and electric vehicles' (BIS, 2009).

Among the early participants in the market are Chargemaster, Elektromotive and POD Point 'with ancillary service providers and systems integrators seeing opportunities in intelligent communication, links to the smart grid and billing systems' (DfT, 2011). Chargemaster runs charging schemes in Oxford, London, Milton Keynes, and Cambridge. They are partnered by a number of significant firms in the auto and electricity sectors including Ford, Renault, PSA Peugeot Citroen, Nissan, Scottish and Southern Energy, as well as location providers such as Asda and Waitrose. Elektromotive has installed over 1,000 electric vehicle charge points across the UK and have exported to more than 20 countries worldwide. POD Point have to date installed 190 bays with 102 under construction, which have collectively supplied more than 8MWh of power to electric vehicles, equivalent to 33,000 miles of charge.

Major players are in discussion to coordinate aspects of the development of the technology. For example, a group of industrials, calling itself the Intelligent Architecture Standards Group, has been convened by the Energy Technologies Institute to 'take a world leading role in the development of standards to enable and simplify the complete plug-in vehicle system (ETI, 2009). The group's membership includes IBM, Siemens, Coulomb Technologies, Elektromotive and 365 Energy.

Nissan plans to produce 60,000 electric vehicles per year at its factory in Sunderland, (Parliament 2010).

The UK has comparative advantage in some of the technologies involved in electrical vehicle charging, such as 'world leading foundations in electrochemical research, [...and] technology specialisms in batteries, motors and power electronics' (DfT, 2011).

In 2008, the Department for Business, Enterprise, and Regulatory Reform and the Department for Transport produced a report entitled 'Investigation into the Scope for the Transport Sector to Switch to Electric Vehicles and Plug-in Hybrid Vehicles' which produced a series of possible uptake scenarios for both types of vehicle. The forecasts for electric vehicles in the UK in 2030 ranged from 500,000 to 5.8m, and for plug-in hybrid vehicles, the range was 2.5m to 14.8m. A more detailed breakdown of the scenarios is given in Table 24 (BERR and DfT, 2008).

Table 24. **Possible electric and electric hybrid vehicle take up under four BERR/DfT scenarios, in '000s**

Vehicle type	Scenario	2010	2020	2030
Electric	Business as usual	3	70	500
	Mid-range	4	600	1,600
	High-range	4	600	1,600
	Extreme-range	4	2,600	5,800
Plug-in hybrid	Business as usual	1	200	2,500
	Mid-range	1	200	2,500
	High-range	1	200	2,500
	Extreme-range	1	500	14,800

Source: BERR, DfT (2008)

2.13.2 Technologies

The settings in which a vehicle may be charged are at home, at the workplace, in public off-street settings and public on-street settings. In some cases, household recharging could be set up with little more than correct wiring and appropriate supply capacity. Other locations will require more investment to set up the supply and charging arrangements. Several technologies may be used, see Table 25.

The main areas of innovation with respect to electric vehicles include battery technology, commercial models of battery ownership, metering and billing, and remotely switched charging (to minimise power costs). The BERR/DfT report into the future of the industry points out that 'The widespread roll out of [electric vehicles] is dependent on advances in battery technology – principally improvements in cost, performance and safety. Although Nickel metal hydride is currently the dominant battery chemistry for HEV applications, there is a consensus that lithium ion offers the most promising combination of power and energy density for wider rollout' (BERR/DfT, 2008). Battery prices are expected to fall significantly.

These innovations come under the umbrella of the government's low carbon vehicles programme. The government has provided £80m of funding for over 60 projects via the Technology Strategy Board over the last three years, supporting collaborations between universities, manufacturers and engineers on the development of low carbon vehicles (Parliament, 2011).

Table 25. **Existing avenues of technological innovation for electric vehicle infrastructure**

Charging Level	Typical Use	Charge time
Level 1 (Slow)	**Domestic:** This includes in garages of single homes and multi-unit apartment complexes as well as on street residential spaces. This already exists in most residences and can be used to charge EVs overnight.	7-8 hours
	Workplace: This includes at outdoor garages, commercial complex parking garages, and station car parks.	7-8 hours
Level 2 (Fast)	**Public, on and off -street**: includes non-home and non-office charging at places such as public garages, supermarkets, cinemas etc.	3-4 hours
Level 3 (Rapid)	**Public, on and off street**: for use when faster charging is necessary such as on street charging as well as at certain off-street public situations such as supermarkets.	30 minutes
Battery Swap	**Station**: facilitated at battery stations similar to (or attached to) petrol stations.	2-3 minutes

Source: Institute of Mechanical Engineers (2011)

2.13.3 Benefits

There is a variety of benefits that may emerge. Firstly, if vehicles are charged overnight, the marginal carbon intensity of the power will be nearly half that of the evening peak (DfT, 2011). As the electricity system is decarbonised the carbon intensity could drop further (DECC, 2010).

Second, it makes the economy less dependent upon oil and more dependent upon gas, coal and renewables, and as a result exposure to oil price fluctuations falls (DfT, 2011).

A recent report for the Committee on Climate Change projects 16 million electric vehicles in circulation in the UK by 2030, completing 45 per cent of all car-km. The authors estimate a saving of 16MtCO_2/year (Element Energy, 2009b).

Third, air quality may improve, especially in congested cities, because electric cars will not emit particulate matter or contribute to the formation of ground-level ozone, which causes respiratory irritation. The benefits come both by avoiding burning fuel in the vehicle and break disc wear due to the application of kinetic energy recovery systems. This is potentially important, with road transport the main source of air pollution in 92 per cent of areas assessed as polluted (DfT, 2011).

Electric vehicles which are fully integrated into a smart grid may improve the performance of the power generation system, withdrawing and supplying power to help balance the system, also reducing the need for power generation capacity and network reinforcement (DfT, 2011).

2.13.4 **Current interventions**

The government published its implementation strategy recently. This contains an up to date list of interventions, including the following:

- £300m over the life of this Parliament in grants to reduce the purchase cost of eligible vehicles;
- Vehicle Excise Duty and Company Car Tax exemptions and Enhanced Capital Allowances;
- £30m available from the Plugged-in Places programme to match-fund eight pilot projects installing and trialling recharging infrastructure in the UK, resulting in the installation of up to 8,500 charging points;
- a programme of Research, Development and Demonstration', (DfT 2011).

There are other more localised plans such as the one commissioned by the Mayor of London. All developments which include car parking will have to provide spaces for plug-in vehicles, (Mayor of London, 2009). Meanwhile, there will be 2,000 charging points in car parks by 2015, covering London Underground, Network Rail and London borough car parks. The Mayor's office will also work with companies, aiming to deliver 22,500 charging points by 2015, (Mayor of London, 2009).

The Plug-In Car Grant (PICG) was introduced in January 2011. It reduces the cost of electric vehicles for customers by up to 25 per cent (up to a maximum of £5,000). There are ten vehicles currently eligible for the subsidy. These vehicles are also eligible for Vehicle Excise Duty and Company Car Tax exemptions, which further enhances their attractiveness to users. The Government has committed £300m over the lifetime of this parliament to this project, (DfT, 2011).

The Government encourages research and development through the Technology Strategy Board's Low Carbon Vehicle Innovation Platform. Through it, the Ultra-Low Carbon Vehicle Demonstrator programme has trialled over 320 electric, plug-in and hydrogen vehicles, (DfT 2011). Finance has been made available for the continued development of projects with £24m awarded in September 2010 to vehicle manufacturers, suppliers and universities which are working on hybrid, lightweight material, engine optimisations and catalyst efficiency projects, (DfT, 2011). In the last three years this programme awarded £80m of funding, (Parliament 2011).

The EU-wide regulation of vehicle emissions through fleet standards will also stimulate demand for charging points. By 2020 new vehicles on average will have to be 40% more efficient than they were in 2007.

2.14 Rolling stock

2.14.1 Current and future market size

Since the privatisation of the UK rail network in 1994, the structure of the market for rolling stock has been as follows DfT/ORR (2011, p. 229):

- train operating companies (TOCs) operate rolling stock and carry out light maintenance;
- rolling stock companies (ROSCOs) own and lease rolling stock and carry out some maintenance;
- rolling stock manufacturers build and sometimes maintain rolling stock;
- specialist equipment suppliers provide sub-systems;
- specialist maintenance suppliers provide maintenance services.

Three ROSCOs were created upon privatisation of the rail network in 1994:

- **Angel Trains** – sold by RBS to a consortium led by Babcock & Brown in 2008 for £3.6 billion;
- **Porterbrook Leasing** – sold by Abbey National to a consortium led by Deutsche Bank in 2008 for £1.4 billion;
- **HSBC Rail (UK) Ltd** (formerly Eversholt Leasing) – reported in 2010 to be sold by HSBC to a consortium managed by 3i Infrastructure plc, Morgan Stanley Infrastructure Partners and STAR Capital Partners for £2.1 billion.

In addition to these three ROSCOs the government spend £300 million to finance a fourth, Diesel Trains Ltd, in 2009, to supply rolling stock at short notice. Initially it appeared that the company would be sold off once up and running however its future has been unclear since the coalition government came to power in 2010 (Butcher, 2011).

UK passenger rolling stock currently comprises 11,619 vehicles which vary in their design depending on the services and routes they run. The procurement of new rolling stock costs between £1-£1.4 million per vehicle. These are broadly outlined below:

2.14.2 Technologies

Rolling stock can be divided into two categories; Electric Multiple Units (EMUs) and Diesel Multiple Units (DMUs). Rolling stock is typically designed for a lifespan of 30 years, which is often extended to 40 years (DfT/ORR, 2011). Minor changes in the technologies involved in the design and operation of rolling stock can be expected in the next decade to improve environmental performance, reduce maintenance costs, enhance passenger services and improve disabled access. Plans are in place to electrify lines running between Manchester and Liverpool, Manchester, Preston and Blackpool. Commuter services on parts of the Great Western main line will also be electrified. These projects will be supplied with some new vehicles with others being transferred from other areas of the network (Butcher, 2011) .

2.14.3 Supply chain

The £7.5bn Intercity Express Programme (IEP), which aims to procure the next generation of vehicles for long distance travel and inter-urban routes, was proposed in 2005 and has received support from the coalition government in 2011. It was decided that the Agility Trains consortium would continue as preferred bidder for the procurement of rolling stock for the project. . The lead partner is Agility Trains owned by Hitachi, John Laing and Barclays Private Equity. The Labour government stated that 2,500 UK jobs would be created under this contract (Butcher, 2011).

Table 26. **Inventory of UK passenger rolling stock**

Basic type	Number of classes	Number of vehicles
High-speed trains	1	174
InterCity	8	2,156
Inner-suburban	16	2,690
Outer-suburban	21	4,172
Rural/branch line trains	16	1,204
Inter-regional	8	1,223
Total	**70**	**11,619**

Source: DfT/ORR, 2011

The current £5.5bn Thameslink programme will increase capacity across the Thameslink route in London and includes the procurement of up to 1,200 new carriages. This contract has been awarded to a Siemens-led consortium. Siemens announced that the contract will create 2,000 new jobs across its UK supply chain (Butcher, 2011). Four companies – Bombardier Transportation, Construcciones y Auxiliar de Ferrocarriles, Hitachi and Siemens – are bidding for the 60-train Crossrail rolling stock contract, which will be awarded in 2013. The capital cost for the rolling stock and the new depot facilities will be approximately £1bn.

2.14.4 **Benefits**

Between the years 1996/97 and 2009/10 the output of the UK rail network increased considerably. Passenger journeys rose 57 per cent to 1.3 billion with rail freight increasing 26 per cent to 19 billion net tonne km. The delivery of new trains has seen capacity rise by 28 per cent. Revenue has risen by 76 per cent in real terms to stand at £6.2 billion but costs have also risen to £12.7 billion meaning that the network as a whole is running at a loss (DfT/ORR, 2011).

Passenger journeys by rail are less CO_2 intensive than journeys by car. National rail journeys emit 0.061 kgCO_2/passenger km compared to 0.13 kg CO_2e/ passenger km emitted by the average petrol car and 0.172.8 kg CO_2e/ passenger km emitted by domestic aviation (DfT, 2008). In the most ambitious modal shift scenario provided by DECC Pathways, train journeys will increase from 7 per cent to 10 per cent and rail distance will be 115 per cent higher by 2050. This and other changes in domestic transport behaviour could provide 15MtCO_2e annual emissions reduction.

Rail freight holds several advantages over other means of transport in terms of the economic and environmental benefits it offers. Rail freight directly contributes £870 million to the UK economy annually and a further £5.9 billion indirectly by reducing road congestion and the number of road accidents. It is estimated that rail freight emits 70 per cent less carbon dioxide per mile than road freight (DfT/ORR, 2011).

2.14.5 **Costs**

Out of the £12.7 billion cost of the UK rail network in 2009/10 rolling stock costs contributed £1.9 billion. This represents 15 per cent of the total cost of the UK rail network. Across the 40 year lifespan of rolling stock it is estimated that maintenance contributes to 44 per cent of costs, capital costs 31 per cent and operating costs 25 per cent (Atkins, 2010).

After the privatisation of UK rolling stock in 1994 the initial procurement price has increased slightly in real terms. There has also been significant volatility in the volume of passenger rolling stock procured. Features of the leasing market for rolling stock may contribute to high costs, such as barriers to entry and shortage of alternative rolling stock available to TOCs, which lessens ROSCO competition on rental leases. Recommendations by the Competition Commission are being implemented to tackle this problem (DfT/ORR, 2011).

2.14.6 **Current interventions**

In addition to the procurement of rolling stock the government has intervened in the market on a number of occasions since privatisation in 1994.

In 2003 the Strategic Rail Authority (SRA) published its Rolling Stock Strategy which concluded that the SRA should continue to facilitate and support private sector investment in the rolling stock market and that TOCs should freely choose their rolling stock fleets. It was also decided that the SRA should set rolling stock performance specifications, ensure procurement processes allow sufficient time for construction and delivery of rolling stock and that TOCs achieve good value for money when renewing leases (Butcher, 2011). The SRA was abolished in 2006, with many of its functions transferring to the Department for Transport's Rail Group.

In 2004 the Transport Select Committee reported that despite delivery of new vehicles the average reduction in the age of rolling stock was 'modest' and also that 'the market may not be acting appropriately to provide rolling stock at economic cost'. (Butcher, 2011, quoting Transport Committee (2004, pp50-51). In 2008 the Transport Committee's report on the 2007 Rolling Stock White Paper noted that new stock was unlikely to significantly reduce overcrowding and that procurement decisions should be made centrally (Butcher, 2011).

In 2006 the Office of Rail Regulation (ORR) reported the leasing of rolling stock by ROSCOs to the Competition Commission (CC) due to their findings that the market was not operating competitively. The CC produced its report in 2009 recommending longer franchising terms for TOCs, rights for TOCs to choose rolling stock, ROSCOs to remove non-discrimination requirements from the Codes of Practice and also that ROSCOs give TOCs standardised information when making an offer so that they might negotiate more effectively (Butcher, 2011).

In response to the CC's findings the former government stated that the Department for Transport would consider longer franchise lengths (over ten years) and introduce changes to the franchise evaluation and award process (Butcher, 2011).

2.15 Flood defence

2.15.1 **Current and future size**

In England, in 2009, approximately 5.2 million, or one in six, residential and commercial properties were identified as being in areas at risk of flooding from rivers, the sea and surface water (Defra and EA, 2011), meaning that the risk of flooding was more frequent than 1 in 1,000 years. Of these properties, almost half a million have a significant chance of flooding, such that there is at least a 1 in 75 chance of flooding in any given year (EA, 2009b). In addition, around 1.1 million properties are in areas considered to be at risk of flooding from reservoir failure (more than a 1 in 1,000 chance in any given year), although there has been no loss of life from reservoir flooding since safety legislation was introduced in the 1930s. Approximately 200 properties are assessed as being vulnerable to coastal erosion at present, although over the next 20 years this is estimated to increase to 2,000, with 15km of major road and railway also at risk (Defra and EA, 2011). The Association of British Insurers reports that insurers paid out £4.5 billion to customers whose homes or businesses had been hit by flooding in the ten years to 2010 (ABI, 2010).

Overall, it is estimated that 11 per cent of the land in England is at risk from flooding from rivers and the sea (EA, 2009a). Further, a significant proportion of infrastructure is at risk, with over 55 per cent of water and sewage pumping stations treatment works, 20 per cent of railways, 10 per cent of major roads, 14 per cent of electricity and 28 per cent of gas infrastructure located in areas at risk of flooding (EA, 2009a). It is clear that there exists a large scope for investment in flood defence systems in the UK.

The proportion of houses at risk in Wales is roughly the same as in England, with an estimated one in six at risk from flooding (Welsh Government, 2011 and WAG, 2011a). It is estimated that 357,000 properties in Wales are at risk of flooding from rivers, the sea, or from surface water, or from more than one of these sources (Welsh Government, 2011). The estimated annual damages in Wales from river and sea flooding alone amount to approximately £200m (WAG, 2011a).

Approximately 100,000 properties are at risk in Scotland (SEPA, 2011).

Flood defence is typically a non-rivalrous and partly non-excludable product which, in many cases, makes it a public good (within each local context). Due to this public good characteristic the UK government takes the primary role in terms of ensuring appropriate action is taking place. In recent years the government, at least in England, has centralised the funding of risk management activity, as raising funds through general taxation is generally more progressive and easier to administer than other potential revenue raising means. However, this approach has also led to capital being constrained and worthwhile schemes having to be deferred due to central funding falling short of economically-efficient levels. Effective prioritisation within this capital constrained environment has resulted in the average benefit to cost ratio of recent investment exceeding 8 to 1, as schemes below the marginal BCR of around 5 are deferred.

Over the next year £521m will be spent by Defra managing flood and coastal erosion risks in England, with investment in new schemes, ongoing work or completion of 108 projects already under construction, and a further 187 schemes receiving funding for development work such as feasibility studies, for possible construction in future years (Defra, 2011). The Welsh Assembly Government invested £36m in the sector in 2009/10, with an additional £6m coming from the Strategic Capital Investment Fund and European funding, to make a total of £42m invested (EAW, 2010).

The government expects to spend at least £2.16bn on managing the risk of flooding and coastal erosion in England over the next four years, improving protection for at least 145,000 homes (Defra, 2011). This funding will build upon the £1.8bn programme over the previous three year period that has improved protection for 180,000 homes since 2008 (Defra and EA, 2011).

The principal players in the provision of flood defence are the Environment Agency (EA), the Department for Environment, Food and Rural Affairs (Defra), local authorities and drainage boards, although a host of other organisations are involved in various aspects of provision. A brief outline of the role of each of the major players in England is given below. The structure of this system and the bodies responsible for each area is broadly reflected in Wales and Scotland, as roles and responsibilities across the UK were largely set out in the Flood and Water Management Act 2010 (FWMA, 2010, covers England and Wales) and the Flood Risk Management (Scotland) Act (2009).

- The **Department for Environment, Food and Rural Affairs (Defra)** leads and coordinates government policy on flood defences in England, although the **Department for Communities and Local Government** is responsible for planning policy and building regulations and civil contingencies are under the remit of the **Cabinet Office** (Defra and EA, 2011).
- The **Environment Agency (EA)** is responsible for the delivery of flood and coastal erosion risk management activities on main rivers and the coast and the regulation of reservoir safety in England and Wales. It is responsible for approximately 70 per cent of the assets used to reduce the risk of river and coastal flooding in England (Defra and EA, 2011). It also works in partnership with the **Met Office** to provide flood forecasts and warnings through the national **Flood Forecasting Centre** (Defra and EA, 2011).
- **Regional Flood and Coastal Committees (RFCCs)** advise on flood risk management, flood defences and also coastal flood risk management. There are 11 RFCCs in England plus one in Wales, and they are composed of a chairperson, members appointed by councils in each region and two members appointed by the EA (EA, 2011).
- The Flood and Water Management Act 2010 (FWMA, 2010) places new responsibilities for planning for and responding to flood events upon **lead local flood authorities** (LLFAs, county councils in two-tier areas).
- The **insurance industry** has an agreement with government, a ‘Statement of Principles’, which sets out the broad terms under which the industry will agree to provide households with flood insurance cover. This agreement expires in the summer of 2013 (House of Commons, 2010). In the past, these agreements have been renewed before expiry.
- In addition, **district councils, internal drainage boards (IDB), land owners, water companies, reservoir owners, highway authorities** and other organisations have a function to play in managing their own assets and structures to reduce the risk of damage from flooding (Defra and EA, 2011).

Average flood damage costs in England are currently estimated to be between £1 billion and £2.5 billion (including indirect damages) per year (EA, 2009b), but these costs could rise to £27 billion by 2080 (Foresight Future Flooding, 2004). It is estimated that maintaining existing levels of exposure to flood risk would require spending on asset maintenance and construction to increase to over £1 billion per year by 2035 (EA, 2009b). This represents an increase of approximately £20m (plus inflation) per year to 2035, and excludes the costs of tackling surface and groundwater flooding, with these costing an estimated additional £150m (2008/09 prices) a year by 2035, although there is more uncertainty surrounding this estimate. This investment would save the economy approximately £180bn over the next hundred years (EA, 2009b).

Foresight Future Flooding (2004) identifies four key reasons why the challenge of flood protection may increase in the future:

- climate change, which could lead to rising sea levels and changes in rainfall;
- ageing drainage and flood defence infrastructure;
- more buildings in flood-prone areas;
- more paving, which increases the volume of water running off the ground.

The Environment Agency (2009b) asserts that flood management assets will need to cope with an expected average 20 per cent increase in river flows by 2080, with the increases varying between regions. In the south east, increases in river flows could be as high as 100 per cent by 2080 (EA, 2011b).

If investment is kept at current levels (in 'cash terms') it is estimated that in addition to the 490,000 properties currently at risk, there will be 350,000 more properties with a significant chance of flooding (more than a 1 in 75 chance in any given year) by 2035 (EA, 2009b). Increasing asset investment in line with inflation would mean that an extra 330,000 properties will be at significant risk by 2035.

In Wales, to maintain the numbers of properties at flood risk in 2035 at levels comparable to the present day would require an estimated investment in flood defence three times the current level. To reduce the numbers of properties at flood risk in 2035 relative to the present day would require investment four times as high as the current level (EAW, 2010).

2.15.2 **Technologies**

A wide number of technologies are used for various aspects of the overall flood and coastal management system.

Some of the more common technologies used to reduce the likelihood of floods or coastal erosion include:

- maintained river channels;
- raised embankments;
- flood walls and sea walls;
- culverts and sustainable drainage systems (SuDS).

Often a number of these assets will be used in combination within a risk management system (Defra and EA, 2011).

Examples of the steps taken to reduce damage and disruption when floods or coastal erosion do happen include:

- controlling inappropriate development to avoid increasing risk;
- adapting buildings to minimise damage;
- moving items such as household goods, possessions or vehicles away from floodwater; and

- making sure that a proper emergency response plan is in place and can be operated when needed as set out in the National Flood Emergency Framework (Defra and EA, 2011).

Other steps that may be taken to manage risk include:

- transferring risk to other areas where the consequences are low, for example by allowing land to flood and contain floodwater to prevent flooding elsewhere; or by sharing part of the risk with others with their agreement, for example by sharing the cost of flood damage through insurance;
- tolerating a residual level of risk, for example by accepting that a flood may cause some disruption that is prepared for or is dealt with when it occurs (Defra and EA, 2011).

2.15.3 **Benefits**

The Environment Agency (2009b) estimates that as much as 69 per cent of the benefits of improved flood protection accrue to private agents, such as homeowners and businesses. This assessment is based on various individual flood risk management projects, an in-depth assessment of the Thames Estuary 2100 strategy, and an analysis of who bore the costs of the 2007 floods.

The benefits of flood defence are illustrated by the following selection of facts.

- The benefits typically outweigh costs many times over, providing significant gains to land and property owners and others by avoiding future damage to property, safeguarding insurance terms, and preventing the serious trauma and health impacts that flooding and coastal erosion cause.
- The cost of the summer 2007 floods amounted to more than £3.2 billion, with the floods in Cumbria in 2005 causing damage of £450 million. Flooding can also cause major disruption to energy, water, communications and transport infrastructure (Morris et al., 2010).
- With an £8 return for every £1 spent, timely investment in flood defences provides significant economic as well as social returns (House of Commons, 2010).
- New or improved flood defences mean that the householders and businesses protected by them will need to spend less of their money in the future recovering from floods. This will be reflected in their insurance costs, and possibly in property values. These financial benefits over the long-term are worth about £20,000 on average for each household provided with additional protection. Central and local government also benefit from having to respond to fewer floods (EA, 2009b)
- In the five spending scenarios used to estimate the optimal spending plans to 2035, the best scenario generated a net benefit of investment over 100 years of over £180bn. The benefit cost ratio for this scenario was 7, with the benefit cost ratio of a more conservative spending scenario estimated at 11 (EA, 2009b). The higher benefit cost ratio is explained by effective prioritisation procedures within a capital constrained environment, ie. only the best schemes proceed within the affordable budget. While more investment will lower the average benefit cost ratio achieved, it will significantly increase the Net Present Value achieved by the programme, as many worthwhile projects (ie. with benefits greater than costs) currently have to be deferred each year due to capital rationing.
- In Wales, the current level of spending on flood defences and substantially increased levels of spending, as high as seven times the current level, are all demonstrated to be economically positive and justifiable investments in terms of the flood risk benefits gained (EAW, 2010).

2.15.4 **Existing interventions**

It is estimated that approximately 85 per cent of the potential annual damages from flooding are prevented by the flood risk management assets and systems already in place (Defra and EA, 2011). However, overall investment, by the private and public sectors combined, needs to keep pace with medium- to long-term pressures arising from climate change and deteriorating assets.

Existing interventions are largely government funded, although there is a move in the recently released National Flood and Coastal Erosion Risk Management strategy for England (Defra and EA, 2011) towards greater cost sharing between national and local flood risk management partners and beneficiaries. This strategy seeks to leverage third party sources of finance by introducing partial funding of flood defence projects, rather than the previous system, in which a project was either completely funded by central government, or not at all.

There has been recent debate on whether the size of the government's budget is adequate to meet the challenge in the coming years. In particular, the House of Commons Environment, Food and Rural Affairs Committee (2010) found that:

> *'the £2.1 billion capital funding allocated under the Comprehensive Spending Review (CSR) for the next four years represents a cut to planned spending on defences. Simply to maintain the current level of protection in the face of increasing flood risks requires increased investment and the significant CSR cuts will increase concerns that funding on flood defences remains inadequate.'*

The Institution of Civil Engineers (ICE) also noted the decline in real annual spending as a result of the comprehensive spending review, asserting that the impact of reduced public funding for flood defences will demand a more innovative approach to managing flood risk (ICE, 2011).

In its new national strategy (Defra and EA, 2011), the government and Environment Agency have acted to counteract the effects of reduced public funding in real terms. The key points of the new strategy, to come into effect from April 2012, are (Defra and EA, 2011):

- Rather than some projects being fully paid for by central government and others not at all, at least some national funding will potentially be on offer towards every worthwhile project, based on the outcomes and benefits each would deliver. Projects that deliver sufficient benefits will still be 100 per cent funded by central government, while others will have to find cost savings or additional sources of funding to proceed. When a project is private sector funded, the GIB might be able to play a role.
-
- Government funding will be targeted towards those most at risk and least able to afford to protect themselves.
- The general taxpayer should not pay to protect new development in areas at risk of flooding or coastal change, now or in the future – new developments completed from 1 January 2012 will not influence the allocation of central funds to projects. The Environment Agency estimates that it

ensures that at least 96 per cent of new proposals that they object to on the grounds of flood risk do not go ahead (EA, 2009b).

- The strategy should enable more local choice, and encourage innovative, cost-effective options to come forward in which civil society may play a greater role. Those with an interest in the areas at risk will have a bigger say in the design of projects, in return for greater local and private contributions towards the benefits delivered.

The Welsh Assembly undertook a consultation exercise in late 2010 that was similar in scope to that undertaken in England. Although the consultation exercise was completed in spring 2011, the National Strategy is yet to be released and has been delayed until summer 2011 (Welsh Government, 2011 and WAG, 2011b). However, it is expected that the National Strategy will be broadly similar to that set out for England. The Welsh Assembly Government has committed to investing £109m in flood and coastal risk management in the three years from 2011, £50m of which is supplemented by European Regional Development Funding. This represents a decrease in funding from the £42m invested in 2009/10 (WAG, 2011b).

The strategy for flood defence and coastal management in Scotland is still at the early stages of being formed. The Scottish Environment Protection Agency (SEPA) recognises that a number of steps need to be taken before publishing flood risk management plans in 2015 (SEPA, 2010). Areas most vulnerable to flooding will be identified and published by December 2011, the damages caused by floodwaters will be estimated by December 2013 and the flood risk management consultation will be released for public comment in 2014 (SEPA, 2010).

Despite the reforms in England and Wales, it seems that a funding gap is likely to exist in the flood defence sector in the coming years. As detailed in Section 1.1.3, it is estimated that funding for flood defence in England ought to rise to just over £1bn by 2035, an 80% increase in funding in real terms, or an increase of £20m per year, plus inflation (Environment Agency, 2009b)[6]. In Wales, funding would have to triple by 2035 to provide the same level of protection as currently exists (Environment Agency Wales, 2010). It is unclear in both cases where this funding will come from. Since incomes will rise over the period, and with them, tax receipts, a proportion of the increase will be achieved by maintaining flood defence's share of government spending, but this may not be enough. Further, a large number of houses remain at significant risk of flooding from rivers and sea; despite 250,000 households benefitting from investment in new or improved flood defences in the decade leading up to 2009 (Environment Agency, 2009b), nearly half a million households remain in the significant risk category, with more than a 1 in 75 chance of flooding in any given year (Environment Agency, 2009b).

In 2010-2011, the year before the comprehensive spending review, a total of £800m was planned to be spent on flood and coastal erosion risk management. This expenditure was broken down approximately as follows (EA, 2009b):

- £205m on development control, warnings, strategies and mapping;
- £25m for local authority surface water plans;
- £270m on the Environment Agency construction programme;

[6] This is scenario 3 in EAW (2010).

- £161m on the maintenance programme;
- £87m Local Authority expenditure;
- £52m on the Local Authority and Internal Drainage Board construction programme.

3 Rationale for intervention

What the problems are and whether the GIB can solve them

Section Contents:

Section Summary

For a long time environmental externalities have not been priced properly. Combined with externalities in research and development (addressed, in part through traditional policy instruments) this has resulted in a lack of innovation in low carbon technologies. Many of these externalities have been corrected, but only recently, and the process of urgent reform of the UK's infrastructure has begun. As the UK moves rapidly to decarbonise driven by targets and policy ambition, it finds that the financial markets are still unaccustomed to the risks involved in low carbon technologies in contrast with their familiarity with established technologies. Left to themselves, financial institutions would become accustomed to these risks, albeit at a rate that is too slow given the pace of investment now needed.

The GIB can help. Its primary function is to speed capital market innovation to deliver green investment and it can do this in several ways. It can enhance the credit of investments in green infrastructure, which brings in new investors. It can put capital into novel assets, which secures learning benefits for financial intermediaries as well as project developers and technology suppliers. It can develop new models of financial product, for example where the asset security is novel forms of receivable, in the expectation that other financial players will adopt the model once it has proven its worth. These could be of benefit respectively in offshore wind refinancing, non-domestic energy efficiency and the Green Deal, to give just three examples.

These interventions may be particularly important where firms are capital constrained. Offshore wind is a sector where the policy ambition exceeds the sector's profit generating capability, and investors have indicated that they would balk at suggestions by incumbent firms to cut returns to shareholders in order to boost investment to the full level that might be needed. Those same investors may also object to a major reallocation of investment in favour of novel technologies. For different reasons, but with similar effect, GIB-sponsored finance may circumvent some of the barriers to managerial support for capital investment, such as in energy efficiency, by taking capital for energy efficiency investment out of direct competition for more familiar and hence favoured uses. In both these cases, the GIB's ability to co-invest and enhance credit may allow viable projects to go ahead (which otherwise would not have) with a lower impact on the firm's balance sheet, and sometimes off its balance sheet altogether, significantly increasing the scope for capital deployment.

There is rationale from the above arguments for intervention in many, but not all of the sectors which have been examined. Those which do not look likely to be suitable for GIB involvement include: onshore wind, because the technology is already mature; nuclear at first, perhaps, because the project unit size is large relative to the GIB's initial balance sheet; and flood defences, because there is little evidence of private provision, and public authorities have access to existing sources of funding, such as the Public Works Loan Board.

In summary, the GIB can act as a catalyst to expand the pool of investors and capital available to fund green infrastructure. With its focus on green infrastructure and late-stage innovation, and by judicious deployment of its capital, it may lead to the better pricing of risk in financial markets, the mobilisation of more risk-averse lenders' capital, and greater managerial support for green capital investment.

3.1 Introduction to market failures

There are a number of market failures which might obstruct investment in the transition to a green economy

Despite clear Government ambition, targets and a good knowledge of the funding requirements, there remains a significant risk that capital investment over the coming years will fall short of what is needed to make the transition in the economy at the required pace. In particular, the combination of a number of different market failures is constraining the availability of finance for investment in new, emerging (and in this case, green) technologies.

This section describes the different types of market failures – market failures can occur in the financial markets or in the individual sectors. The role of the GIB will be to address some of these market failures in conjunction with other policy mechanisms.

3.1.1 An economic rationale based on market failures

If markets work well, they allocate capital and other resources so that no further reallocation could make one party better off without making another worse off. Market failures interfere with this process and the result is that less benefit is created. If the market failures affect the resources deployed in innovation or if they limit access to and the discovery of resources, then they can also detract from growth.

3.1.2 Taxonomy of market failures

Before embarking on a discussion of market failures in various industries, it is worth setting down a brief explanation of the main types of market failures and how they might be described. There are essentially five types of market failure, each of which is discussed in turn: externalities, information asymmetry, market power, complements and public goods (Stiglitz et al., 1993).

3.1.3 Externalities

An externality, which can be either positive or negative, occurs when an individual's actions has an impact on others, and where that impact is not reflected in the price. Where this effect is a positive one, it is referred to as a positive externality, and where it is negative, it is a negative externality.

To take an example, a firm choosing to burn fossil fuels to generate electricity and emit carbon dioxide. The environmental costs imposed on others by the firm are not included in the price he or she paid for the fossil fuels unless they are already covered by a policy designed to do this. This leads to over-consumption.

3.1.4 Information asymmetry

Information asymmetry occurs when during a transaction one party has better information than the other, or information is costly. The effect of this is to make markets less efficient as some of the participants do not make the best trades. In relation to market failures around the GIB, the most common application of this is known as the principal-agent problem. Here the principal hires an agent to undertake a task. So for example, shareholders (the principal) who own a company hire a manager (agent) to run the company on their behalf.

However, as the shareholders have less than perfect information about how the agent is performing, for instance, whether or not the agent is working as hard as possible and making the best decisions, then the agent may pursue their own interests rather than those of the shareholders.

There is a great deal of literature which argues, for example, that while shareholders wish to maximise their returns, managers prefer to manage ever bigger companies, and hence many firms do not profit maximise. To some extent their interests align, but at some points they do not, and because the shareholders cannot fully monitor their managers, managers may follow a growth rather than a profit maximising strategy.

Another failing is that managers can make trade-offs between short- and long-term benefits which favour the short term, because of the incentives they face. This can make firms behave myopically.

In addition to all of these factors, information is costly to obtain and managers may rely on simplifications and rules of thumb (heuristics) in their decision-making, with suboptimal outcomes. The cost of information is another departure from a perfectly functioning market.

Valuable information that is acquired by one person will often leak to another, so that after a time all market participants will come to know it. In markets which are new, or rapidly changing, some participants will lag behind current information and in general information may be more costly to obtain. New and evolving markets include several examples of green infrastructure.

3.1.5 **Market power**

In a perfectly competitive market, firms cannot influence the price that they charge, they simply have to charge the 'market rate'. They are, as the literature puts it, price takers. When a company, or a group of companies acting together, has market power then they have the ability to determine what they charge. They are no longer price takers and become price makers. Typically, they will use this market power to charge a higher price than under competitive conditions. Firms may also choose to do this by restricting output or reducing the quality of their goods and services.

Typically market power can be found where there are few incumbent companies, and where there are features of the market that prevent other companies from entering easily. So, for example, a company responsible for electricity distribution may have market power as it would have no competitors. It would be difficult for new firms to enter the market given the high costs of building a network, and indeed it may be undesirable for society, from an efficiency point of view, to have two large networks delivering power. In such circumstances, the typical response is to rely on competition law to prevent or punish the abuse of market power, or to regulate the prices and service quality of the incumbent company or to provide the goods and services directly via the public sector.

3.1.6 **Complements**

The issue here is where the consumption of one good requires the consumption of another. So, for example, the consumption of electricity requires both the power station to generate the power, and the transmission or distribution grid to bring it to the customer's door. Market failures where there is a failure to provide a complementary good are often termed 'co-ordination failures' and a good example of this is electric vehicles. Individuals may be unwilling to buy an electric vehicle unless there are charging stations for them. Likewise, investors will be unwilling to commit capital unless there is a large enough market for the infrastructure. Consequently, if neither party is prepared to commit first, the market develops slowly and is smaller than is optimal.

3.1.7 **Public goods**

A public good has two features: it is non-rival and non-excludable. Non-rival means that an individual's consumption of the good does not affect the amount available for someone else to consume. Non-excludable means that no-one can be effectively prevented from consuming the good.

It is because it is difficult to prevent an individual from consuming a public good, that it is difficult to charge a price for it. If it is difficult to charge a price for a good, then the market will not supply it. Typically then public goods are supplied, if at all, by the state.

3.1.8 **A final comment**

When examining the potential sectors in which the GIB could invest, it is apparent that these market failures could be present in either or both the capital markets and the relevant sector and may interact. The following analysis looks at all these possibilities. In addition to market failures, policy or public institution failures may be present. There are a number of drivers of policy uncertainty, including the following: the cost of making firm domestic commitments while negotiating international agreements, the legal restrictions on a government's ability to bind future administrations, limited information on market conditions, the pressure of lobbying leading to changes in policy instruments on which investment decisions had been made, and the practical compromises which have to be made in legislation and regulatory institutions. Together, these create regulatory uncertainty for investors, which can raise costs and deter investment. These policy and institutional problems lie outside the GIB's sphere of influence.

3.2 Financial market failures

Financial markets face constraints where risks are difficult to assess due to novelty and where players face constraints to scale up balance sheets

3.2.1 Financial market failures

Some of these failures are manifesting themselves in the financing of the green economy and for green infrastructure in particular, as follows:

- **Temporary restrictions in company and bank balance sheets resulting from the cost of raising new capital**: Companies, including utilities, industrial players and waste companies, are the traditional source of investment in much green infrastructure, using traditional corporate finance. For large, discrete projects, project finance raised in the banking community may also be used. However, the scale of investment required now (driven by the rapid scaling up of policy ambitions) can temporarily exhaust available capital from corporate balance sheets or banks, leading to investment below the level required to meet policy objectives. The origin of these restrictions is the cost and asymmetry of information.

- **Long-term bank lending via structured finance products will be further affected by new regulations** (such as Basel III, which requires banks to increase their capital across all asset categories) and by uncertainty around liquidity in credit markets following the financial crisis. This relates to the externality of one bank's solvency on that of another.

- **Risk aversion due to imperfect information and information asymmetries**: Often, investments in key sectors of the green economy lack deal precedent and a track record of performance. Uncertainty can exist around construction costs, technology reliability and performance, policy certainty or counterparty risks. While different investor groups can be comfortable with different elements of risk profiles, the number of investors willing to take the set of required risks may be limited by lack of information and experience. As a result, Government interventions, which help partition the risks for certain types of investment, may be required to expand the range of willing investors, by supplying information, which becomes a public good.

- **High financing transaction costs:** Many green projects involve novel technologies and business models, which increase the costs of due diligence checks. In addition, green projects can sometimes be high in number, but small in size and distributed across a large number of sites – for example energy efficiency projects across a large corporate estate or within the domestic sector. These factors can raise the costs of assessing and monitoring as well as organising external finance for projects. They are another feature of information costs and asymmetry.

The following sections assess the issues of balance sheet restrictions and risk aversion in more detail

3.2.2 Rapid scale-up beyond the financial capacity of incumbents leading to temporary restrictions in banks and companies' balance sheets

Some of the sectors face a dramatic increase in capital investment if government and EU policy ambition is to be met. However, there appears to be a natural limit to the pace of capital investment which the relevant, incumbent firms can achieve. The reason is that companies typically try to maintain stable net earnings and dividends over long periods of time – however, this is not possible when companies move from periods of low investments into periods of high investment as is the case with utilities in most of Western Europe who face a significant increase in investment well above historic levels. This is a symptom of information asymmetry. It also signifies a need for coordination between government (ambition and policy support), financial institutions (capital allocation and supervision) and sector firms (delivery capability). Each part provides complementary services.

Reason for companies' limitations to increases investment

Firms need high levels of equity in order to make investments, especially innovative firms (Hall, 1992). Conversely, high levels of leverage in firms lead to reductions in investment. A further factor is that the capital is generated mostly through retained earnings rather than equity issuance (Auerbach and Hassett, 2003; Myers, 1984). This is in part because, if they were forced to seek external capital from markets, their cost of capital would increase. Together, these factors create a natural limit to the pace of capital investment which the relevant, incumbent firms can achieve. In particular, capital budgets are especially sensitive to net earnings, since companies tend to pursue a fixed pay-out ratio, which they adjust to cut investment if earnings fall (Lintner, 1956). They seek to maintain dividends, because stock market valuations respond to unanticipated dividend changes (Miller and Modigliani, 1961).

Unsurprisingly, it is not easy for firms to increase the proportion of earnings which they retain. Corporate treasures find themselves under pressure to pay out cash rather than retain earnings, except for growth stocks. This is because many investors, such as pension funds, need to maintain income to match their outgoing obligations (Brealey and Myers, 1996; Gordon 1959). The market failure which is information asymmetry between managers and shareholders acts to prevent managers (Stiglitz et al 1993) being given the freedom to expand capital investment much ahead of profits, even in the most productive firms (Vlieghe 2010). This is an appropriate control in private markets with information asymmetry, but it can frustrate the delivery of policy goals involving rapid investment in the private sector.

For example, a sector such as offshore wind where market returns are uncertain and truncated by capped levels of policy support, the returns may not be high enough to support capital allocation at the rate demanded and the risk perceived. Furthermore, current economic conditions are likely to limit the quantity of equity that is available and the number of investors willing to make investments which they view as exotic, such as offshore wind. This is partly because, in many markets, firms' profits have been cut both by a reduction in quantity demanded and by an associated fall in margins as capacity has moved into over-supply. This reduces access to capital (Gertler, 1988). With lower profits, there are fewer internal resources for investment. It is also because, as market volatility has increased (Bank of England, 2010), investment has been discouraged (Dixit and Pindyck, 1994). This is likely to hit exotic sectors harder than most: the Bank of

England reports on market sentiment that 'increases in the required compensation for uncertainty around future dividends [is] linked to the general retrenchment from risky assets', (Bank of England, 2010). In sectors which were already a specialist opportunity, against a background of increased risk, capital availability has declined. The supply of capital is a complement to the supply of specialist project development expertise.

The GIB can add equity capital and may also act as a catalyst, generating additional or accelerated investment if it can overcome some of the market failures relating to information and public goods at the same time.

3.2.3 Risk aversion due to imperfect information and information asymmetries, e.g., due to novel technologies and novel business models

Often, investments in key sectors of the green economy are held back because investors lack information or face information asymmetries, in particular in the case of novel technologies and novel business models.

Novelty is a common characteristic of many of the green sectors considered in this report. For example, in offshore wind, the third round of offshore wind farms is further out to sea, in deeper water, and uses larger turbines than previously tried. In waste and heat, the development of a solid recovered fuel market, wider-spread use of renewable heat and development of more efficient innovative advanced conversion technologies are new. In industrial manufacture and in buildings, investment which is paid from energy savings—receivables-backed finance—is a novel credit model. These technical and business model innovations may succeed or fail, but if they succeed, the knowledge gained will become widely available, a public good, and will signal an investment opportunity, which is itself a positive externality. The investment made in bringing forth that knowledge becomes a public asset (Stiglitz, 1999), and the originator sees a fraction of the total return for her efforts. This is a reason for government to step in.

In financial intermediation, innovation is made in response to changing market conditions, of which novel technologies and business models are two examples. The innovation may improve one or more of the financial market's functions, such as pooling risk, managing risk, extracting information to support decision-making, addressing moral hazard and information problems, or facilitating exchange through a payment system (Merton, 1992). The innovation is likely to come in the form of data on technology or business model track record, methods of valuation of novel risks and types of asset (such as paid from savings contracts), and the design of commercial contracts. These innovations are public goods and the market will tend to under-supply them.

In past financial innovations, imitation has been rapid (Tufano, 1989), which suggests that future innovations that are valuable will also be adopted quickly. It suggests that the GIB can be effective as a catalyst. There is evidence that large financial institutions tend to be the innovators and therefore, a substantial number were interviewed during the GIB work programme. If these institutions are not offering particular products, and are not aware of the market offering them, then they are unlikely to be on offer anywhere. The interviews establish the evidence that the institutions have not made these innovations in green investment yet.

This creates the space for the GIB to become involved in novel asset creation and to build a body of financial products and information in response to changing sectoral markets. Other private capital providers can later adopt and modify these innovations, a process which will be facilitated if the GIB works closely with them, and treats them as customers for adoption of innovation (Freeman, 1982). This will lower information and transaction costs for private sector financial providers and so encourage them to supply capital to green sectors.

3.3 Sector market failures

Market failures affect sectors in different ways

3.3.1 Introduction

The mainstream economics literature seeks to explain market outcomes by looking at three broad strands: market failures (a lack of information, asymmetric information, externalities and so on); market barriers (low priority of energy efficiency for businesses, lack of access to capital and others); the distribution and equity of consumption; and other factors (essentially organisational or behavioural features) (Gillingham et al, 2009). There is strong evidence for all of these.

There can be inertia in investment and innovation decisions for behavioural reasons (Aghion et al 2011), particularly as firms wait and see in the face of market uncertainty. Also, firms often place emphasis on revenue or market share as well as or instead of profits, and this helps to explain why firms leave do not always pursue profitable investments. This has been shown to be a long-term profit-maximising strategy in markets where there is the threat of entry (Fershtman and Judd, 1984). For example, it helps to explain why energy efficiency has a low priority on senior management's agenda (in addition to the fact that energy is a small share of costs in the majority of firms). Of course, there are exceptions, both in energy-intensive and non-intensive firms.

The market failures and other imperfections outlined above can be found in many of the sectors relevant to the green economy. These need to be addressed through a comprehensive policy approach such as the pricing of carbon, innovation support, competition regulation, efficiency standards and public provision of services which the GIB can complement as and where appropriate.

3.3.2 Main types of market failure identified

Externalities are not always fully addressed: For example, in industrial energy efficiency for smaller plant and for buildings, and in households, the cost of gas for heating may not incorporate a sufficient cost of carbon, and in the waste sector, the cost of virgin materials may not build in a cost of greenhouse gas emissions associated with their production. Both of these are potentially significant omissions though arguably not for the GIB to address.

However, it is worth noting that in some cases incentives are set that go beyond the cost of the environmental externality, and probably beyond the additional innovation benefits too. For example, the Renewables Obligation rewards offshore wind to a higher degree than is justified by the social cost of carbon, and the Landfill Tax rate is set at a higher rate than the disamenity costs of landfill. Both more than compensate for the externality in order to drive investment to meet quantity (share of supply) targets.

There is a diversity of market failures across the sectors which is summarised in Table 27. The three sectors assessed in more detail in this document face the following market failures:

Offshore wind: The key challenge facing offshore wind is the pace of contribution intended by policy coupled with perceptions of risk around technology, construction, offtake and price (though the latter is being considered through the Electricity Market Reform). This creates the potential for market failure in coordination between policy ambition, capital allocation and delivery capability. There is also market failure in information asymmetry between investor and asset owner, and some information used in finance is a public good. As mentioned before, public goods are under-supplied in private markets. The externality of fossil fuel emissions from rival generation technologies has been addressed and connections to power networks appear to be provided in a timely fashion. There remains the possibility of missing complements in the form of parallel investment in the supply chain (ship and turbine manufacture) in order to match planned installations, where there is already some policy, mostly focused on research, development and testing. The financing of supply chain capacity, addressing the risk and speed of development needed, is something the GIB might examine.

Non-Local Authority collected commercial and industrial waste: In this waste market, value recovery from waste requires greater capital intensity and technical prowess, and both create economies of scale which favour larger over smaller firms. The market is adapting via consolidation and is building scale, but there are also investments unable to secure finance. The main failure here is coordination between buyers of waste services, who purchase through short-term contracts, and suppliers of those services, who own long-lived assets. In addition, increases in Landfill Tax rates have created space for new services markets, some using technologies in contexts where they have not been used before. This novelty is potentially fertile ground for the GIB, in particular in relation to the evolution of markets in solid recovered fuel, development of advanced conversion technologies and related markets for biomass fuels and recovered materials. The novelty is associated with information asymmetry and the public good nature of information.

Non-domestic energy efficiency and commercial buildings: market failures and other barriers are much studied, qualitatively. Without doubt, market failures are present and arise from the principal-agent problem and manager myopia, lack of knowledge and bounded rationality. The GIB is not in a position to correct these directly, but it might support financial models which show promise in alleviating some of them. In particular, it might help to address coordination between investors and intermediaries, overcoming information asymmetry and increasing the supply of information which is a public good.

Table 27. **Prevalence of five types of market failure in sectors**

	Sector market failures					**Financial market failures**			
	Externalities	**Information asymmetry**	**Market power**	**Complements**	**Public goods**	**Access to bank capital**	**Novelty and risk aversion**	**Transaction costs**	**Balance sheet limits**
Offshore wind	✓	✓	✓	✓	✓		✓		✓
Non-municipal commercial and industrial waste	✓	✓	✓	✓	✓	✓	✓		✓
Non-domestic energy efficiency	✓	✓					✓	✓	
Electric vehicle infrastructure			✓	✓			✓		
Green Deal	✓	✓					✓		✓
Rolling stock			✓	✓					
Carbon capture and storage	✓		✓	✓	✓		✓		✓
Flood defence			✓		✓				
Nuclear power	✓		✓						✓
Smart meter			✓				✓		✓
Marine	✓	✓			✓		✓		✓
Renewable heat	✓	✓		✓			✓		
Solar PV	✓		✓						

Source: Vivid Economics

3.4 Offshore wind

A sector in which the ambition of policy is challenged by the availability of private capital within the sector and investors' appetite for risk given the rewards on offer

3.4.1 Context

The market is already investing in some offshore wind projects. To date, that investment has been carried out by utility companies. There is approximately 1.3 GW of offshore wind generation capacity currently operating and 5 GW in or awaiting construction. Another 2.5 GW are in the planning permission stage (Committee on Climate Change, 2011a, p. 20). If the UK is to meet its carbon reduction and the UK renewables targets, this figure would need to rise to between 13 and 32 GW by 2020.

This section identifies and analyses the potential market failures and barriers to meeting this objective. It also identifies potential interventions that a GIB could make.

3.4.2 Potential market failures and barriers

The potential market failures and barriers to investment fall broadly into three categories: issues relating to the asset class (newness, expected returns, attitudes of investors) issues relating to the utility companies (balance sheet strength, management resources), and wider issues (i.e. the correction of externalities around carbon and innovation spillovers).

3.4.3 Issues relating to offshore wind as an asset class

These issues relate to two key themes: incomplete or asymmetric information and costs. The argument is that because offshore wind is new there are fewer data on its performance and costs and so fewer investors may be willing to invest, and the transaction costs may be higher because of the small volume of deals.

Although the wind turbine is a mature technology, its use in an offshore environment is novel, and the unit size in which it is being deployed offshore is significantly greater than the largest size that has been used on land. Inherent in this innovation is uncertainty over performance. A lack of information on asset performance over its lifetime could make it difficult for the utility companies to recycle their cash by selling all or some of their stake in an offshore wind farm to other investors. Fewer investors are willing to invest in an asset which is regarded as exotic.

Meanwhile, the current owners of wind turbines, the utilities, have access to performance information and so do the turbine manufacturers. This information is likely to leak out gradually and become accessible to other players, but for the time being the incumbents have an information advantage. It is in their interests to maintain this advantage in order to create a barrier to new entrants.

The number of offshore wind projects is fairly low, and the projects are large. A 500 MW farm involves perhaps £1.5 – 2 billion of capital expenditure. There were 17 projects in round one, 15 in round two and 9 are being considered in round three. They have been increasing in scale. The round three projects will take place over a 10 – 15 year period, probably in phases. Up to five projects may be under construction in any year to begin with. The projects are complex and new, and institutions will consider whether they can recoup any investment in building up expertise to assess risk. After a period of 10 – 15 years, the deal flow in the UK might reduce to a lower level, as policy demand becomes satisfied. Since it is a specialist area with a temporary life and low deal flow, institutions may choose not to develop expertise in it. This would reduce competition and raise costs of finance.

In summary, the key market failure related to offshore wind as an asset class is likely to be incomplete information on risks, such as performance. Due to the sectors newness, the resulting uncertainty may deter investors or lead them to overestimate the risks.

3.4.4 Issues relating to the utility companies

Given that some investors are unlikely to be willing to lend due to a lack of information on risks, utility companies will make use of their balance sheets. Energy utilities have been involved in all offshore wind farm developments to date. As a consequence, offshore wind projects are going to have to compete with all of the other investments that the utility companies are planning to make, as they spread their capital across countries and assets. To compound the problem, this is at a time when, due to the old age of some generation assets and requirements of higher emissions performance from coal- and oil-fired power stations, a large replacement programme is about to begin. The utilities will shift the balance of their core competence from a blend of operations, supply and construction substantially towards construction. The financial structures which they have adopted over recent years will be flexed to accommodate this investment programme.

Hence there is a natural market constraint on the level and rate of increase of activity. The utilities have a pool of capital available and can pursue construction projects at a certain rate, without the value of their share capital being marked down.

The key issue for businesses is the newness of the characteristics of Round 3 offshore wind farms, and the scale of investments funded from retained earnings within the generation sector. This places a natural constraint upon the level of investment.

3.4.5 Wider issues

It is possible that there may be market failures due to lack of co-ordination. This would typically be the case where for the market to work there are a number of pieces of the jigsaw which need to come together at the same time. So, for example, in the case of offshore wind, the timing of power transmission construction, installation shipping, turbine and tower delivery and foundations completion all need to be coordinated. The GIB might become involved in their finance.

With regards to the externality of climate change from the emissions of greenhouse gas emissions, this is covered by the EU ETS and the carbon price floor. Further significant compensation is provided by the Renewables Obligation, and in the future may be achieved through feed-in tariffs. Given the policy interventions already present in this area, it is safe to conclude that there is no residual uncorrected carbon externality market failure.

However, while the proposed feed-in tariffs, which are in the form of a premium on the power price, provide a known revenue uplift at project level, there is no guarantee as to the volume of these tariffs that will be made available. The firms which supply goods and services to the sector are exposed to the risk that policy ambitions towards offshore wind will change, and in particular that the timing of volumes will change.

In offshore wind, as in other sectors where innovation is taking place, there may be innovation spillovers, perhaps particularly for marine energy, through improvements in offshore power infrastructure, and for onshore wind, in the form of greater reliability of turbines.

In terms of wider issues relating to offshore wind, the key point is likely to be concern about co-ordination failures. There may be an incentive for some producers, such as turbine manufacturers, to lag behind demand in their investments in manufacturing capacity.

3.4.6 Evidence from interviews

Interviews were held with six energy companies spanning large mainstream utility providers who were investing in offshore wind, and smaller producers who invested in onshore but not offshore wind. Another participant was a large multinational company who had considered, and decided not to produce, turbines for the UK offshore wind market. The interviews sought to test a number of hypotheses around potential market failures that would prevent investment in offshore wind.

Two broad hypotheses were tested at interview:

- that the utility company balance sheets were not capable of supporting sufficient investment to be funded on balance sheet;
- that given that offshore wind is a new asset class, there was insufficient risk data to make banks willing to lend.

3.4.7 Utility balance sheets

The large utility companies confirmed that investment was allocated across country and asset classes on a best return for risk and portfolio diversification basis. These companies confirmed that access to finance was the most significant barrier of all. Offshore wind has to compete for funding, not just with other renewables but with other investments in more established technologies. One argued that there was sufficient space in their balance sheet to finance their ambitions in offshore wind until 2020, but beyond that, they were likely to be squeezed. However, another stated that it was unable to fund its ambitions in this area and would actively look for equity partners. The companies consistently described their appetite as being to conduct no more than two offshore wind projects simultaneously, while entertaining a variety of financing and ownership models between them.

When discussing constraints, one company argued that the constraints lay in construction and that there were bottlenecks around cable and grid access. This view was confirmed by another, who stated that there was a shortage of cable and construction ships, but that they expected this situation to ease. There was however, a growing problem around access to the skilled labour required to build these projects. They went on to argue that staff needed to be trained on projects and that the market was not bringing forth skilled workers in the numbers required.

3.4.8 Risk as a barrier

All respondents highlighted that returns to offshore wind were approximately 12 per cent, broadly equivalent to onshore, but with more risk. One smaller company explained that the imbalance of risk and return was why they did not invest in the asset class. Another company argued that infrastructure funds wanted a return of 15 per cent and so were not attracted to offshore wind. Meanwhile, pension funds, which they were beginning to target, were looking for lower returns. The problem however, was that pension funds were seeking a very low level of risk. Even though operators were willing to offer ‘fairly risk free’ operating and maintenance contracts, they would not take the wind output risk.

A power company which does not invest in offshore wind, stated that there were significant construction risks. In contrast, another company that does make these investments argued that it had developed an expertise in building offshore, and so was willing to take on the construction risk. It would commission the wind farm and would then seek equity partners to share the operational risk, releasing some of its capital which it could then recycle. It was not attracted, as yet, to seeking partners at the construction phase as it wanted to retain control of the project.

All of the respondents identified significant risks around operations, which was largely related to a lack of historical data about how these farms would perform over time. When discussing why they did not invest in offshore wind, one company argued that the key, and as yet unknown risk, was not turbine or wind availability, but repair times in the event of breakdown. When asked how much data was required to make investors comfortable, they responded that two years operation should be sufficient. Another respondent argued that the asset life was 20–25 years, but key guarantees, for example for turbines were only 2–5 years, and investors might want to know how the asset performed over its whole lifetime. In the example of one site, a pension fund made an investment during the operational phase, but it is understood that contractual arrangements were written to transfer away most of the risks.

All respondents argued that construction risk would fall with familiarity, and markets would become more comfortable with operational risk as more data becomes available.

Finally, one respondent raised the issue of co-ordination failure around offshore wind. It had considered designing and supplying turbines for UK offshore wind farms. The key factor in the project economics for it was to avoid significant delay between project start and orders being placed for turbines. While it was prepared to take the risk that the developers might buy from someone else, it was not prepared to take the risk that the developers might not buy at all, either because other components were not in place, such as transmission lines, or because policy incentives were absent. This point was reinforced by the utilities who argued that they wanted to see greater competition in the turbine market. This was evidence of the potential for co-ordination failure.

In summary then, the interviews support the cases that there is a limit to the capital that utilities can allocate to UK offshore wind. It also confirmed the view that a lack of data on the performance of offshore wind over time was adding to the problems of raising finance, but the companies involved thought this would resolve itself over time. Finally, there was a possible example of co-ordination failure.

3.4.9 Implications for a GIB

There are already companies investing in offshore wind but there may be significant market barriers at work which would prevent the investment rate being fast enough to meet policy targets. Some of these barriers, such as a lack of history in the performance of offshore wind, are likely to be transitory and hence any GIB involvement to resolve these issues would also be transitory, given that no further involvement by the GIB would be required once market failures have been addressed.

While it is clear that utilities' balance sheets are constrained, and that there are potential difficulties accessing capital from the financial market, there are also potential barriers created by co-ordination failure.

Interview respondents argued that there may be a role for GIB products with regard to:

- equity over the next five years or so, while data is generated, risks better understood, and the financial markets became better educated and more comfortable with the asset class;
- mezzanine finance, to allow companies to crystallise value, or at least some of it, when a wind farm is proven operationally, and so that the equity can be recycled into new projects;
- co-investment debt for project finance.

Two interviewees sounded a note of caution around the construction and operating phase interventions. The key issue they argued was that as the market grew, participants continue to face incentives to develop their products and knowledge, and that GIB action should not dilute or obstruct these incentives by adopting risks itself. For this reason, the GIB will not offer guarantee and insurance products.

3.5 Waste

A sector in which volume risk and fixed costs for merchant plant, as well novel technology risk lead to a cautious expansion of capacity

3.5.1 **Context**

The management of non-Local Authority commercial and industrial waste has changed dramatically over the last decade as the market has responded to incentives to divert waste away from landfill. It now achieves much higher rates of recycling and value recovery. As the Landfill Tax rate continues to rise this movement up the waste hierarchy is expected to continue.

While there are several legally binding targets on municipal waste, the same is not true of non-Local Authority commercial and industrial waste. However, there is an ambition to see greenhouse gas emissions reduced and to see a move up the waste hierarchy , as described in the *Waste Review* (Defra, 2011a).

The policy driver is that commercial and industrial waste, in its treatment and disposal, creates some externalities, in most cases and to varying degrees, in the form of pollution risk and disamenity. This is recognised in the waste hierarchy (Defra 2011b), and by the substantial and rising tax on landfilling of waste and regulations on the disposal of waste (Eumonia, 2006; Palmer and Walls, 1997; Kinnaman and Fullerton, 1999), though there remain some elements in relation to the environmental impact of the extraction process of virgin materials which are not explicitly covered by policy (Conrad, 1999).

3.5.2 **Potential market failures and barriers**

The potential market failures fall into three broad categories: issues relating to the waste companies (e.g. balance sheet strength, management capability); issues relating to the asset class (e.g. newness, expected returns, attitudes of investors); and, wider issues (e.g. correction of externalities around waste disposal).

In order to meet government ambition to push the management of resources up the waste hierarchy and increase generation of renewable energy from residual waste, there is a need for more waste management capacity to divert waste from landfill, for example more waste sorting capacity, known as materials recovery facilities (MRFs), and greater capacity for recovering energy from waste using a range of technologies. This ambition requires more capital intensive infrastructure to be built than the simple historical approach of disposal to landfill.

The main incentive to invest in this infrastructure comes from the Landfill Tax (Martin and Scott, 2003). As the Landfill Tax continues to rise, demand for diversion away from landfill is likely to increase, and this will attract investment to build more capacity.

For example, infrastructure to sort waste will be needed. Where this is done centrally rather than at source or at the kerbside, the MRFs which do it vary in technology from low-technology manual picking to high technology automated sorting. Novel technologies and business models such as mixed waste anaerobic digesters and solid recovered fuel manufacture are appearing.

When lending to the waste sector, banks take into account the quality of the management, the business plan, the underlying financial strength of the business and the riskiness of the project. A key feature of the non-Local Authority C&I waste sector is the nature of the risks involved: there are few or no long-term contracts for the management of waste. Typical contracts in the non-Local Authority C&I waste sector are for a year and sometimes shorter, a stark difference to the municipal waste sector where Private Finance Initiative contracts last 25 years, and other local authority contracts may be five to seven years long. The short length of contracts and associated volume risk means that generally banks do not participate directly. Two further factors reinforce this pattern. Firstly, a MRF (and also Anaerobic Digestion Plants) costs approximately £20m to construct (personal communication, waste management company, 2011) and so falls below the scale typically associated with project finance, leaving it on the firm's balance sheet. Second, across the sector as a whole, the relatively small size and number of deals in the C&I waste sector does not drive banks to build capability in the field. Therefore, banks are less likely to understand the sector and the risks involved.

The larger players have more diversified, asset-backed businesses, greater management resources and wider access to finance. They have a mix of municipal and non-Local Authority C&I waste contracts, resulting in reduced volume risks across their asset portfolio. It is possible that these advantages will allow the larger players to increase their market share of merchant infrastructure over time. This would continue a trend towards consolidation that has been ongoing in the waste sector for the last 15 years or so. There is anecdotal evidence of this trend, but it is not backed up with quantitative evidence.

Nearly all the energy from waste plants built to date have been commissioned by waste disposal authorities. In some cases, additional merchant capacity to serve non-municipal commercial and industrial waste streams has been incorporated in the project, supported by waste management company equity funding, but in many cases, the assets were designed for dedicated use on municipal waste streams. Waste disposal authorities have not shown an interest in over-sizing energy from waste plants in order to serve non-municipal waste streams, and the fleet of new assets needed to deliver municipal policy targets is now either built, under contract, or in progress for local authority financial approval (Defra, 2011a).

Within the family of energy from waste technologies, applications of gasification, pyrolysis and anaerobic digestion to mixed non-Local Authority C&I waste streams have been uncommon. It is a greater technical challenge to make the technology perform well when the composition of the waste input is variable, and for this reason established developers have tended towards the use of direct combustion, encouraged by financiers who are put off by operational risk associated with the advanced methods. The GIB might, through its focus on particular sectors, be able to judge and price the risks involved more expertly. In that case, the advanced technologies might not be disadvantaged because of novelty when developers contemplate using them on mixed waste streams.

In summary, while there has been a great deal of investment in the treatment of municipal waste driven by European targets, government support through PFI and long term waste contracts, the disaggregated nature of non-Local Authority C&I waste arisings presents a challenge for the management and energy companies wishing to make large capital investments. Some firms may struggle to raise external finance to make investments in merchant capacity. Further firms wish to apply advanced conversion technologies in novel circumstances. The banks' unwillingness to lend is principally driven by uncertainty in securing waste volumes at sufficient prices, but may also be a feature of the small market size and poorly-characterised risks, leading also potentially to a lack of expertise by investors in this area. The GIB may be able to price these risks more accurately by becoming an expert in this niche, and having established a track record, refinance the projects with access to a wider financial market.

3.5.3 Evidence from interviews

In addition to interviews with banks, five interviews with companies in the waste sector spanned small, medium and large firms.

The interviewees suggest that there may be differences in investment capability according to firm size. So for example, the smallest company interviewed reported that its mechanical biological treatment facility was supported by local authority contracts, giving the local authority a right to call on 100 per cent of the capacity. It argued that a company of its size would have trouble raising bank finance for investment in merchant capacity. A mid-size company interviewed agreed that small companies would struggle developing merchant capacity. In its case, it would only invest in capacity with volume guarantees. It cited the example of one of its plants, in which it was only willing to take a certain amount of merchant risk, and so had contracted half of the plant's capacity to another company. It went on to argue that only large, vertically integrated companies had the financial strength and capacity to source feedstock for a plant, and so these were the only players able to take the risk of investing in merchant capacity. On the other hand, there is evidence from other sources that the presence of mid- and small-sized firms may bring advantages of greater competition and innovation.

A large firm supported some of these sentiments. It reported much less of a problem in funding merchant capacity. While it was true that it wanted to feed its plant with an element of non-merchant waste to give it base volume, the proportion of guaranteed volume it needed is lower than that required by smaller companies. So, for example, whilst some banks had told a mid-size company interviewed that no more than 10 per cent of merchant capacity would be acceptable, this figure could be much higher for the large company, which gave an example of one of their plants that runs on 50 per cent client and 50 per cent merchant volumes. Furthermore, the strength of the large company's balance sheet meant that it is able to make the investment without bank debt, and its integrated business model means that it is more confident about supplying its merchant capacity.

A large company pointed to Germany and the Netherlands as a cautionary tale for the UK. Here, an excess of capacity has been created and as a consequence gate prices had fallen and assets had become stranded. An interviewee said that internal rates of return on refuse-derived fuel production had fallen to 12 per cent, the minimum viable level. A small company interviewed corroborated this story. It sends its refuse-derived fuel to Germany or Sweden to be burnt. An excess of processing capacity in Germany had made refuse-derived fuel attractive to export. It was certain that it would have no problem in signing contracts for off-take in the UK, but the German market was offering better prices.

The position was echoed by a mid-size company. It argued that there is around 1 mtpa of excess capacity in the Netherlands together with excess capacity in Germany, and that substantially lower gate fees had resulted. For example, gate fees which had been above €100/t had fallen on spot to €50/t, and in contract to about €80/t.

There is a common theme amongst the respondents around the distinction between established and new waste technologies. All of the respondents argue that banks are unwilling to lend on new, unproven technologies and that there may be a role for the GIB in these projects.

3.5.4 **Implications for a GIB**

Progression up the waste hierarchy helps to reduce the carbon intensity of the sector and contribute to the urgent goals within the climate change strategy (Defra,2011a, b). It also addresses policy targets beyond the waste sector, contributing renewable power and heat and if advanced technologies are developed, potentially transport fuels towards the UK's renewable energy targets. This adds to the diversity of UK's energy mix and the use of waste from feedstock rather than virgin materials can bring about further greenhouse gas savings. The development of more innovative technologies can enhance the UK's science base.

In recent years, the non-Local Authority C&I sector has achieved higher rates of diversion from landfill than the municipal solid waste sector, and diversion rates are likely to be pushed higher by rising Landfill Tax rates. Yet, developers of non-Local Authority C&I infrastructure face a major economic barrier in the form of volume risk because long-term contracts are not available to them. Some companies are large enough to mitigate the volume risk through vertical integration and sufficient market presence. Others struggle to raise finance for merchant projects. This slows the market response, limits which players can respond and is likely to constrain the ultimate level of value recovery achieved in the sector.

The policy question is whether the enhancements to infrastructure will happen fast enough, whether they will deliver the most beneficial outcomes (including through the adoption of the most cost-effective technologies) and whether the market could be made more responsive through the intervention of the GIB.

The GIB might get involved in two ways: first in derisking/ encouraging the adoption of advanced conversion technologies, and second to speed the financing of merchant recycling and recovery facilities of various types, in order to drive waste further up the hierarchy.

3.6 Non-domestic energy efficiency

Incentives and resources have grown but market failures persist

3.6.1 **Introduction**

Economic theory tells us that the marginal return on one class of projects should be equal to the rate of return on other projects with comparable risk. Consequently, where industrial energy efficiency projects exist with good returns relative to their risk profile, a profit maximising firm should undertake them. Energy efficiency does improve over time (Pizer et al, 2001), but we should not expect to find that profitable energy efficiency projects are not undertaken. However, there is good empirical evidence to suggest that this is not the case. This finding is referred to in the literature and more commonly as the 'efficiency paradox' (Jaffe and Stavins, 1994).

There are a number of ways to explain why energy efficiency projects do not happen. One is that there are transaction and other hidden costs associated with energy efficiency projects, and when these costs are also included, they are sufficient to reduce the returns to the outstanding energy efficiency investments to such a degree that they are objectively unattractive. Of course, these hidden costs are difficult to quantify, and so it is hard to test this hypothesis. The other explanation is that there are market failures present.

3.6.2 **Market failures**

Whilst the literature on energy efficiency identifies many potential market failures, among them being externalities, perhaps the more interesting in the context of the GIB, are insufficient information and split incentives (the principal-agent problem). In terms of insufficient information, it could be argued that firms may have incomplete knowledge or information about the energy efficiency projects that are available to them, what the costs are and what the returns would be. In other words, some energy efficiency projects do not happen because management is not aware that they could. Furthermore, the information required to make sound investment decisions is costly to acquire (Sorrel, 2004).

The other main market failure cited is that of split incentives (the principal-agent problem) (De Canio, 1994a). Here the key point is that the incentives of managers and shareholders may not align: shareholders wish to see the returns on their investment maximised, while managers may prefer to focus on short term results, sometimes referred to as 'myopia'.

This managerial myopia is driven by managers only expecting to be in post for a short number of years and so needing instant results. Consequently they will only back projects where the return is quick. This may be reinforced by the pay structure which often incentivises short run profit maximising behaviour. Indeed, managers may prefer projects with rapid results as this has a stronger effect on their reputation. There also tends to be a focus of capital investment on output enhancement rather than input reduction (De Canio, 1994b). It is suggested that the former is particularly the case in situations where it is difficult to disentangle the effects of the manager's actions from say broader market movements.

Taking these factors together, it could be argued that energy efficiency projects can fall foul of this myopia as they are often characterised by up-front investment, with either longer payback periods or a difficulty seeing the effect of the project. For example if energy use rises, on the one hand this may be because the project did not work, on the other, because production has been made more efficient but output growth has outstripped the productivity gain.

For industrial plants and occupier-owned buildings, the principal-agent market failure is essentially about rational management myopia in the absence of shareholder control. For landlord-owned buildings, the principal-agent problem prevents sufficient investment in energy performance of the building because the capital costs fall to the landlord while the operating benefits accrue to the tenant. However, it is also possible to argue that good energy efficiency projects do not go ahead regardless of how good shareholder supervision is, because managers are fallible.

Managers may suffer from bounded rationality. In short, the world is a complex place and managers cope with that by generating rough approximations, rules of thumb (Simon, 1972). As a consequence, their behaviour becomes ‘satisficing’ or near maximising rather than maximising. They may also tend to fire-fight. So long as their intellect, skill and concentration is bounded, they tend to focus on the big issues of the day. Consequently, smaller projects, and in particular energy efficiency ones, if management is not familiar with them, can tend to be overlooked.

One benefit from energy efficiency is a reduction in production cost, which confers relative competitive advantage. Vivid Economics finds that the competitive advantages of cost improvements are often not well understood by managers because they are difficult to quantify, and so they are not fed into business cost-benefit calculations.

3.6.3 **Market barriers**

To develop some of the management bounded rationality argument further, it is possible to argue that especially when energy is a low share of costs, management is not concerned with energy efficiency as it is not a business success driver.

Finally, there are arguments around a lack of access to capital as a market barrier to energy efficiency projects. De Canio and Watkins conclude ‘The usual preference for internal financing, if relaxed in the case of energy-efficiency investments of low risk, could enable the capturing of profit opportunities that might otherwise be missed’ (De Canio and Watkins, 1998). For example, banks may be unwilling to invest directly in energy efficiency projects because the energy efficiency assets may have little recoverable value. They might require a charge over other assets, making the facility indistinguishable from general corporate or equipment finance. Indeed, as they tend not to supply project finance but to lend more generally to corporates, it is the balance sheet strength of the company that matters to the lender, and not the forecast return from the energy efficiency project. Within a firm, energy efficiency projects may not be awarded capital if they compete with other investments a firm could make that offer better returns. This issue can be exaggerated if managers misperceive the risk profile of energy efficiency investments and compare lower return but lower risk energy efficiency investments with higher return but higher risk alternative investments. Sub-optimal capital allocation can also occur where expenditure is compartmentalised into budgets within a firm. The implication of such an analysis is that some companies do not invest in energy efficiency projects because they are capital constrained either in general or in the budgets from which the capital would be drawn.

In summary, whilst the literature has put forward a number of explanations for firms' failure to invest in good energy efficiency projects it seems possible to advance another hypothesis in addition. That is that mangers focus on what is immediately important to their business. Therefore energy intensive companies are more likely to invest in energy efficiency projects than those which are not.

3.6.4 **The supply chain**

Energy efficiency improvements can be outsourced, and a market has grown up around the supply of energy and energy efficiency investment. In the US, it is focused in the public sector, under a Federal programme, and the supply firms are called Energy Service Companies (ESCOs). In 2008, 87 per cent of ESCO revenues came from public sector contracts and only 3 per cent from commercial and industrial contracts. ESCOs have found it hard to sell long-term contracts to firms in general and to get acceptance of monitoring and verification in complex industry (Satchwell et al, 2011). In the UK, the sector is known as Contract Energy Management (CEM) (Sorrell S. (2007). It is fairly well developed, with its own industry association, the Energy Systems Trade Association. Many of the larger players are subsidiaries of large utilities, such as RWE and GDF Suez. The turnover of ESCOs in the UK was just under €1 billion in 2006 (Bertoldi et al, 2007). Bertoldi estimates that they have access to capital of their own or through banks to increase funding to five times the current market level in the UK, €700 million.

There are two sorts of contract known as energy supply, which involves the supply of power, heat, or compressed air; and, energy performance, which has a greater focus on energy efficiency. The US market is predominantly public-sector performance contracts but the UK has developed a focus on supply contracts in the private sector. The introduction of energy performance certificates has helped the development of ESCOs in the UK, according to Bertoldi.

Sorrell describes further differences between the US and UK markets. In the US, around 95 per cent of performance contracts involve clients taking on debt, but in the UK, many clients prefer off balance sheet projects. He finds that project finance has rarely been applied to performance contracts, and concludes 'the key reason appears to be the difficulty lenders have in recognising energy cost savings as security for a loan'.

Bertoldi concludes that 'EPC contracts are perceived to be more risky, [and so] interest rates are high and debt terms are short]'. He goes on to say 'the real problem however is not the lack of funds ...but the disconnect ... between established methods of corporate 'asset based' lending and the special financing ...requiring 'cash-flow based' lending' (Bertoldi and Rezessy, 2005). There is a contrast between the length of supply contracts, which are typically 5 to 15 years, and corporate lending, which is typically for working capital and is shorter term.

3.6.5 **Evidence from interviews**

The hypothesis to be tested at interview was that because managers focus on what will have the most immediate impact on their business, energy intensive firms are more likely to keep a close watch on their energy costs and are more likely to invest in energy efficiency projects. Furthermore, as energy intensive companies are more likely to be large companies, they are also more likely to be able to invest resources in identifying and conducting energy efficiency projects. Consequently, there may be a correlation between business size and the uptake of energy efficiency projects.

Industrial companies interviewed in several markets all report enhanced management resources on energy efficiency in recent years, which they attribute to administrative compliance with new regulations, higher energy prices and emissions pricing. All three recounted that there is good knowledge of energy efficiency opportunities and that capital projects in this area face the same scrutiny and tests as other types of project. They all confirmed that investments take place wherever returns are high enough. In some firms, the payback period required is 5 years, while in others it is 3 years and in some even as short as one year: an example of severe capital rationing.

Evidence to the contrary was given by firms which provide energy and engineering procurement services to industry, and by a bank involved in a special energy efficiency lending programme. Here, there was a consensus of experience which confirmed the market failures analysis above: that energy efficiency receives little management attention, capital budgets are diverted towards output capacity and the landlord-tenant divide in buildings acts as a barrier to improvements in energy efficiency.

For those assessing the opportunities for energy efficiency from outside firms, there appear to be severe capital constraints in many companies, even quite large firms. It is difficult to supply capital from outside the firm because the legal advice makes the contract set-up expensive, and banks are not interested in lending to small projects. The energy procurement services companies themselves cannot supply capital. They have few assets. They need working capital to cover short–term construction performance bonds, but they could not offer 8 or 10 year lending: it would be too much of a tie.

There are no standard forms of contract in the UK, so each project requires its own investment in legal advice and due diligence. This is a contrast with the Federal public energy efficiency programme in the US, where standard tendering, contracting, performance monitoring and verification have been introduced, together with tax breaks which make the private capital extremely attractive to public bodies. A similar programme is to be found in Berlin, where the Berlin Energy Agency developed standardised contracts to facilitate the improvement of energy efficiency in public buildings in Berlin. The programme has been operational since the 1990s and has been effective in securing improvements. An interviewee suggested that the US Federal programme would be very much smaller in scale in the absence of the tax break for capital deployed in the programme.

The interviews also covered those offering energy supply and energy performance contracts to industrials, public organisations and commercial firms. These often involve contracts of 5, 10 or 15 years duration, allowing the capital cost of investments to be recovered. The capital amounts are in the range £2 to 10 million for energy plant in large industrials. Banks will sometimes lend against the receivables in these contracts, but in many cases the credit risk of the firm makes it difficult to obtain lending.

It was suggested that good contract design can overcome some of the capital rationing which results from a credit risk. The claim is that engineering service companies have not innovated the contract designs that are needed to overcome this problem, because their core competence is engineering not commercial contracting, and the banks have not innovated the credit assessment appropriate to energy efficiency investments because it is too specialist for them. Even the sophisticated UK financial services market has not offered lending secured against energy purchasing, although any firm or other organisation is forced to keep up its energy purchasing if it is to continue in existence.

The EBRD already operates an energy efficiency lending model for firms in Eastern Europe. It has the advantage that it is the sole provider of finance to some sorts of firms in certain geographic areas. If those firms are seeking finance, the EBRD is in a better position to impose terms. When agreeing a loan, generally for large-scale investment in industrial plant, it may offer additional lending to be earmarked for energy efficiency improvements. This is arranged as a part of the larger loan. It reports some success with this model, and has found management receptive and surprised by scale of opportunities available. The GIB might offer similar facilities to corporate banks to lend to customers, and if it were to do this, some thought will be needed as to the incentives for the corporate bank to participate and the channels through which monitoring, enforcement, and project opportunities would be identified.

3.6.6 **Implications for a GIB**

The themes which emerge from this evidence are:

- there are opportunities for improving energy efficiency which are not being taken up because finance is not available;
- in the case of projects of greater than £50 million capital investment, participation of the GIB at some level in the capital structure might help bring the other financial parties to contractual close;
- in the case of small and medium-sized projects, there is scope for innovation in contract design and finance in order to create lending products which are secured against energy performance contract receivables, and to standardise both the prime contract and the lending arrangement to reduce transaction costs;
- that for the small and medium-sized projects there may be potential to aggregate receivables contracts and thus create a portfolio which can be sold on to lenders and other investors, bringing down the cost of capital;
- there may also be opportunities to lend for the specific purpose of energy efficiency improvements alongside general corporate lending, like the model followed by the EBRD.

3.7 Renewable heat

3.7.1 **Rationale for intervention**

Non-domestic renewable heat is similar in many ways to energy efficiency measures, but different in some others. It is similar in that energy efficiency measures include the reduction of emissions from the supply of low- and high-grade heat for space heating and industrial processes through the replacement of inefficient boilers with efficient ones, or through insulation and controls reducing the heat load. Analogously, renewable heat includes measures where heat supply from a boiler is replaced or supplemented by heat supply from a renewable source. The renewable heat source has a higher capital cost. Some renewable heat will be sourced from biomass boilers, which involves boiler replacement, similar to certain energy efficiency measures.

As a consequence, renewable heat faces many of the same market barriers as non-domestic energy efficiency. These are discussed comprehensively in the previous section. They include market failures such as split incentives between landlords and tenants, focus on core capabilities, and prioritisation of revenues and market share over cost control.

There are also significant differences between energy efficiency measures in heat supply and some sources of renewable heat supply. First, the solar technologies offer uncontrollable, intermittent heat. Second, most of the biomass sources involve the purchase of a more expensive fuel, provision of fuel storage facilities, and reliance on periodic fuel re-supply. Heat pumps can involve ground works to access the heat source. This higher cost is offset by the receipt of revenues under the RHI, but it exposes the consumer to fluctuations in fuel prices which may be greater than under conventional fossil heating, and for which it may not be possible to hedge or fix under contract. This is a risk which the RHI payment can help to compensate for.
The supply of biomass is expected to come from within the UK and from overseas. Investment in the supply chain is expected to lag demand as the market waits to see how quickly demand grows. As a consequence, fuel supply costs are likely to be higher than they might otherwise be. Exchange rates also enhance the price risk as supply of biomass is required from overseas. A strengthening of sterling could increase the price of the imported biomass significantly.

Drawing the analogy with energy efficiency, there are three vehicles through which the GIB might become involved in renewable heat supply: restricted loans, large projects and ESCOs. The restricted loans are a type of corporate lending for specified purposes. The GIB would supply funds to corporate banks which would lend to firms investing in renewable heat projects. As with energy efficiency, it is not clear whether this arrangement could overcome the main market barriers or significantly reduce the costs of finance for the firm. It would have higher transaction costs and a lower loan size than traditional corporate lending. The second vehicle is large projects of sufficient scale to be financed off balance sheet. Here, like large energy efficiency projects, the GIB might participate directly on a pari passu basis with other equity sponsors or lenders. The number of projects of this scale coming forward will be small, but the GIB might tip the balance between a viable project proceeding and halting where the financing is nearly in place, but some additional funding is still sought. The third vehicle is ESCOs. These ESCOs are likely to offer renewable heat within their portfolio of capabilities just as they offer energy efficiency measures, so the GIB might participate in the same way, helping to bring together or complete the financing of aggregators which fund the projects, so that the asset lies not on the balance sheet of the customer, nor the ESCO, but with the financiers. With all three vehicles, the GIB can take the same approach to energy efficiency and renewable heat when making investments.

In addition to the financing of the renewable heat plant, the GIB might consider involvement in the biomass supply chain. The supply chain will involve aggregation, logistics, storage, growers and waste managers. It is likely to be fully within the private sector and investment would take place on the balance sheets of the firms involved. Market pricing may not be well enough established and project scale may not be sufficiently large to make project finance worthwhile. Hence if the GIB is to be involved, it would be to provide restricted lending via corporate banks and the rationale would be that the banks are unwilling to sponsor renewable heat supply because they cannot assess the commercial and market risks in a rapidly expanding, immature market as well as being reluctant to invest to develop expertise in this area. The GIB's involvement allows them to gain experience while free-riding on the GIB's sectoral expertise. After some time, the GIB would be able to withdraw, leaving the banks to provide a full service to the supply chain. If successful, the increase in availability of finance would allow the supply chain to expand more quickly, increasing competition and scale and bringing down costs. This would enable the renewable energy targets to be hit more cheaply and increase the likelihood of compliance with it.

3.7.2 **Alternative policies**

The alternative policy is to monitor how much renewable heat is supplied under the RHI and to increase the level of support to projects if the pace of development is lagging behind target. This is analogous to the increase in Renewables Obligation support for offshore wind. It has the effect of rewarding all new projects with additional incentives, creating additional transfers from consumers to renewable heat users: it is a blunt instrument, not targeted on the supply of finance. Hence the GIB intervention would be a more targeted and therefore, more efficient instrument, offering better value for money if the sector is struggling to obtain finance because lenders are struggling with poorly-quantified risks.

3.8 Low carbon projects within the Green Deal

A finance mechanism to increase investment in energy efficiency, primarily in the domestic sector

3.8.1 Rationale for intervention

The Green Deal has some key features that help overcome energy efficiency market failures. In addition to the novel finance mechanism that allows costs to be borne by consumers only when they receive a benefit, the Green Deal will only finance measures that pass a 'golden rule'. This rule is that 'the charge attached to the bill should not exceed the expected savings, and the length of the payment period should not exceed the expected lifetime of the measures' (DECC, 2011d, p. 11). Furthermore, the charge is levied on the point of electricity supply, so a consumer taking part in the Green Deal ceases to pay the charge should they move. The charge will continue to be paid by the next occupier, who also benefits from the energy efficiency investment implemented by the previous occupier. These features allow the Green Deal to overcome poor access to capital, high discount rates and incentive incompatibility, which are some of the market failures facing energy efficiency (DECC, 2011e, p. 16).

Significant consumer safeguards and the accreditation of advisors and installers are also part of the Green Deal. These aim to provide assurance and information, which tackles the other energy efficiency market failures of inertia and information failure.

The Green Deal creates a novel mechanism for paying for energy efficiency improvements since the measures are packaged with the finance and payment is taken with the supply of energy. This is supported by the statutory regime relating to the recovery of energy bills from customers to the recovery of payments for energy efficiency improvements. What is more unusual still is that the liability passes from one occupier of a property to the next because the liability is registered with the meter point rather than with a person. From the investor's point of view, the advantage is that the proportion of energy payments that are not collected is low and the systems for chasing payment are already in place, so little additional payment infrastructure is needed. From the consumer's point of view, the advantage is that the capital costs are spread out over a long period and the cost of capital is low because the loan is secured against the meter.

The Green Deal providers will write contracts with customers to install energy efficiency measures and micro-renewables. They will invest capital in properties and obtain access to a stream of payments in compensation. However, Green Deal providers do not want to hold Green Deal debt (which may be up to 25 years) on their balance sheets for long periods. If existing sources of finance were utilised by the Green Deal Providers this would also create an uneven playing field between utilities (who can already access finance at low rates) and other potential participants, limiting their ability to compete effectively. The market research carried out by DECC suggests that the novel nature of the contract and, in many cases, the small portfolios of debt being offered for sale, means that there will not be a market to buy the debt from Green Deal providers. However, it is desirable to take the debt to market so that the providers can clear their balance sheets and continue writing contracts, to stimulate competition and innovation among a wide range of providers, and to aggregate and scale up the debt, thereby reducing the cost of finance.

DECC has been consistently advised that accessing the capital markets will provide the lowest cost of finance for all Green Deal providers. This suggests a creation of one or more aggregator vehicles to warehouse debt from a number of different Green Deal providers and refinancing via bond issuance once sufficient volume had been reached. On-going consultation with potential market participants by DECC suggests that the novel nature of the contract and perceived political risk associated with demand means that there is not appetite for finance providers to invest risk capital in such a vehicle in the initial stages until ‘proof of concept’ has been achieved.

DECC is aware of at least one consortium involving banks, potential Green Deal providers and energy companies that is looking to establish a special purpose vehicle (SPV) to buy and aggregate Green Deal debt. The consortium may approach the European Investment Bank seeking senior debt at some point. The banks in the consortium may also contribute the debt, but would not provide equity. The GIB could potentially supply this missing tier of capital to establish a fund. Its presence may immediately, or over time, attract other equity participants. Once the fund establishes a successful track record with appropriate risk-reward profile, the GIB may sell its stake in the fund. Alternatively the SPV could buy the fund out over time. In these circumstances it would therefore have a catalytic role in establishing the market. It is currently unclear what level of initial equity commitment would be required but it could be up to £100m. The requirement would also depend on take-up of Green Deals in the market.

In these circumstances the GIB would become involved because if no other market participant was willing to do so, or only on condition the GIB were involved. In the former circumstance, it would be more difficult to prove that GIB’s participation was at market rates or to supplement other sources of capital lending.

Some of the activity under the Green Deal, indeed perhaps a large part of it, will be driven by the Energy Company Obligation (ECO). This is a regime whereby supply companies pay for part of the costs of energy efficiency measures in some households and recover these from across the customer base. The arrangement makes it easier to design packages of measures which satisfy the Golden Rule, that the Green Deal charge is no greater than the energy bill. A lower cost of finance would increase the range of measures that satisfy the Golden Rule. There would be a trade-off between take-up of Green Deal measures and the rate charged on Green Deal - a concessionary rate of return on the investment might stimulate more take-up, however, low returns would make later refinancing or sale to private investors more difficult. Market research might establish how the cost of finance affects take-up.

3.8.2 Alternative policies

Alternatively, Green Deal providers and energy suppliers could use their own balance sheets, and become investors in Green Deal contracts directly. This would place potentially significant extra demands on their balance sheets particularly for energy companies operating at a time when they will be stretched to deliver investment in generation and network. Therefore, it would be preferable to keep these assets off the utilities’ balance sheets. Since without a large scale financing vehicle, SMEs and some retailers would not be able to compete with utilities on price, they would be unlikely to participate in the market. This would leave the market to be dominated by the utilities, reducing the benefits to consumers of competition and the extent to which the Green Deal stimulates the wider economy. Further details of the Green Deal are given in the Energy Bill Green Deal Impact Assessment (DECC, 2011e). Qualitative and quantitative value for money measures are discussed later in the report.

3.9 Nuclear Power

3.9.1 Rationale for intervention

Nuclear power plant are not the most capital intensive of the low carbon power generation technologies (PV and offshore wind take that accolade), but they do come in the largest minimum scale of investment, with individual projects costing around £5 billion per reactor. This scale is so large relative to the initial capitalisation of the Green Investment Bank that the Bank may find it challenging to play any significant role in plant financing. The government has made a commitment to no public subsidy, so the GIB could only act under the Market Economy Investor Principle. So, after exploring the possibilities for plant finance, the opportunities for financial support to the supply chain are considered. The supply chain has lower capital requirements, which may make it a more appropriate client for the GIB.

The first few plant investments are likely to be made against the balance sheets of the utilities. They will compete with all the other investments that the utility is considering in particular the investments to upgrade and update other infrastructure. This is likely to limit the amount that will be available to investments in nuclear plants and the progress that is required in the timeframe to make a contribution to the reduction in CO_2 emissions. As more plants are built to time and cost, then there may be the possibility of financing projects in different ways. The analogy with offshore wind is strong, except for the regulatory aspects. The GIB might, for example, supply contingent debt to a project during construction freeing up some of the capital for other investments. This facility could be drawn down under specific or general circumstances of capital cost over-runs. Alternatively, or in addition, it could participate in refinancing after construction, allowing an initial investor to exit some of their equity.

As with offshore wind, these models would only proceed if they are attractive for all the financial participants, but, unlike offshore wind, there is the additional requirement for regulatory clearance. The nuclear sector has a regulatory regime to ensure high standards of safety and the licence for a nuclear site requires the licensee to have a high degree of operational and financial control over the plant. It may be the project finance models which do not give recourse to a financially strong and technically competent parent would not gain regulatory clearance.

The capital unit size of nuclear plant is high. Each plant costs several billion pounds. As a consequence, the GIB's resources as currently constituted would be able to play only a small role in a scenario in which multiple plants are being built. However, such a scenario might strain the capital resources of the utilities as well. In due course, and in the right circumstances, this could become a reason to expand the resources of the GIB.

Turning to the supply chain in the UK, the question arises whether the GIB might provide finance to firms looking to supply to their home market, with a view to expansion into global markets. For the time being, the suppliers face uncertainty because developers have not made final commitments to build new plant, and will not do so at least until regulatory approvals have been received. It will have been 20 years since the last nuclear plant was built in the UK, and these firms have experienced little demand for new nuclear plant in the UK over that period. Some of the firms may need to raise finance in order to take on contracts for the new build programme, and they may depend on other firms in the supply chain for specialist materials or fabrication. A question is whether the firms have sufficient access to finance to meet the demands of the new build programme, and whether lack of finance could impair the efficient function of whole segments of the supply chain. There may be critical parts of the supply chain where bottlenecks are expected due to globally rising demand for nuclear power. If these bottlenecks are discovered, and some are found in the UK, then the GIB might fund investments which relieve these capacity constraints. An illustration of the circumstances in which this might arise is where the contract size is large relative to the firm's turnover, and a temporary expansion of the firm's activities is warranted. A conventional commercial lender may feel that there is insufficient security for the loan in the form of debentures over specialist plant and materials, and the firm may need to invest in designs and staff training which offer no security at all. The GIB might be prepared to supply finance with lower levels of security and might strategically value the multiplier effects of the firm's activities in that sector. These are questions which the GIB may wish to investigate further. They could only be answered through quite detailed conversations with firms in the supply chain, with developers and with financiers.

3.9.2 **Alternative policies**

Suppose, as a result of investigation, it is found that there are bottlenecks in the supply chain which are of financial origin and could be solved by the GIB. How else might they be solved? Take, for example, a specialist manufacturer which wishes to invest in tooling and prototyping work and the company wishes to borrow money. Given that banks or other investors are unlikely to be familiar with the industry or technologies as demand in this area in recent years has been relatively weak, they are more likely to misprice the risk.

It is difficult to envisage alternative government interventions which might be effective in these circumstances. Here is a specialist firm in need of expanding its balance sheet. General raising of revenues available for nuclear generation would be a blunt instrument and might not filter down the supply chain, particularly in advance of contract negotiation.

3.10 Photovoltaics

3.10.1 Rationale for intervention

The supply of PV forms a global market. It is a fast-moving sector with leaps in technology and rapidly increasing deployment. Most of the large-scale manufacturing takes place in China, with installation in the UK divided between large and small-scale installations. The large installations contribute most of the power output but the small installations constitute the largest number, and are carried out by a large number of small firms.

The UK forms a small part of the global market, and although the technology is developing rapidly, the sector has currently access to substantial capital to fund product innovation and capacity expansion. Any GIB investment in the manufacturing supply chain would have to demonstrate value when ranked against other uses of the funds.

The technology has high upfront costs and low operating and maintenance costs. It also enjoys a long operating life. Until recently, the returns on capital employed have been too low to attract financial investors and project developers, but for a while the FiT has offered a high enough subsidy to bring both groups into the market. Until they became involved, only a small number of households took up PV and they paid for it out of cash reserves.

Now that the subsidy level is being cut, the installation rate of large 'solar farms' is expected to fall. The evidence suggests that over the next few years the unit costs will fall substantially too, and that returns on investment may become attractive under the two ROCs support mechanism. The efficient finance of PV will then start to make a great difference to life-time costs of generation, capital availability, and for both reasons, uptake. Some firms, public organisations and households will have sufficient free capital to make investments in PV, but the required return for firms will generally be between 12% and 25%, limiting uptake. Households may pursue PV under the Green Deal, which is covered elsewhere. This leaves public organisations. The public estate is large and offers enormous potential for PV. It is also severely capital-constrained with capital budgets often separated from operating budgets and with organisations having restricted borrowing powers.

The GIB might have a role to play in both the household sector (through the Green Deal, which is covered in 2.6) and the public sector. In the public sector, the GIB might provide low cost finance either directly to public organisations, or indirectly via PV developers, banks or the Public Works Loan Board (part of the UK Debt Management Office). Once installed, PV requires little maintenance and no operational capability on the part of the public organisation, so it is ideally suited to simple financing arrangements. The GIB could create a number of standard public sector financing contracts approved by Treasury and suitable for financing PV. This would reduce the transaction costs and capital allocation hurdles for PV installations. Since a risk assessment might be expected to show a low level of risk, the financing arrangement might lead to a dramatic increase in take-up. In helping to drive scale in the installer supply chain, it would bring further benefits in the form of lower costs for households and firms. Furthermore, the development of technology in PV to further generations of solar panels could potentially lead to more involvement of the GIB in this sector once new technologies have passed the demonstration phase and are ready for commercial deployment. However, this is not expected to be the case in the near future.

3.10.2 Alternative policies

An alternative is to increase the level of subsidy for PV power. The PV market is sensitive to the level of subsidy, evidenced by the jump in installation when the FiT was increased for a period. A higher rate of subsidy would achieve an increase in scale, but would not improve the efficiency of financing, nor address the barriers to capital allocation within the public sector. With the technology changing rapidly and unit costs falling, it is also difficult to control. Periodic adjustments to the level of support are needed, and this brings with it political difficulty (protest from sector interests) and risk for investors. Furthermore, an increased subsidy might also create deadweight given that projects might receive the subsidy which would have been implemented anyway. In contrast the GIB intervention would be more targeted to the projects on the margin of being viable and where the issues outlined above might apply.

For local authorities, Parish Councils and internal drainage boards, the Public Works Loan Board could offer a finance product for PV installations. These loans would be secured against the revenues of the authority and subtract from the remaining borrowing capacity of the local authority. However, the PV investments would compete directly with other claims on the local authority's budget. In contrast, the Green Investment Bank might secure the loan with a charge over the revenues from the PV itself, effectively taking the PV investment off the local authority's balance sheet. This is likely to result in a much higher rate of take-up and could be attractive if, for example, there is a sudden rush of demand.

3.11 Marine

3.11.1 Rationale for intervention

Wave and tidal stream devices are at an early stage of development. They are so new that the first few small demonstration projects have only logged a few years of operating time, and there are currently no larger array-based demonstration projects in existence. The WaveHub infrastructure project is intended to encourage the deployment of some of the first arrays.

Now that they have moved out of the engineering workshop and into testing at commercial scale, and now that there have been sites licensed for multiple-hundreds of MW of capacity, large-scale deployment may begin later this decade. The technology developers, some of which were once very small enterprises with little capital, have grown and now enjoy the backing of large global firms with technology, engineering contracting, power generation and finance experience, such as Siemens, ABB, E.ON and Morgan Stanley, to name a handful. This gives them both the opportunity and the capability to scale up and contribute a significant amount of energy to the UK.

Kreab & Anderson (2010) in their investor survey for DECC point out the major risks perceived by investors were:

- technology: corporates, in particular, worry that they technology is at an early stage;
- high industry fragmentation: banks say that the sector is too small and fragmented for them to invest;
- large start-up costs: venture capital funds have a lifetime of around ten years, which is not long enough to realise profits on a typical wave or tidal stream project.

To date, the sector has relied on grant funding for capital and revenue support, and for the next few years this is likely to continue, to complete the testing of small numbers of machines of various designs. For the next few years, production will lack scale and unit costs will remain high. The first small arrays may also be funded in this way, but larger arrays will be beyond the budgets of central government and regional development agencies. They might be subsidised wholly through revenue support, such as the Renewables Obligation. Like wind power, these technologies are capital intensive, and when large-scale deployment begins, later in the decade, or early in the 2020s, it will need mainstream sources of capital finance at a scale of multiple hundreds of millions of pounds per annum, involving the balance sheets of utilities and other energy developers. The achievement of scale in production brings the promise of lower unit costs.

It is rather too early to predict whether the costs and performance of some of these technologies will be sufficiently attractive to make it a commercial substitute for offshore wind and other renewable technologies, leading to large-scale deployment, but it is a possibility on current evidence. If and when it happens, the projects may be rather similar to offshore wind projects today, albeit perhaps at a smaller scale, reflecting the lower energy potential of wave and tidal power. There would be deployments of arrays, on the scale of large marine engineering projects, with capable equity sponsors and banks participating either from construction, or later, when refinancing a working project. If the sector offers sufficient overall scale to make it profitable for banks to enter the sector, and if sufficient track record is available to provide comfort to lenders' credit committees, then the banks may provide capital. If the history is too short, as it will be initially, or the scale too small, or if there is a strong policy need for fast scale-up of deployment, then banks may not be in the market as a lender at sufficient scale or at all. As has been seen in interviews of the financial community relating to offshore wind, some investors will stay out if they cannot assess the probability or severity of downside risks. In other cases, they might demand high returns in order to participate, and this might make the economics of the project unattractive to the principal sponsors.

This is where the GIB can step in, being able to accept a degree of uncertainty, supplying mezzanine debt to cushion senior debt from risk, or as a senior debt lender. As with its offshore wind product, the mezzanine debt could be designed to modify the senior debt characteristics to bring them within a bank credit committee's lending criteria, thereby giving access to debt at a reasonable cost, making a geared project work commercially. This helps attract equity too, because a geared structure enhances the equity returns (and risk), and may bring it into the range necessary to attract the investors which these projects need.

The GIB could play a role especially in the episode between the construction of the sector's first large-scale arrays and the proving of them. This period requires substantial capital and it is likely to be difficult to obtain any from lenders, except for the GIB. The GIB may make the financial structure of these larger projects work. Once they become established, the financial markets can take over the model that has been established, making use of performance evidence that has been obtained, and the GIB may withdraw.

In playing this role, the GIB would support learning which would disseminate improved practice and design across the sector, and commercial learning which would propagate within financial markets: both are public goods. It would also overcome information asymmetry by building a track record of financial performance similar to that which would be achieved in offshore wind.

The experience which the GIB gains in other sectors, such as offshore wind, is likely to indicate what role it can play in the marine sector.

3.11.2 **Alternative policies**

The most plausible alternative to a GIB is to raise the level of renewable energy revenue support, through the Renewables Obligation or a feed in tariff. There have already been calls from within the sector for a substantial increase in the reward level for this sector. Even then, the individual marine technologies may be at different stages of maturity and might have different costs, requiring different levels of support, creating considerable complexity or inefficiency in the scheme. This is a particularly acute issue in marine because of the diversity of technologies under development and the rate at which unit costs may change as learning takes place and economies of scale are built up. The GIB approach potentially ameliorates these differences in need because it absorbs the technology-specific risks, and is better able to facilitate finance than revenue support is able to attract it. It is able to tailor financial products for specific technologies and standardise risk levels through credit-enhancement.

If neither the GIB nor premium revenue support were used, then the arrays built would be smaller in size as they would be wholly equity financed, and they may continue to be limited by the amount of capital grant available. The pace of deployment could be substantially lower. The Danish experience of wind power development was that considerable, sustained capital grant support by the state was needed. In the do minimum scenario, it would take longer to build up the scale of activity and track record to bring the sector to a position where its unit costs were attractive and its risk profile fitted lenders' commercial models.

However, given continued state support, it is quite possible that it would achieve this outcome eventually, at which point large-scale projects could be undertaken.

As has been seen in the detailed analysis of offshore wind, waste and energy efficiency, the GIB is able to achieve results with much lower transfers than broad price support instruments. The same benefits from the GIB might be expected in marine energy.

In summary, the GIB may allow a more efficient financial structure to be adopted in the early stages of large-scale deployment. The cost of these projects to the consumer and taxpayer would be lower with the GIB because the instrument is cheaper, being better targeted and because the cost of finance would be brought down through a faster expansion of assets in the sector and the increased availability of information on the track record of the assets. By expanding the pool of capital willing to participate such that it includes lenders, the GIB creates further value. It increases the scale of commercial investment that takes place in this phase of the sector's development, or put another way, it brings forward in time the benefits from the sector's expansion.

By developing scale deployment early, the UK might retain the leading design, manufacturing and construction capabilities that it currently enjoys in this emerging sector. This would have benefit in adjacent sectors, through the increase of capability and scale which are the foundations of competitiveness. This would raise income levels and returns on capital directly in the marine energy sector and indirectly in adjacent sectors, potentially contributing to the growth of the UK economy.

3.12 Carbon Capture and Storage

3.12.1 **Rationale for intervention**

CCS is thought of as a novel sector, not because the technologies which it encompasses are individually new, which they are not, but because their application and commercial packaging is new. No one yet knows how well the technologies will perform when attached to power stations and other large combustion plant, nor the best way to structure the commercial arrangements. Furthermore, there is a question mark around how the three parts of CCS will fit together in one business model. This novelty has the potential to constrain finance that is available to firms, since all three parts must be in place for this business to work. Uncertainty around this and the lack of familiarity of investors with these models (although they might be familiar with the technologies on their own) might prevent them from investing or over-pricing the risk due to a lack of information/ track record of the company in this area. The GIB could provide a signalling function in this market indicating the viability of certain business models and helping to establish a track record in this area.

While the components themselves are not new, the application of capture plant to large-scale combustion processes is new, and since it is the most expensive of the components of the CCS system, considerable scope for cost reduction is expected. For these reasons, the capture technology is one of the focuses of research and development funding in the UK.

The government aims to support four commercial-scale demonstration plants. The first of these will receive some capital grant funding and revenue support. The subsequent three will receive revenue support only. The projects comprise capture assets, together with pipeline and storage facilities. It may be that there is some sharing of infrastructure between the projects, but it is equally possible that each operates independently, with its own infrastructure.

Since support for the additional projects will be paid principally through revenue, the projects will require finance, and given their large scale, there is the option of choosing project finance or balance sheet finance. If the former route is chosen, the GIB might become involved as a lender. This might be particularly attractive to a firm whose investment is a high proportion of its balance sheet, which could be the case for smaller firms, given that balance sheet borrowing might be limited for them. Although attention is currently focussed on the demonstration programme, thought may also be given to the deployment phase which would come in the 2020s.

The government has chosen a market arrangement in which pipeline infrastructure is developed by third party firms acting as merchant developments. Funding for pipelines will be available through the demonstration programme, but only to the scale needed for the purposes of the demonstration projects. However, many of these demonstration projects are likely to be located in regions of the country where there are high level of carbon dioxide emissions and where, at the point CCS is deployed in line with forecasts, there would be considerable financial benefits in expanding this initial pipeline investment to anticipate this future demand. The marginal costs of investing in pipelines of greater capacity at the time of demonstration is relatively modest. So, for example, DECC estimates that expanding a typical CCS pipeline from the scale needed to handle a single installation to a cluster ten times larger would about double the cost of the pipeline (DECC, 2010f). Current DECC policy encourages private capital to invest in additional pipeline capacity, but because of uncertainty about the timing of additional demand DECC believes that private capital is unlikely to be forthcoming to meet this requirement.

Therefore, the pipes are likely to serve a single installation initially. Other installations might join in time, but with the first demonstration plants proceeding in 2014/15 and broader revenue support beyond the demonstration programme not likely to commence before 2020, it could be some time, perhaps seven to ten years, before other users join the first pieces of the nascent networks.

Commercial planning of the first pipelines is likely to be advanced by the end of 2012, so the GIB might explore the case for its involvement during the course of 2012. It might similarly look at the case for lending to storage developers. There could be opportunities to lend if a project finance route is chosen or if the developers are small relative to the capital expended.

The GIB has a strategic reason to expend effort in understanding this small, nascent sector, because CCS deployment helps to achieve policy objectives. This makes the GIB better able to invest in credit assessment and due diligence in what is a small sector, and in due course, when the sector achieves scale and track record, commercial lenders might participate alongside the GIB. If and when the sector becomes well established, the GIB could sell off its loan book to commercial lenders and reinvest its money elsewhere.

3.12.2 **Alternative policies**

If the CCS developers (capture plant, pipelines or storage) find it difficult to finance the demonstration and early deployment projects, the government could, instead of making commercial loans available through the GIB, provide higher revenue support or capital grants. Of these two options, revenue support has already been chosen as the main mechanism for the demonstration programme and is likely to be preferred. It offers strong incentives to deliver performance, which makes it attractive.

It may be cheaper to supply finance via the GIB than to increase the subsidy level via revenue support. This makes the GIB potentially more attractive than the alternative policy.

3.13 Onshore wind

3.13.1 **Rationale for intervention**

Onshore wind is a mature sector with established players and supply chain. Wind farms have been operating onshore in the UK for two decades and there is a large global market and support infrastructure, supplying a significant proportion of power in some countries.

In the UK, most of the onshore wind power generation is owned by energy utility companies, with a fringe of smaller independent owners. Capacity has been expanding steadily, limited by land use planning controls, with more than half of applications turned down over recent months. There is no evidence that there are difficulties obtaining finance for good quality projects and a number of banks are familiar with the sector and are lending to it.

The GIB might keep open the option of participating in onshore wind so that if circumstances change adversely it is in a position to intervene.

3.13.2 **Alternative policies**

No GIB intervention is proposed in this sector and therefore, alternative policies and value for money have not been considered.

3.14 Smart meters

3.14.1 **Rationale for intervention**

The government intends to place an obligation into the licenses of energy suppliers to install smart meters and to complete the rollout of smart meters for all households and smaller non-domestic customers in 2019. The total investment is in the order of £11.7 billion. Thus suppliers will generally be expected to arrange the capital funding to deliver the rollout and they will be in breach of license if they do not. Most of the suppliers are part of integrated energy companies who will have a wider capital programme that includes new generation plant.

Although the supply companies will have an obligation to deliver meter roll-out, they are not obliged to take ownership of the meter. Ownership and operational responsibility could sit with a third party. This third party would then need access to capital.

The revenue stream to pay for the upfront and ongoing costs of the meter will come from the current supplier, and in the event that a customer switches supplier, the new supplier will undertake to pay revenue. On the revenue side the assets are therefore relatively low risk, because they benefit from statutory arrangements for the payment of energy bills, although they will still be exposed to supplier counterparty risk.

There is currently no indication from energy suppliers that they expect difficulties in raising the capital required for smart metering investments. An involvement of the GIB in this sector can therefore not be seen as a requirement that delivers any additionality. However, there is uncertainty regarding the cumulative effects of the decarbonisation of the energy sector on access to investment capital and a beneficial role for the GIB at some point in the future should not be ruled out at this stage. Where capital constraints for energy investments, including smart metering equipment, might occur in the future, the GIB could provide gap financing and bridging capital on a temporary basis. The GIB should do so on a strictly commercial basis, the only difference to a commercial lender being that the GIB would also apply environmental criteria in its decision whether to provide funding for a project.

3.14.2 **Alternative policies**

The value for money case for smart meter investment is sound, particularly in the non-domestic sector, and is discussed later in this report. The green impact and social benefits are higher than in most other minor sectors under consideration. But because there is no indication at the moment that industry is concerned about raising the funds required for smart metering investment in the private market, it seems that the GIB would not be needed in this case, given that finance on commercial terms is available already. However, in light of aggregate capital requirements for the decarbonisation of the energy sector this situation might change in the future and the GIB might be able to ameliorate a potential lack of capital by providing further finance on commercial terms.

3.15 Plug-in vehicle recharging infrastructure

3.15.1 **Rationale for intervention**

It is expected that the majority of plug-in vehicle recharging infrastructure will be installed at the two thirds of households who have off-street parking, at work places and at large retail sites. These are expected to be financed privately and they will cover the majority of journeys people make. Recharging facilities will also be introduced in areas where there is no off-street parking and perhaps to provide rapid charging on long-distance routes. It is the on-street parking which is of most interest for the GIB.

The demand for infrastructure which drives its utilisation is extremely hard to judge. Neither consumer behaviour at a recharging point, nor the level of charge delivered, nor future vehicle demand at specific geographical locations is known. And yet, since electric vehicles and charging infrastructure are consumed jointly, growth in vehicle ownership will be constrained by the under-provision of recharging points. Conversely, demand for recharging services will depend upon investment decisions and technical progress in the automotive sector.

From the perspective of a lender, investment in charging infrastructure looks risky because so much is unknown. From the perspective of government, electric vehicles are a key part of the transition to a low carbon strategy, and in order to contribute to carbon targets, the penetration of electric vehicles is assumed to proceed at a certain pace. If it does not, more effort will be needed elsewhere.

The coordination needed between vehicle adoption and infrastructure provision and the novelty involved create ideal conditions for market failure in the supply of investment. The coordination problems can also raise the costs of the project (for example with respect to the enforcement of contracts with all parties involved) to the point that the project would not be viable anymore.

In due course, a number of players might choose to participate in the infrastructure roll-out, including the power utilities, but the main suppliers in the market now are small companies such as POD Point and Chargemaster. As the commercial models develop, it may be that the GIB can play a role in the finance of the infrastructure assets which use their technologies, or it may be that private investors seize the opportunity without the GIB's involvement. The market is at such an early stage that it is difficult to predict what will happen and whether there will be a gap to be filled by the GIB.

3.15.2 **Alternative policies**

An alternative policy could be to require electricity distribution companies to provide public charging points through their Regulated Asset Base. This would require legislative and regulatory changes and the obligation would be difficult to specify. It would be difficult to effectively target infrastructure as provision would be top-down rather than demand-led. Charging infrastructure would be unlikely to be central to the distribution company's businesses meaning that cost reduction rather than location optimisation is likely to be the main consideration. In addition sharing the costs of infrastructure across all electricity consumers via the Regulated Asset Base raises issues of equity that would need to be addressed.

3.16 Rolling stock

3.16.1 **Rationale for intervention**

The rolling stock programme is associated with major expansions of rail services and the renewal of obsolete fleet. The investments are large and in the past these assets have been financed through specialised asset-backed operating leases. These are quite suitable for ownership by financial institutions and bank lending, and a number of financial institutions and banks have been involved in owning and financing UK rolling stock companies.

The question is whether these companies or new entrants will be able to raise the capital to finance the new rolling stock which the UK's transport programme involves. The market evidence collected by DfT indicates that there will be sufficient appetite in the capital markets to finance privately this investment to a maximum of £1bn a year. If, as the processes of procurement proceed, it transpires that there is some but not sufficient capital available, then the GIB could participate on *pari passu* terms to increase the pool of capital available. It might wish to keep open the option of becoming involved in this way, however for the near future it is clear that the existing arrangements for rolling stock financing are secure. Value for money case for rolling stock is considered later on in this report.

3.16.2 **Alternative policies**

The alternative would be to change the terms of the new train operating franchises to make it easier to finance the rolling stock companies (ROSCOs Policies which have been considered and rejected by the government include:

- creation of a fourth ROSCO;
- the provision of government guarantee to lenders;
- direct purchase of rolling stock;

Another attractive option would be to change the price of a franchise contract to cover a higher cost of finance, however, this is unavailable as franchise contract prices are set by a competitive process.

3.17 Flood defence

3.17.1 **Rationale for intervention**

Flood defence has always been funded from a mixture of operational and capital budgets. Local authorities and central government have been the principal sponsors, and it used to be that central government controlled capital spend on all major projects. The responsibility for funding is shifting towards partnership arrangements between national and local agencies, giving more control and accountability locally. Therefore, local authority capital availability will become a more important factor. Now, central government will fund some schemes more than others, allowing local choices to be made on whether a project is worthwhile taking forward at all, and if so, who might fund the rest of the amount required.

Local authorities have prudential borrowing powers, which means that they can borrow so long as they keep within their means, and have a number of routes available to them to fund capital projects, including loans from the Public Works Loans Board (which has not been a popular source of flood defence funding in recent years) and public private partnerships. Proposals being brought forward under the Localism Bill and Growth White Paper, such as tax increment financing, the new homes bonus and business rates retention, offer the potential for new sources of funding and revenue financing at the local level. The majority of flood defence investment protects existing properties and assets at risk of flooding and coastal change. In cases where new defences are built to protect land under development, there is scope for capital contributions to be obtained from developers (either through the Community Infrastructure Levy or Section 106 planning obligations), or in a few cases, where the land belongs to the local authority, for the development to be carried out through a public private partnership or an alternative asset-backed vehicle that covers commercial development and flood defence.

If the GIB were to lend to local authorities, it would be a substitute for the Public Works Loans Board. It would offer similar loan products, operating within the local authorities' borrowing limits, and there would be no additional benefit from its activities.

On the other hand, there may be circumstances in which private developers are seeking capital for flood defences to protect land development schemes. Here, if the financial structure is suitable, the GIB might become involved.

3.17.2 **Alternative policies**

One other option, which might increase the availability of capital for flood defences is to create long-term service contracts written between local authorities and private providers of flood defences. Under such an arrangement, the local authority would take on the liability of a long-term contract and the private firm would invest capital. It is not clear whether the local authority would find relief of its capital constraints given the contractual liabilities that it would take on. As with the public private partnership model, only if the local authority's capital leverage is extended would there be additional benefits. Long-term contracts also reduce the flexibility for risk management authorities to change requirements and take alternative approaches as the understanding of risk improves over time, and as priorities change. The alternative for the Local Authority is to borrow from the Public Works Loan Board, a statutory body operating within the Debt Management Office, itself an Executive Agency of HM Treasury.

Another, more radical option, is to create a flood defence utility locally, similar to a drainage board, with powers to levy charges on households and businesses. This could be a stand alone utility or subsumed within existing water and sewerage utilities. In this circumstance, the utility would raise money privately and might have legal protections which give investors comfort, allowing it to finance itself efficiently. However, difficulties in identifying and charging individual flood defence beneficiaries will be problematic, given that flood maps are inherently uncertain especially in relation to surface water flooding. Further, unless cross-subsidised, charges would be prohibitively expensive for the relatively small numbers of property owners concerned. If cross-subsidised, the charges would be classified as part of 'tax and spend' within the national accounts, therefore offering no advantage (and several significant downsides) in comparison with revenue raising through general taxation. Defra consulted on a flood plain levy in 2003 and this was rejected due to political sensitivities as well as practical difficulties in creating a charging mechanism that captured the betterment provided by defence projects but would not be open to challenge by those identified as beneficiaries.

There appears to be little merit in the GIB offering loans to Local Authorities who already have access to funding from the Public Works Loan Board. There are already provisions for private land developers to make financial contributions to local authorities to supply flood defences for new developments. There are also arrangements for requiring developers to erect protections for the developments themselves. It may be that there are cases in which additional funding, if it were available, would result in a higher standard of protection, generating benefits substantially in excess of the costs. What is less clear is whether there would be assets in the form of receivables contracts as collateral for the loan, since most flood defences are currently paid for out of general taxation. For these reasons, there is no clear opportunity for the GIB in this sector at the present time.

4 Value for money and cost-effectiveness

The GIB's targeted intervention reduces the need for transfers associated with alternative policies

Section Contents:

Section Summary

The value for money analysis conducted here uses scenarios of future policy demand for investment, coupled with sensitivity analysis around the cost of projects, to explore the net economic benefit of investment programmes supported by the GIB. It makes assumptions about the rate at which the GIB's capital levers the participation of other capital, and further assumptions about the strength of alternative policy incentives that would achieve a similar effect in terms of capital deployment.

The assessment describes the net present value of the investment in line with the Treasury's Green Book guidelines; it covers changes in the cost of taxation, where the GIB's intervention or alternative policies involve a change in receipts from a tax or tax-like instrument; and, it includes the redistribution of monies as a result of taxation. It does not include second order effects on the long-term availability of finance in the sector or the costs of the technology. These are more difficult to estimate and the other benefits are sufficient to justify the GIB's role.

The assessment takes into account all market costs and benefits at market prices, the cost of the GIB, and the benefits of avoided carbon dioxide emissions. The set-up costs of the GIB are relatively small, of the order of some tens of millions. The carbon dioxide emissions are valued in line with government guidance. This has been modelled as an increase in the supply of finance at the current price.

Hence, the GIB does not change the cost of the investments, but does change the quantity.

The impacts are quantified for offshore wind, non-Local Authority commercial and industrial waste, and non-domestic energy efficiency. The alternative policies are an increase in the level of Renewables Obligation or Feed in Tariff support for new offshore wind projects, an increase in the Landfill Tax for commercial and industrial waste, and an increase in the Climate Change Levy.

In all three cases, the GIB is more efficient and equitable than the alternative policies and acts as a complement to current policy. It is able to make contributions to policy targets in all three sectors. It has the greatest impact in waste, because of the large size of the GIB relative to the investment need in the sector. In contrast, the GIB's ability to influence the achievement of the renewable energy target in the short term is potentially quite limited, although still important, because of the scale of investment needed in comparison to the GIB's initial balance sheet.

The analysis shows that the consumer will experience greater impacts from redistribution effects than the net present value of the investments or the costs of taxation. These redistribution effects will impact consumers' energy or waste costs by more than the investments themselves. Hence the redistribution effects are important.

While some of the investments have a positive net present value (materials recovery facilities for waste, energy efficiency investments), others do not (offshore wind, direct combustion energy from waste) due to the higher cost of low carbon products (eg renewable electricity generation) compared to more traditional products (eg fossil fuel electricity generation). These net present value results corroborate existing impact assessments for the current policies in these sectors. What is new is the finding that the GIB, through a targeted investment, can substantially improve the policy outcome even without reducing the cost of finance.

4.1 Approach and metrics

Following the Green Book guidance, benefits and costs are monetised where possible and expressed as a net present value, and transfers are reported

4.1.1 Approach

This appraisal closely follows the guidance set out in HMT's Green Book (HMT, 2003), as well as, where appropriate, supplementary guidance. In addition to this guidance the Chancellor has set three specific tests for the assessment of the GIB: (i) effectiveness and value for money, (ii) affordability and (iii) transparency.

Assessment of value for money is provided by a social cost-benefit analysis of the GIB relative to a 'do minimum' and an alternative policy scenario. In addition effectiveness may be measured along three dimensions. These are the distributional impacts of policy, the progress towards policy goals that a policy delivers and the rate at which public spending leverages private sector investment, i.e. the ratio of private investment to public funding.

Affordability is a narrower criterion. It may be measured by looking at the cost to the exchequer of the GIB, while treating any tax revenues raised as a benefit. The remit of this report includes effectiveness and value for money but excludes affordability. Transparency is outside the remit of this report.

The appraisal requires quantitative work that assesses the need for investment in each sector and the impact of policy on investment. This is carried out for the three main sectors.

- The offshore wind model provides a bottom-up appraisal of the UK offshore wind investment opportunity and matches viable projects to available capital. It thus allows an evaluation of the impact of policy that changes the viability of projects or changes the availability of capital and so can describe the costs and benefits of both GIB intervention and alternative policies.
- The waste sector model estimates the capital required to meet scenarios of demand, assuming that all investments will be viable. It is a top-down model in the sense that the quantity of capital required is determined by scenarios of demand, rather than the economic fundamentals of supplying that demand.
- The non-domestic energy efficiency (NDEE) modelling calculates the benefit of an investment in NDEE measures, using data from the McKinsey GHG Abatement Cost Curve v2.1, which was constructed from expert estimates.

The capital required by the offshore wind sector is an order of magnitude greater than the quantity of capital required by either the waste sector or industrial energy efficiency. Furthermore, the uncertainty in the net benefit of investment of offshore wind is greater than in other sectors, which use established technologies in more hospitable conditions. These differences justify the differences in complexity of the sectoral models used. The modelling methodology is laid out in appendix 5.

4.1.2 The GIB and alternative options

A critical step in cost benefit analysis is to define the alternative options to the main policy. First, it is necessary to specify what is termed in the Green Book a 'do minimum' option, i.e. the counterfactual or baseline. This is considered to be the most likely outcome with current/announced Government policies and without a GIB. Second, it is necessary to specify the configuration of the GIB. This is shown in Table 28, which relates GIB products to sectors.

Table 28. **Matrix of GIB products and sectoral scope**

Sectors	Co-investment Equity	Mezzanine debt	Contingent debt	Senior debt
Offshore wind	✓	✓	✓	
Non-Local Authority commercial and industrial waste	✓	✓		✓
Non-domestic energy efficiency	✓	✓		✓

Source: Vivid Economics

Third, it is necessary to define the alternative options in which policy objectives are achieved. The value for money of alternative policies must also be assessed to reveal the quality of available substitutes to the GIB. The alternative policies assessed for each sector are described in Table 29.

Table 29. **Matrix of sectors and alternative policies**

Sectors	Alternative policy
Offshore wind	An increase in Renewable Obligation Certificates per MWh (or equivalent Feed in Tariff) such that returns are sufficient to attract a level of investment equal to investment generated by the GIB
Non-Local Authority commercial and industrial waste	A higher rate of Landfill Tax such that landfill declines by an amount equal to the diversion achieved by the GIB
Non-domestic energy efficiency	An increase in the Climate Change Levy per MWh such that energy use declines by an amount equal to the energy savings achieved by the GIB

Source: Vivid Economics

4.1.3 The benefits of the GIB

The GIB may generate benefits either through its direct investment in valuable infrastructure or by mobilising other capital into worthwhile investments. This infrastructure may create benefits in several ways. It may supply valuable market services, such as power and heat. It may provide non-market public goods, for example reduced flood risk for householders through investment in flood defences, or reduced damage from global warming through investments that abate greenhouse gas emissions. It may improve the environment, measured in physical units such as reduced quantities of pollution. Not least, it may deliver policy objectives which the government has set or agreed to as well as potentially contribute to the UK's reputation as a good place to invest.

The deployment of novel technologies may have other benefits. These benefits include unit cost reductions from learning by doing, knowledge spillovers and information on the risk characteristics of investments. Therefore the GIB may indirectly reduce the future cost of infrastructure. The potential benefits are set out in Table 30.

Table 30. **Potential benefits and costs of the GIB**

Benefits	Costs
Reduced greenhouse gas emissions	Administration costs
Reduced cost of green technology deployment	Initial capitalisation
Spill-overs from innovation	Any crowding out of private-sector investment
Efficiency gains from infrastructure	Default risk on GIB's investment portfolio
Ancillary environmental benefits (especially from waste)	
Energy security	

Source: Vivid Economics

Not all of the above benefits will necessarily be brought about solely by the GIB. In some cases, statutory targets require the products or services to be produced by whatever means, GIB or otherwise. If the GIB is involved, it may accelerate the timing of production, reduce its cost, or reduce the level of payments made between parties to induce the production to take place. The GIB may also complement or substitute existing or planned policies relating to statutory targets.

The GIB may have distributional benefits relative to the alternative policy, where the GIB can cause prices to fall, perhaps through enhanced performance of infrastructure, or through the promotion of competition in the provision of goods and services. It might achieve enhanced competition by supporting small and medium sized enterprises and new entrants. The GIB may also have preferential distributional characteristics in comparison to other alternative policies if it achieves an effect with less transfer of monies between parties than a blunter tax or tax-like incentive would offer.

A non-market benefit common to several of the sectors is carbon dioxide abatement. Carbon dioxide abated under each option is valued at the official DECC shadow price of carbon. This is a monetary estimate of the benefits of these emissions reductions. The guidance uses one value for emissions falling within the administrative scope of the EU Emissions Trading Scheme and another, higher valuation, for those falling outside it. These figures are applied in this report. Other non-market benefits such as increased energy security and positive spillovers from technology deployment are listed as part of a larger narrative, but not valued.

4.1.4 The costs of the GIB

The GIB will have fixed and variable costs. Fixed costs are the cost of set-up, which have been estimated by McKinsey at £11 million. Variable costs are the opportunity costs of the project and the administrative costs of the GIB. Those costs include the operating expenditure, costs of finance (payments of dividends and interest) and capital charges. It is assumed that the GIB will recover its variable costs through product fees but set-up costs will not be recovered. Fixed costs are therefore included as a cost when calculating the net present value of GIB investment. Fixed costs are assumed to be written off over the first £3 billion of GIB investment, so if a sector receives £1 billion, then there is an associated cost of £3.6 million. This cost is assumed to be incurred in the first year of the GIB's operation.

4.1.5 Discounting

A time horizon of 25 years is used for waste, starting in 2012 and ending in 2030. For offshore wind, a period of 38 years is used, from 2012 to 2050. Costs and benefits in real terms are discounted at 3.5 per cent,, the UK social discount rate. The Treasury's guidance, the Green Book, recommends a lower discount rate for costs and benefits beyond 30 years, but the additional complexity involved in this particular calculation and the low value beyond 30 years justified the simpler approach. For NDEE the time period over which to discount depends on the assumed life time of NDEE measures, and a range of results are presented, the maximum of which is 25 years.

4.1.6 Bias

There are official Government optimism-bias multipliers for standard built infrastructure projects and similar, but there are none for a project like the GIB. Optimism bias could be corrected through upward adjustment of costs, possible downward adjustment of benefits and delayed receipt of benefits. This adjustment would have to be a matter of judgement as there is no precedent to follow and no evidence upon which to base it. For these reasons, no bias adjustment has been made to the final results.

4.2 Scenarios to address uncertainty

Major uncertainties are treated transparently

4.2.1 **Scenarios consider major uncertainties**

Scenario analysis provides an opportunity to deal with the deeper uncertainties about economic, social and environmental conditions. Uncertainty around the demand for green infrastructure and the availability of finance are the key concerns. Each sector is driven by the demand for services, for example renewable energy from offshore wind, and the division of waste between landfill, recycling and energy recovery, which in turn is driven by government policy.

4.2.2 **Comparison of outcomes**

Scenarios, in combination with the sensitivity analysis explained in section 5.3, explore the full range of possible contexts and outcomes. The impacts of cases, such as the 'do minimum' case or a GIB intervention case, are presented across a set of states comprising of the ranges of parameter values explored in sensitivity analysis. These are summarised into a base case, a worst case and a best case.

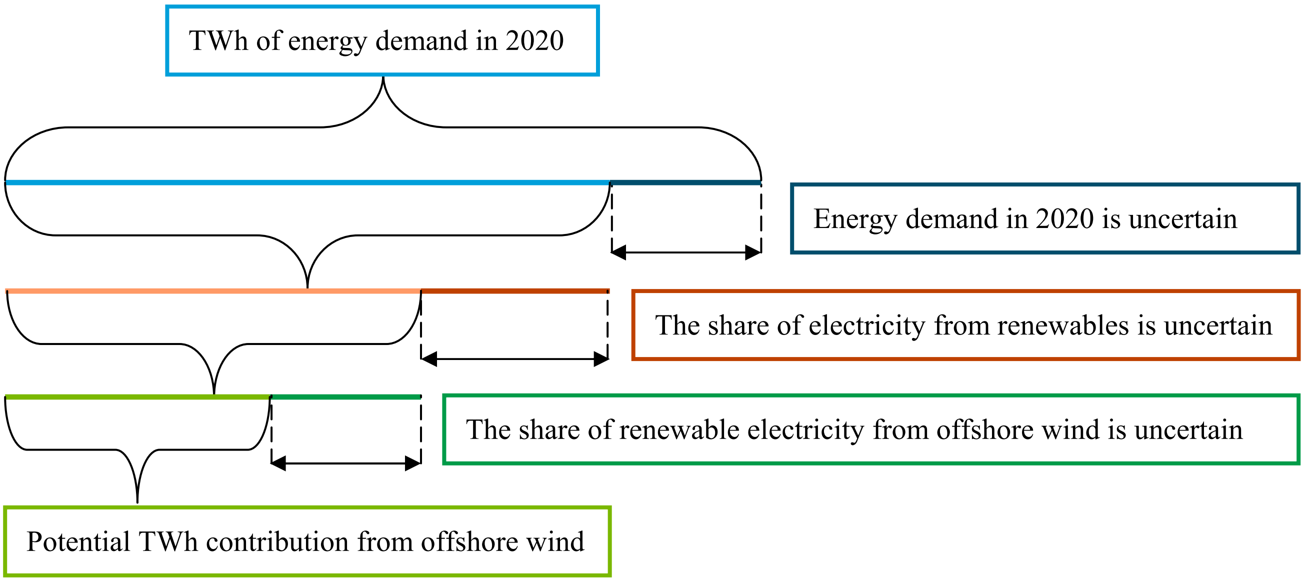
4.2.3 **Scenarios in the offshore wind sector**

Demand for electricity from offshore wind is driven by policy. Offshore wind is not a competitive source of electricity, even with the cost of CO_2 internalised by fossil fuel generators through the EU ETS; for instance the current levelised cost of offshore wind is around twice that of gas CCGT (Mott MacDonald, 2010).

Offshore wind is expected to provide a significant share of the renewable energy required by the European Renewable Energy Directive (2009/28/EC) in 2020. The quantity of renewable energy that could be required from offshore wind depends on the total quantity of energy demanded, the share of renewable energy that comes from electricity and the share of renewable electricity that comes from offshore wind.

These scenarios are a benchmark showing the effect of a change in output in the context of policy targets, but they do not affect the modelling of value for money. The key uncertainty is the percentage of renewable electricity that may be provided by offshore wind. The other factors are shown in the cascade pictured in Figure 14. The resulting scenarios span a wide range. In the lowest case 33 TWh of offshore wind may be required in 2020, while in the highest case the requirement could be 87 TWh, which is ~2.5 times greater than the lowest case. The full figures are listed in Table 31 and the assumptions behind them are found in Table 32 and Table 33.

Figure 14. **The uncertainty of the contribution of offshore wind to 2020 targets builds in three steps**



Source: Vivid Economics

Table 31. **Assumptions for scenarios of offshore wind contribution to 2020 renewable energy target**

		Low case	Base case	High case
Electricity demand in 2020	GWh	332,000	336,000	338,000
Percentage of electricity from renewable	%	25%	30%	37%
Percentage of renewable electricity from offshore wind	%	40%	50%	70%
Percentage of total electricity from offshore wind	%	25% x 40% = 10%	30% x 50% = 15%	37% x 70% = 26%

Source: Vivid Economics

Table 32. **Rationale for offshore wind scenario assumptions**

	Low case	Base case	High case
Electricity demand in 2020	DECC (June 2010) 'high-high price' energy demand forecast	DECC (June 2010) 'central price' energy demand forecast	DECC (June 2010) 'low price' energy demand forecast
Percentage of electricity from renewables	Percentage in policy option C of Renewable Energy Strategy Impact Assessment (DECC, 2009)	Percentage in policy option A of Renewable Energy Strategy Impact Assessment (DECC, 2009)	Scenario of low delivery of renewable heat
Percentage of renewable electricity from offshore wind	5 per cent lower than percentage in lead scenario of Renewable Energy Strategy (DECC, 2009)	5 per cent greater than percentage in lead scenario of Renewable Energy Strategy (DECC, 2009)	Scenario of very low delivery of onshore wind and bioenergy
Percentage of total electricity from offshore wind	Product of the percentage of electricity from renewables and the percentage of renewable electricity from offshore wind		

Source: Vivid Economics, DECC 2009a & DECC 2010g

Table 33. **Scenarios of offshore wind electricity contribution to 2020 renewable energy target, GWh**

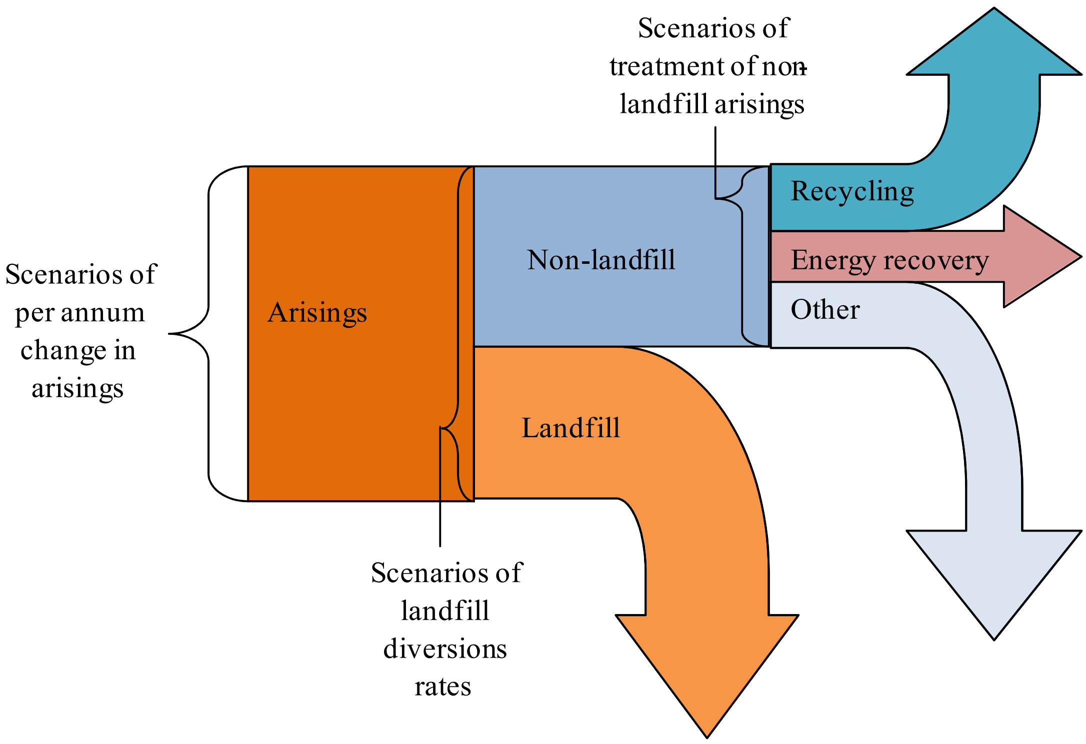
		Electricity demand		
		Low case (332,000 GWh)	**Base case (336,000 GWh)**	**High case (338,000 GWh)**
Percentage of total electricity from offshore wind	**Low case (10%)**	33,000	34,000	34,000
	Base case (15%)	50,000	50,000	51,000
	High case (26%)	86,000	87,000	88,000

Source: Vivid Economics

4.2.4 Scenarios in the waste sector

Demand for new capacity in non-landfill infrastructure is the key uncertainty in the non-municipal commercial and industrial waste sector. The types of waste treatment process considered are direct combustion energy from waste (EFW) and materials recovery facility (MRF). Energy from waste covers a plurality of technologies which allow energy to be recovered, including: direct combustion, anaerobic digestion, combustion, gasification and pyrolysis, of which only one, direct combustion is modelled. It is chosen because it is the dominant technology. Only one EFW technology is chosen because the objective here is to construct some simplified scenarios of capital investment in the sector. They have to be simplified in order to keep the number of scenarios manageable and within the resources available for this project it has not been possible to extend work to other EFW technologies. However, as stated above we see a role for the GIB in supporting more innovative advanced technologies. The investment estimate is based on the capacity required of these waste treatment processes and the unit capital costs. The capacity is itself a function of the quantity of commercial and industrial waste, the proportion of these arisings diverted from landfill and the proportion of non-landfill waste treated by either EFW or MRF. This is illustrated in Figure 15 and scenario assumptions are outlined in Table 34.

Figure 15. **Schematic of commercial and industrial waste scenarios**



Note: not drawn to scale

Source: Vivid Economics

Scenarios are structured such that there is a low, medium and high scenario for each of growth rate of arisings, landfill diversion rates and the treatment of non-landfill waste. This creates a three-dimensional state space with nine cells. As the communication of three-dimensional state spaces is difficult the presentation of results will focus on the medium scenario of treatment of non-landfill waste while exploring the results across the scenarios of per annum change in arisings and landfill diversion rates.

A full methodology for the waste sector modelling can be found in appendix 5.

Table 34. **Scenarios of capacity required for Energy from Waste plant and Materials Recycling Facilities**

Scenario	Per annum change in arisings	Landfill diversion rates	Treatment of non-landfill arisings	Total capacity of plant, ktpa	Capital investment, £m
Low	-3 per cent per annum (CAGR since 1999)	23 per cent (diversion rate in 2009)	Both EFW and MRF treat same percentage of non-landfill as in 2009 (2.7 and 62.4 per cent respectively)	EFW: 0 MFW: 0	EFW: 0 MFW: 0
Medium	0% per cent per annum (i.e. arisings remain at current levels)	declining to 20 per cent by 2020	EFW percentage of non-landfill increasing to 5 per cent by 2020 MRF percentage of non-landfill increasing to 65 per cent by 2020	EFW: 800 MFW: 3,400	EFW: 480 MFW: 510
High	0.75 per cent per annum	Declining to 15 per cent by 2020	EFW percentage of non-landfill increasing to 10 per cent by 2020 MRF percentage of non-landfill increasing to 70 per cent by 2020	EFW: 2,900 MFW: 6,000	EFW: 1,730 MFW: 900

Source: Vivid Economics

4.2.5 Scenarios in the NDEE sector

A range of lifetimes over which energy efficiency measures deliver both energy savings and CO_2 savings is used, with the lower bound representing a case where measures have a lifetime of 10 years and the upper bound where measures have a lifetime of 25 years.

4.3 Sensitivity analysis of risks

Minor uncertainties generate ranges of results

4.3.1 **Sensitivity analysis is used to explore minor risks**

Minor uncertainties in parameter values are dealt with via sensitivity analysis, which is the process of testing a model across the range of possible parameter values. Where multiple parameters are uncertain a model is tested across combinations of parameter values. In combination, uncertainty across a number of parameters can have a significant effect on results, which are presented as ranges.

4.3.2 **Treatment of probability in sensitivity analysis**

The probability of a state occurring is not estimated here because there is no information available on the probability distributions of parameter values. The simple sensitivity analysis shows only the range of possible states of the world with no greater weight attached to one outcome over another.

4.3.3 **Sensitivity analysis in the offshore wind sector**

At the core of the offshore wind model is a cash flow model for each site, or phase of site, for Round 2 and Round 3 projects. There are 13 parameters, excluding finance parameters, affecting every cash flow and a further 5 site-specific parameters affecting site-specific cash flow. There are 43 sites or phases of sites. The 13 general parameters are sensitivity tested using ranges discussed with stakeholders throughout the project, but the site-specific models have not been checked with the sites' ownera or developers. Sensitivity analysis is conducted using the @Risk 5.7 software to run the model 1,000 times. This provides a range of results that are ranked from worst to best, from the perspective of an equity investor. The 200^{th}, 500^{th} and 800^{th} results in the ranking are presented to show the range of possible outcomes.

4.3.4 **Sensitivity analysis in the waste sector**

The parsimony of the waste model limits the need for sensitivity analysis, with the key sensitivity being the demand for capacity and uncertainty over this being dealt with through scenarios. The chief remaining uncertainty is in the treatment of CO_2 savings from waste treated by a materials recovery facility (MRF). Most waste processed by an MRF is recycled, which avoids the production of virgin materials, and as a result the CO_2 benefit of an MRF is significant. The CO_2 abated through the avoidance of the production of virgin material is treated as a saving of traded CO_2, produced from processes covered by the EU ETS. Sensitivity analysis is not conducted for other key parameters in the model: the capital cost of a tonne of capacity, the difference in gate fees between landfill and EFW's and MRF's and the total CO_2 abated through the non-landfill treatment of waste.

4.4 Offshore wind

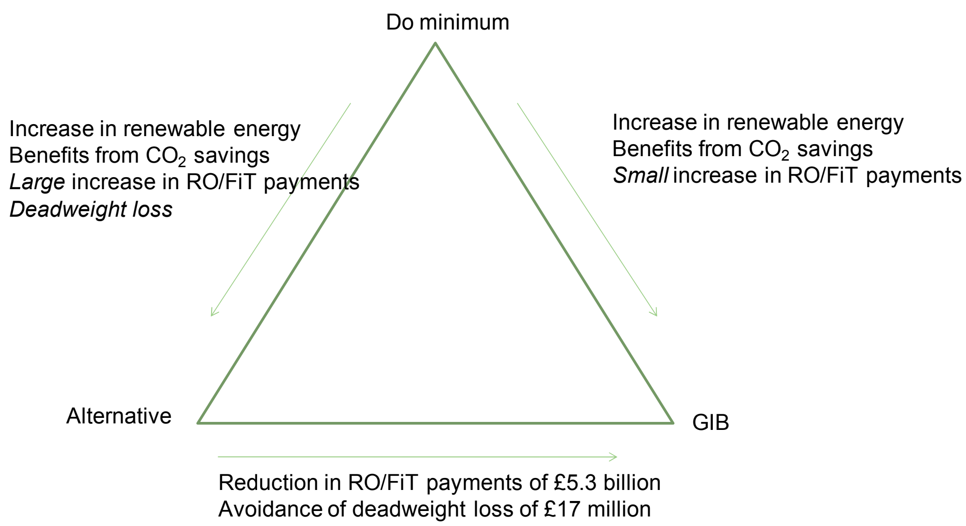
The GIB offers substantial distributional benefits over enhanced tariff support

4.4.1 Conclusions on the assessment of value for money

Capital constraints are the binding constraint in the offshore wind sector, except in worse than expected states of the world, where the quantity of viable projects is less than the capital available. The gap between capital available and capital required to meet policy goals for offshore wind deployment is large, £40 billion to 2020 in the central scenario. This means that the Green Investment Bank is targeting the correct constraint but it might not close the gap by itself. However, it can contribute to begin the closing of this gap and initialise further investments in this area. In line with earlier impact assessment findings (see for example Dhanju et al. 2005), each £1 investment in offshore wind has a negative net present value (£-0.48).

The GIB is preferred over the alternative policy because it has a better distributional outcome and lower costs. GIB interventions are better value for money because they create much lower transfers from electricity consumers to power generators and lower increases in electricity prices. In worse-than-expected states of the world the alternative policy makes offshore wind investment viable while GIB intervention does not, but in other scenarios the GIB is the better policy. The comparison between the policies is summarised in Figure 16.

Figure 16. **Summary of effects of GIB and alternative interventions**



Source *Vivid Economics*

Operational mezzanine debt is more effective than co-investment equity or construction contingent debt because it mobilises more private sector capital. In comparison to the alternative policy of increasing the number of ROC's per MWh (feed in tariff), the GIB reduces transfer payments by £5.3 billion, and avoids a deadweight loss of £17 million.

4.4.2 Introduction

Offshore wind is expected to provide a significant contribution to meeting the UK's obligation under the European Renewable Energy Directive (2009/28/EC) in 2020. Scenarios of the contribution that offshore wind may make are described in section 5.2.3 and these will now be compared with the 'do minimum' case and cases with GIB and alternative policy interventions.

The quantity of investment achieved in the 'do minimum' case is constrained by three issues: the quantity of capital available, the rate at which the supply chain can add additional capacity, and the number of sites that are financially viable. Build constraints prevent the high scenario contribution from being reached. For the medium and low scenarios, the constraining factor is most likely to be available capital. Although there are some feasible combinations of parameters in which a lack of viable projects becomes limiting, the Government has expressed its commitment to feed in tariffs sufficient to make projects viable. Although capital availability is not entirely separable from the level of support, for reasons which become clear, capital availability itself is likely to be a limiting factor in most scenarios.

4.4.3 Contribution of power generated by offshore wind

In 2020, 33 – 87 TWh per annum of electricity from offshore wind may be needed, with a central case of 50 TWh. The range is primarily driven by the power output assumed to come from other renewable energy sources, as section 4.2.3 details. A model evaluates the viability of Round 2 and Round 3 offshore wind sites. A second model distributes finance between these sites up to a total estimate of available capital. The viability of sites, which is dependent on a large number of variables, is sensitivity tested and the results for the 35th, 50th and 65th percentiles are presented here. The 50th percentile may be thought of as the expected value, while the 35th percentile represents a worse than expected state and the 65th percentile a better than expected state.[7] These percentiles do not connote a probability because probability distributions for all parameters are not known. A detailed description of the models is included in appendix 5.

Nameplate capacity is the maximum output rate a turbine is able to produce instantaneously. The model calculates the capital cost of installing this nameplate capacity. In the 50th percentile it costs approximately £4 million in nominal terms (£3.65 million in real terms) per MW of nameplate capacity by 2020 and the average output per MW is approximately 3.2 GWh/year.

[7] The parameters which vary across the percentile states in the Monte Carlo simulation are availability, load factor, capital costs, operating costs, electricity price, wholesale power price discount, asset beta, risk free rate, debt premium, CPI inflation, construction price inflation, operating expenses inflation, length of consenting period, length of operating period and rate of construction. The 65th percentile value is a more favourable combination of these variables than the 50th percentile, which in turn is more favourable than the 35th percentile.

The lowest contribution examined, 33 TWh in 2020, takes £50 billion (nominal) of capital investment by 2020, while the maximum contribution, 87 TWh in 2020, takes £130 billion. In the central case £90 billion leads to 50 TWh per annum of output. Supply chain constraints are assumed to limit output to 58 TWh per annum, associated with £100 billion of investment by 2020. These results are presented in Table 35.

Table 35. **Achieving the contribution of offshore wind to meeting 2009/28/EC requires £50-130 billion (nominal) by 2020**

	Electricity generated in 2020 (TWh)	Nameplate capacity installed by 2020 (GW)	Capital required by 2020 (£billions, nominal)
Low scenario	33	13	50
Central scenario	50	22	90
High scenario*	87	32	130
Maximum considered feasible by 2020	58	23	100

*Notes: *High scenario is not considered feasible by 2020 in this study, due to build constraints; data for high scenario is based on meeting high scenario without time constraints; all data is for 50th percentile. The renewable energy roadmap states a central range for offshore wind in 2020 of 11 – 18 GW.*

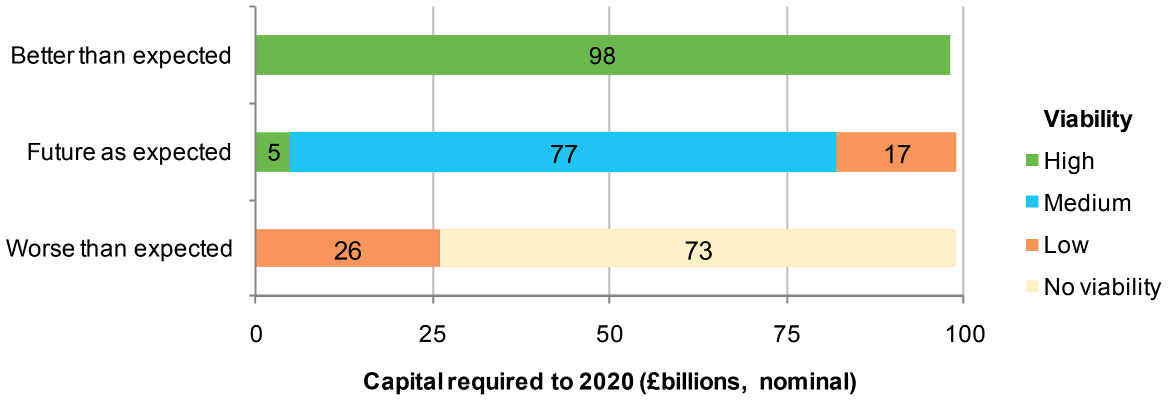
Source: Vivid Economics

In the 'do minimum' case the capital available to 2020 for offshore wind investment is a fraction of the £54 billion that the 'big six' utilities have available for all capital investment, plus finance brought into the sector by other other sponsors. This includes the £8 billion already committed to Round 2 sites, a further £10 billion invested in remaining Round 2 sites, and £30 billion for Round 3 sites. This figure is based on an analysis of utility balance sheets, detailed in appendix 3, and discussions with stakeholders. It is not sufficient to fund offshore wind's contribution to 2009/28/EC in the low scenario and well short of funding compliance in the central case. It leaves unfunded some 'high' or 'medium' viability projects, those with pre-tax nominal project IRRs of greater than 16 and 14 per cent respectively. The proportion of demand which can be met from high and medium viability projects is shown in Figure 17.

An investment of 54 billion would construct approximately 12 GW of offshore wind capacity. This is in line with the advice of the Committee on Climate Change, that 'the UK ambition for offshore wind should be limited to 13GW by 2020' (Committee on Climate Change, 2011), and with DECC's central scenario of 13 GW by 2020 (DECC, 2011c and 2011o), unless costs are reduced to £100/MWh from their current medium level estimate of £198/MWh (Arup, 2011).

A capital constraint in the offshore wind sector can therefore be observed in the states of the world with higher levels of build. There is likely to be less capital available to 2020 than there are viable projects. In addition, the quantity of capital available is constraining the achievement of policy.

Figure 17. **In expected and better than expected states of the world it is likely that viable projects will go unfunded; these must be funded if renewable energy targets are to be met**



Source: Vivid Economics

4.4.4 GIB products

The level of investment in the 'do minimum' case could be increased by policy intervention. The GIB may intervene by offering financial products to the market. The GIB may offer three products: co-investment equity, contingent debt during construction and operational mezzanine debt; these products are not mutually exclusive and may therefore be used at the same time.

The GIB may invest equity in a project, alongside another investor, such as a utility. It would put in less than 50 per cent of the equity, to leave its partner in control. Co-investment equity increases the capital that is available by the amount that the GIB invests and the amount of debt funding that is brought along beside it. In the 50 per cent gearing structure that is assumed for offshore wind, for every £1 of GIB equity, an additional £1 of debt is added. The total increase of capital available is £2. However, if debt is constrained, then no additional capital would be released.

The contingent debt gives comfort to the other creditors that the project will not run out of cash if construction costs overrun. This allows the other creditors to deploy elsewhere the contingent provisions that they would otherwise have had standing by, and place them in additional projects. For each £1 that the GIB provides as contingent capital, the same amount of creditor's capital is released for participation in a project at 50 per cent gearing. This means that for every £1 of GIB money added, a further £1 of private equity might be added. Again, the capital deployed in offshore wind has increased by £2. This is true so long as equity is not constrained; otherwise no additional capital is released.

GIB operational mezzanine debt involves the GIB offering mezzanine debt to projects that are refinancing once they become operational. This allows a new class of more risk-averse lender to lend to the project: one who is not comfortable with the usual level of offshore wind debt risk, but is happy to write lower-risk (credit-enhanced) debt, where the enhancement is provided by the mezzanine debt. This releases the old lender to re-use the debt in other investments. For each £1 which the GIB puts in, the pool of debt available is expanded by £1 from new lenders. If this is levered in a capital structure with 50 per cent gearing, and the equity is new, then the total increase in capital available is £4, £1 of GIB contribution, £1 of new debt, and £2 of equity.

The alternative policy considered in this report is to increase the number of ROCs awarded to offshore wind. The level of the increase is chosen to improve returns from the extra subsidy, and so attract the same amount of additional investment in offshore wind as the GIB achieves. To determine the increase in ROCs it would be necessary to know the responsiveness of capital markets to an increase in the return to investment in offshore wind: a property that is unknown. However, illustrative quantitative work is presented to give a flavour of the impacts of the alternative policy, and it convincingly shows the relative benefits of a targeted GIB investment. These calculations use an increase in support level of 0.2 ROCs/MWh or its equivalent as a feed in tariff.

4.4.5 **Value for money of 'do minimum', GIB interventions and alternative policy in the offshore wind sector**

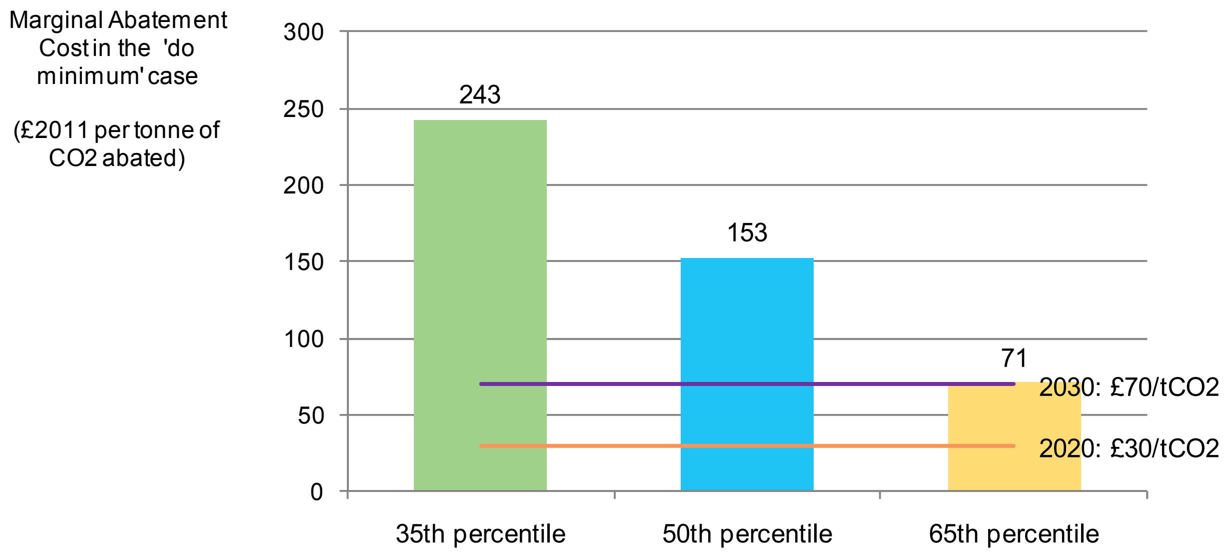
The gap in investment required between 'do minimum' and the central scenario of investment needed by policy, described in section 5.2.3, is £40 billion by 2020 and £80 billion in the high scenario. For illustrative purposes, for each £1 of GIB involvement an additional £2 to 4 is made available to the sector. No additional GIB capital is included for the period after 2015, even though more might become available then. None of the interventions are therefore sufficient to fully ease the capital constraint.

The alternative policy would, by assumption, be as effective as the GIB at increasing capital invested. However the alternative policy acts in a different way to the GIB. Every investor is rewarded by an increase in the number of ROCs (or feed in tariff) awarded to offshore wind, whereas the GIB supports only viable projects that would otherwise not go ahead, assuming the GIB's selection procedure is robust. The less tailored nature of the alternative policy makes it less desirable when the binding constraint on offshore wind development is a lack of capital for good projects. However, in the cases where a large number of projects are not viable without increased subsidy, the alternative policy's ability to improve the returns of all projects is complementary to the GIB intervention.

The GIB's effectiveness depends upon the level of policy support through ROCs (feed in tariff), since these provide around half of an offshore wind farm's revenue. over its lifetime (energy prices are expected to increase in real terms, while the value of the ROC is not, so the current 2/3 contribution of ROCs to revenue is likely to decline). Investments in offshore wind are costly relative to some other carbon reducing options, but are nevertheless a significant contributor to the low carbon pathways plotted out by the Committee on Climate Change and by DECC (due to non-financial constraints on deployment of other technologies). The cost of offshore wind per tonne of CO_2 saved is shown in Figure 18 alongside HMG projected price of CO_2 in 2020 of £16/tCO_2 and 2030 of £70/tCO_2 (DECC, 2010g) plus the carbon price floor, which brings the price of CO_2 for electricity generation to £30/ CO_2 by 2020 and £70/tCO_2 by 2030 (DECC, 2011f). The marginal abatement cost is calculated by dividing the net present value of the stream of net benefits (excluding CO_2) by the net present value of the stream of CO_2 abated, valued using the inter-departmental analysts group trajectory of traded carbon prices over time (DECC, 2010p), following HMT Green Book advice.

There are also non-quantifiable benefits from offshore wind, such as air quality improvements and potential innovation spillovers.

Figure 18. **The marginal abatement cost of offshore wind is greater than the carbon price floor in 2020 and 2030**



Source: Vivid Economics

4.4.6 **Value for money assessment**

The additional offshore wind capacity brought on line by a GIB motivated investment of £1 billion has a net present value of £-620m to £-240m, with £-480m as a central case, over 25 years. This is the sum of the costs of building and operating offshore wind farms, and the benefits from the sale of power and reduction in CO_2 emissions. GIB costs are one third of the £10.6m fixed costs that will be incurred for the GIB's £3 billion portfolio, and therefore are £3.6m in the first year only. A summary of the value for money of a £1 billion investment in offshore wind is provided in Table 36.

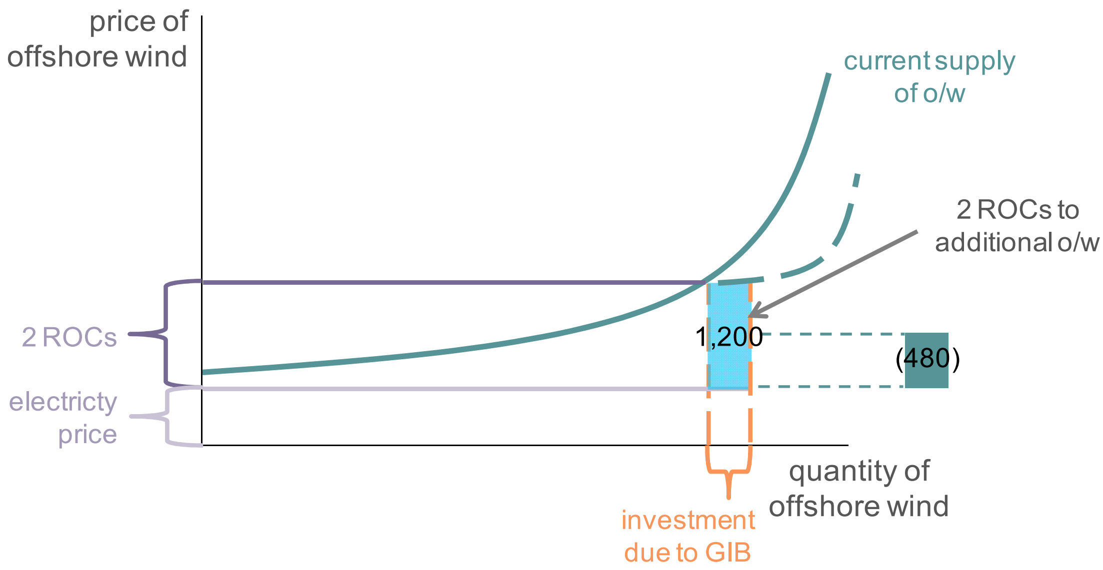
This extra capacity is built at the same cost as in the 'do minimum' case, as the GIB causes the extra capacity to be built but does not change its unit cost. The additional capacity receives revenue support in the form ROCs (or FiT) worth £1,200m over its 25-year life and these are counted as transfers. These figures are shown in Figure 19.

Table 36. **The value for money of a capital investment of £1 billion in offshore wind**

	Units	Central case
Capital invested	(£ millions, 2011)	1,000
Capacity installed	(GW)	270
Electricity supplied in 2020	(TWh)	880
% of electricity required in 2020 in low scenario	(per cent)	2.7%
% of electricity required in 2020 in central scenario	(per cent)	1.7%
% of electricity required in 2020 in high scenario	(per cent)	1.0%
Total CO2e saved in 2020	(thousand tonnes per annum)	350
Discounted sum of CO2e savings over lifetime	(thousand tonnes)	3,100
NPV for society	(£ millions, 2011)	-480

Source: Vivid Economics

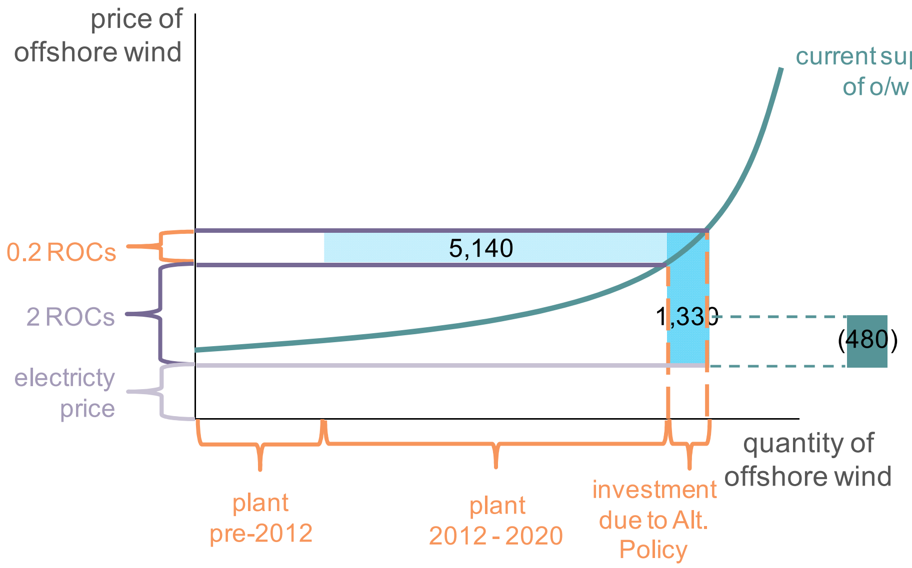
Figure 19. **The GIB is a more targeted intervention than the alternative policy of increasing ROCs awarded**



Source: Vivid Economics

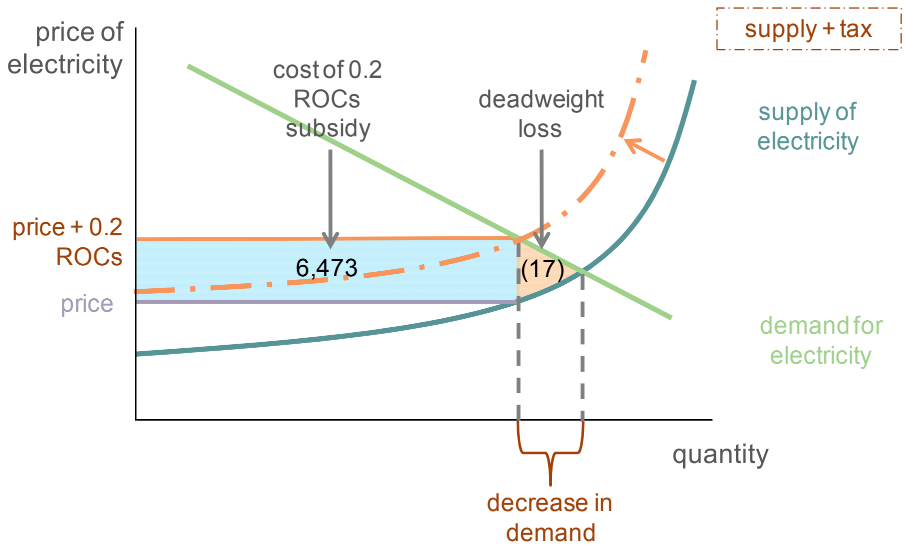
The alternative policy, an increase in revenue support equivalent to 0.2 ROCs/MWh, creates the same present value of plant operation, £(480)m in the central case. In addition, there is a small loss, £(17)m, known as deadweight, due to the higher cost of electricity, since the RO (or feed in tariff) acts like a hypothecated tax. It appears as the triangle in Figure 21. The additional revenue support benefits the new plant to the tune of £1,330m over 25 years and plant that would have been built without the additional support to the tune of £5,140m, shown in Figure 21. Both these payments are transfers, summing to £6,470m, as shown in Figure 21.

Figure 20. **The transfer payments from the alternative policy of additional ROCs on new wind farms arise from higher payments made to all new plant and the whole revenue support paid to the additional plant brought about by the policy**



Source *Vivid Economics*

Figure 21. **The transfer payments from additional ROCs for new offshore wind farms are large, while the policy costs in terms of deadweight are not significant**



Note: the price on the y axis already includes 2 ROCs currently received

Source *Vivid Economics*

The estimates are repeated in Table 37 and in Table 38. The GIB intervention and alternative policy would contribute around 0.9 TWh per annum of additional renewable electricity by 2020 and reduce emissions in 2020 by 0.3 $mtCO_2$ per annum.

Table 37. **Value for money impact of £1 billion invested in offshore wind via the GIB**

Variable	Worse than expected	Central case	Better than expected
Net present value of offshore wind (£ millions)	(620)	(480)	(240)
GIB costs (£ millions)	(3.6)	(3.6)	(3.6)
Total change in welfare (£ millions)	(624)	(484)	(244)
Total transfers (£ millions)		1,200	
Renewable electricity generation by 2020 (TWh pa)		0.9	
Change in carbon dioxide emissions in 2020 ($mtCO_2$ pa)		0.3	

Source: Vivid Economics

GIB operational mezzanine is twice as effective as GIB co-investment equity and construction contingent debt because it mobilises more private-sector capital, which increases the total capital available and therefore results in more electricity being generated in 2020, as can be seen in Table 37**Error! Reference source not found.**.

Table 38. **The alternative policy of higher rate ROC (or FIT) support involves much larger transfers**

Variable	Worse than expected	Central case	Better than expected
Net present value of offshore wind (£ millions)	(620)	(480)	(240)
Deadweight cost of support increases (£ millions)	(17)	(17)	(17)
Total change in welfare (£ millions)	(637)	(497)	(257)
Transfers to additional plant (£ millions)	1,330	1,330	1,330
Transfers to non-additional plant (£ millions)	5,140	5,140	5,140
Total transfers (£ millions)	6,470	6,470	6,470
Renewable electricity generation by 2020 (TWh pa)		0.9	
Change in carbon dioxide emissions in 2020 ($mtCO_2$ pa)		0.3	

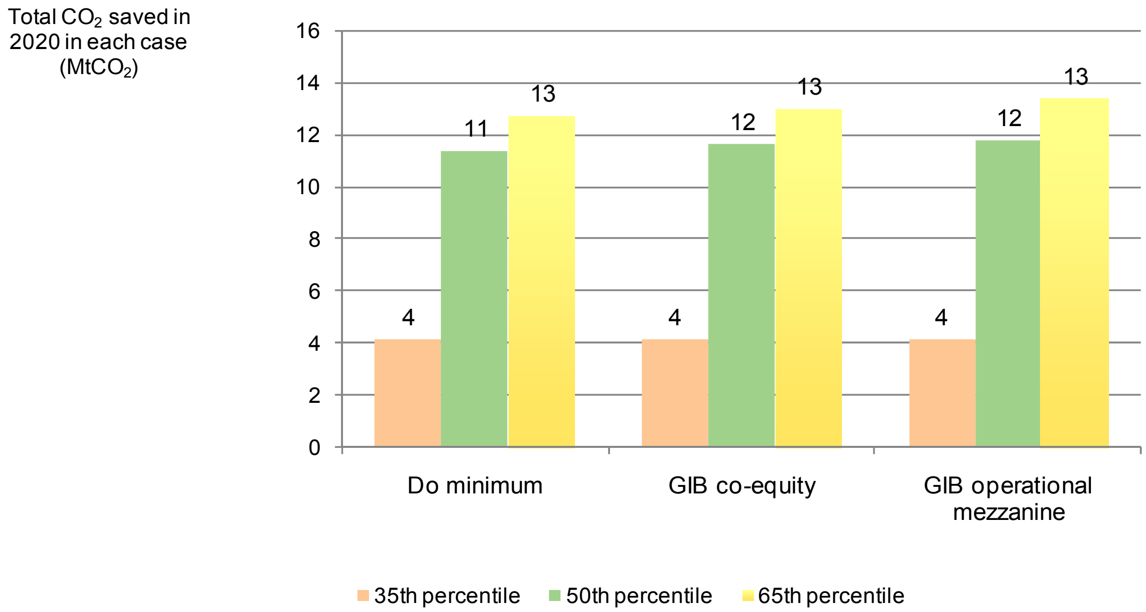
Source: Vivid Economics

4.4.7 Environmental benefits of GIB interventions in the offshore wind sector

Offshore wind prevents the emission of greenhouse gases by displacing electricity generation by the marginal (fossil-fuel) power plant. Since offshore wind could provide a significant percentage of UK electricity by 2020 the CO_2 savings are important. CO_2 savings are directly related to the quantity of electricity generated by offshore wind. CO_2 savings could be as little as 4 $MtCO_2$ per annum if offshore wind is not developed as much as expected, with savings 11-13 $MtCO_2$ across the cases with expected performance. 11 $MtCO_2$ saving is roughly 2 per cent of 1990 emissions, meaning that offshore wind could provide one tenth of the CO_2 saving required by 2020. The CO_2 savings across the cases and the sensitivity analysis are presented in Figure 22.

In addition to the CO_2 saving there is also likely to be an improvement in air quality due to a reduction in sulphur and particulate matter emissions from the fossil fuelled plant, however these benefits have not been quantified.

Figure 22. **The CO_2 savings from offshore wind are significant, reducing per annum emissions by 1-3 per cent on 1990 levels by 2020**



Source: Vivid Economics

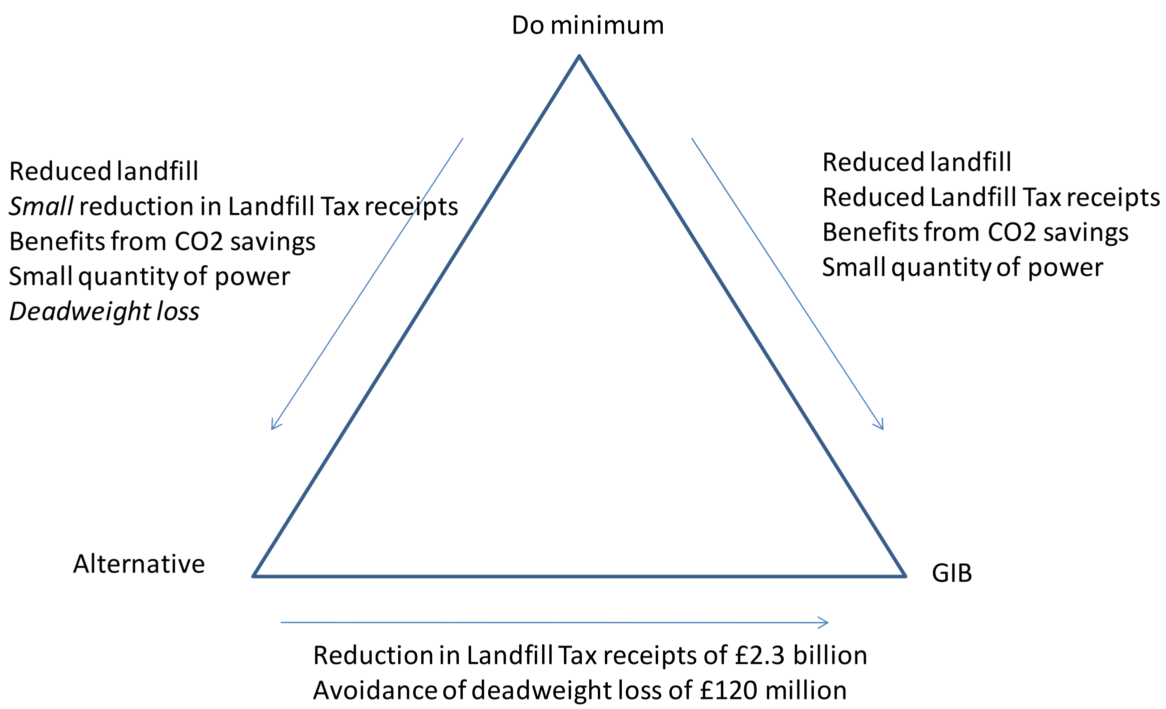
4.5 Non-Local Authority commercial and industrial waste

The GIB assists the delivery of valuable recycling infrastructure with lower cost and less redistribution than alternative policies

4.5.1 Conclusions for the waste sector

There are four main results from this analysis. First, the quantum of GIB intervention can be significant, relative to the size of waste infrastructure. Second, investment in recycling is more advantageous than investment in direct combustion (the less-used advanced conversion technologies are not modelled here because they are likely to have a small market share but as explained above the GIB might consider getting involved in these areas as well). Third, the GIB intervention is significantly more attractive than a higher rate of Landfill Tax, both in cost-benefit terms and in distributional impact. Finally, the infrastructure contributes towards emissions reductions targets and renewable energy targets. The results are summarised in Figure 23.

Figure 23. **The GIB has the same effect as the alternative policy with lower transfers and no deadweight**



Source *Vivid Economics*

4.5.2 **Waste sector investment**

In order to simplify the analysis, the quantitative work has focussed on direct combustion energy from waste (the most common type of EFW facility) and materials recovery facilities (MRFs), which are modelled separately. The figures are reported for all C&I waste that is not collected by local authorities, since this component carries the same contracted volume risk

The total demand for capacity of EFW's and MRF's in 2020 ranges from zero to 9 million tonnes per annum, depending on arisings growth and level of ambition in value recovery. In the low scenario, it is assumed that 23 per cent of waste arising continues to be sent to landfill, and in the high scenario, the figure reduces to 15 per cent. The origin of these figures is explained in the section 4.2.4 and the appendices.

The maximum estimate of capital expenditure is £2.6 billion. At the low end of the range, EFWs and MRFs continue to treat the same proportion of non-landfill waste as they do currently and current and planned capacity suffice even if the quantity of non-landfill waste increases. It may also be the case that no additional capacity is required if waste volumes decline or there is spare municipal capacity available to treat merchant waste. At the upper end of the range, merchant commercial and industrial EFW capacity in 2020 is 2.25 times greater than current capacity and MRF capacity in 2020 is 25 per cent greater than current capacity. Under a central scenario, in which capacity increases by 60 per cent and 15 per cent from current levels by 2020 for EFW's and MRF's respectively, the total demand for new capacity in 2020 could be 4.2 million tonnes, which might require £1 billion of capital investment, a proportion of which would come from the GIB.

The GIB could offer three products to the waste sector: co-investment equity, mezzanine debt and senior debt. For illustrative purposes, suppose that there is £500 million made available for co-investment equity and the GIB contributes 50 per cent of the capital to a project; then the total capital invested would be £1 billion. Similarly, if there were £125 million available for mezzanine debt and this contributes 25 per cent of project capital, with the balance from private sources; total capital invested in this case would be £500 million. For this illustration, the capital available is distributed equally between EFWs and MRFs.

4.5.3 **Value for money of GIB interventions in the waste sector**

The value for money estimates have been based on an additional 4.1 mtpa of capacity (3.3 mtpa MRF and 0.8 mtpa EFW). This involves total capital expenditure is £1 billion, of which the GIB provides between 25 and 50 per cent. As a consequence of its involvement, the GIB brings about additional capacity and allows the capacity to be financed using a more efficient capital structure. In addition to this scenario, where there is a total of £1 billion of capital spent equally on EFW and MRF, Table 39 provides the value for money of a £1 billion investment in EFW and a £1 billion investment in MRF.

Table 39. **The value for money of a capital investment of £1 billion in either EFW or MRF**

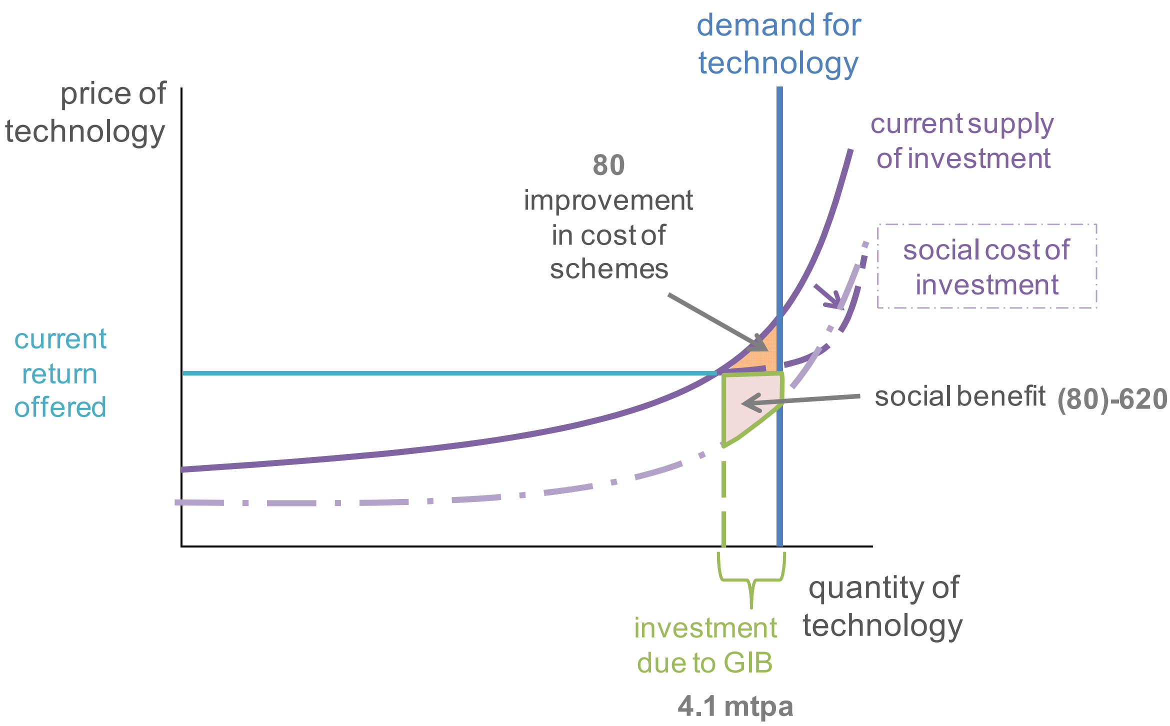
	units	EFW	MRF (all CO2 savings as non-traded)	MRF (all CO2 savings as traded)
Capital invested	(£ millions, 2011)	1,000	1,000	1,000
Cumulative capacity installed	(thousand tonnes)	1,700	6,700	6,700
% of capacity required in 2020 in low scenario	(per cent)	Negative capacity required	Negative capacity required	Negative capacity required
% of capacity required in 2020 in central scenario	(per cent)	210%	197%	197%
% of capacity required in 2020 in high scenario	(per cent)	53%	94%	94%
Non-traded CO2e saved in 2020	(thousand tonnes per annum)	120	4,620	0
Traded CO2e saved in 2020	(thousand tonnes per annum)	350	0	4,620
Total CO2e saved in 2020	(thousand tonnes per annum)	470	4,620	4,620
Discounted sum of CO2e savings over lifetime	(thousand tonnes)	5,400	49,400	49,400
NPV for society	(£ millions, 2011)	-1,200	2,330	910

Source: Vivid Economics

The MRF capacity is cheaper than landfill disposal, once the value of avoided emissions from virgin material production is taken into account. It has a net present value of £430-1,130m, with the range reflecting a choice of values placed on carbon dioxide savings. The EFW capacity is more expensive than landfill because its additional costs are not fully compensated by its power sales and emissions savings. It has a net present value of £(510)m.

In addition, the GIB's involvement may reduce the cost of finance through the greater tax efficiency of debt. Taking as a yardstick a change from zero to 50 per cent debt in the capital structure, this reduces the internal rate of return by between 1 and 2 percent, cutting costs by £2-4/tonne. The net present value of this cost saving is around £60-120m, with a best estimate of £80m. Assuming that the GIB's costs are no greater than those of other sources of capital, there is no cost to add for the GIB itself. Overall, the programme has a net present value of £(80)-700m. In addition, the programme reduces transfers paid under the Landfill Tax paid by around £2,700m. For those familiar with supply-demand diagrams, the results are shown schematically in Figure 24 and Table 40.

Figure 24. **Schematic representation of the net present values and transfers of the GIB intervention in the supply of MRFs and EFWs**



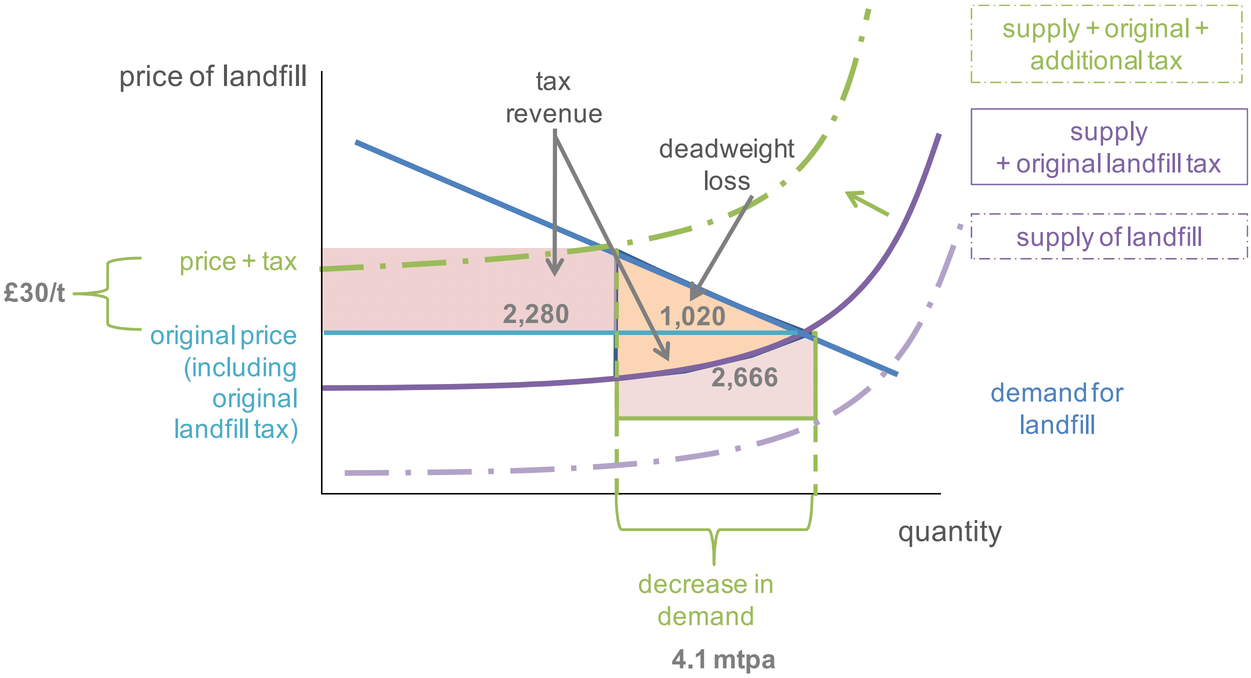
Note: the social benefit varies according to the valuation of carbon dioxide used

Source: Vivid Economics

The alternative policy is to raise the Landfill Tax rate. It is estimated that the Landfill Tax rate would have to be raised by around £30/t to achieve the same 4.1 mtpa diversion. The net present value of the infrastructure created is the same as in the GIB example, but there is reduction in welfare (a deadweight loss) associated with the tax increase. This is estimated at £1,020m. Overall, the programme has a net present value of £-400m to £-1,100m. The programme reduces transfers paid under the Landfill Tax by around £385m. The results are shown in Figure 25 and Table 40.

The GIB option generates a better outcome than the tax increase because it has lower costs (a more positive net present value) and it reduces transfers by more.

Figure 25. **Schematic representation of the net present value of £1 billion investment and transfers associated with the alternative policy: an increase in the rate of Landfill Tax**



Source: Vivid Economics

Table 40. **The impact of a GIB intervention leading to capital investment of £1 billion**

Variable	**Low**	**High**
Net present value of EFW (£ millions)	(510)	(510)
Net present value of MRF (£ millions)	430	1,130
Net present value of reduced cost of capital due to GIB (£ millions)	0	80
Total change in welfare (£ millions)	(80)	700
Transfers (£ millions)	(2,700)	(2,700)
Renewable electricity generation by 2020 (TWh pa)	0.4	0.4
Change in carbon dioxide emissions in 2020 (mtCO_2 pa)	2.6	2.6
Waste diverted from landfill by 2020 (million tonnes pa)	7.4	7.4

Source: Vivid Economics

Table 41. **The alternative of a higher rate of Landfill tax reduces welfare**

Variable	Low	High
Net present value of EFW (£ millions)	(510)	(510)
Net present value of MRF (£ millions)	430	1,130
Deadweight cost of tax increase	(1,020)	(1,020)
Total change in welfare (£ millions)	(1,100)	(400)
Transfers (£ millions)	(385)	(385)
Renewable electricity generation by 2020 (TWh pa)	0.4	0.4
Change in carbon dioxide emissions in 2020 ($mtCO_2$ pa)	2.6	2.6
Waste diverted from landfill by 2020 (million tonnes pa)	7.4	7.4

Source: Vivid Economics

4.5.4 Environmental benefits of GIB interventions in the waste sector

The treatment of waste via EFWs and MRFs abates CO_{2e} emissions. These savings occur because emissions from landfill are avoided in both cases. EFWs provide electricity, which displaces fossil-fuel, electricity generation. MRFs reduce the production of virgin material, which avoids the emissions associated with their production. Provided the MRF-sorted waste is recycled, the CO_{2e} benefit of MRFs is significantly greater than the CO_{2e} benefit of EFWs. The diversion of one tonne of waste from landfill to an MRF for recycling saves 0.72 tonnes of CO_{2e} compared to 0.28 tonnes of CO_{2e} for diversion to EFWs (Defra 2007 and AEA 2010)[8].

The programme of 4.1 mtpa diversion could abate 2.6 $MtCO_{2e}$ per annum. Ninety per cent of these savings are from MRFs. EFWs also produce electricity and sometimes heat which will count towards the renewable energy target the UK must meet in 2020. The programme establishes 800 ktpa of EFW capacity, generating

[8] *2010 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting*

0.4 TWh of electricity per annum. This is a small proportion of the 82 – 125 TWh of renewable electricity that may be required in 2020.

As mentioned above GIB intervention could also bring through development of more innovative energy recovery technologies such as gasification and pyrolysis which can produce a wider range of renewable fuels than standard EFW plant , adding to diversity of energy supplies and helping to meet wider climate change goals. This is a nascent sector and it has not been possible in the time available to model the costs and vfm for these technologies.

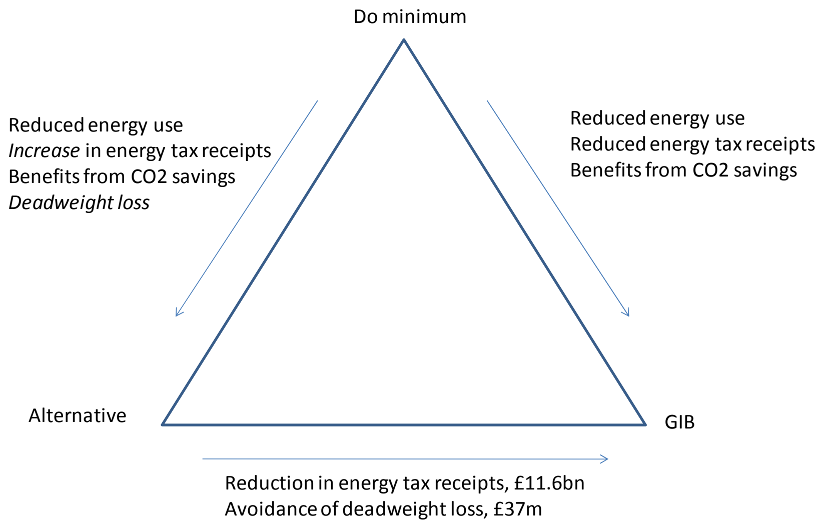
4.6 Non-domestic energy efficiency

The GIB creates substantial value added through energy savings with less redistribution than alternative policies

4.6.1 **Conclusions for non-domestic energy efficiency**

Non-domestic energy efficiency investments offer substantial positive net present value due to significant energy savings and reductions in emissions. If the GIB is able to bring about these savings, it would avoid large transfers associated with the alternative, an increase in the Climate Change Levy, and so is preferred.

Figure 26. **The GIB achieves the same outcome with reduced tax redistribution and costs of taxation**

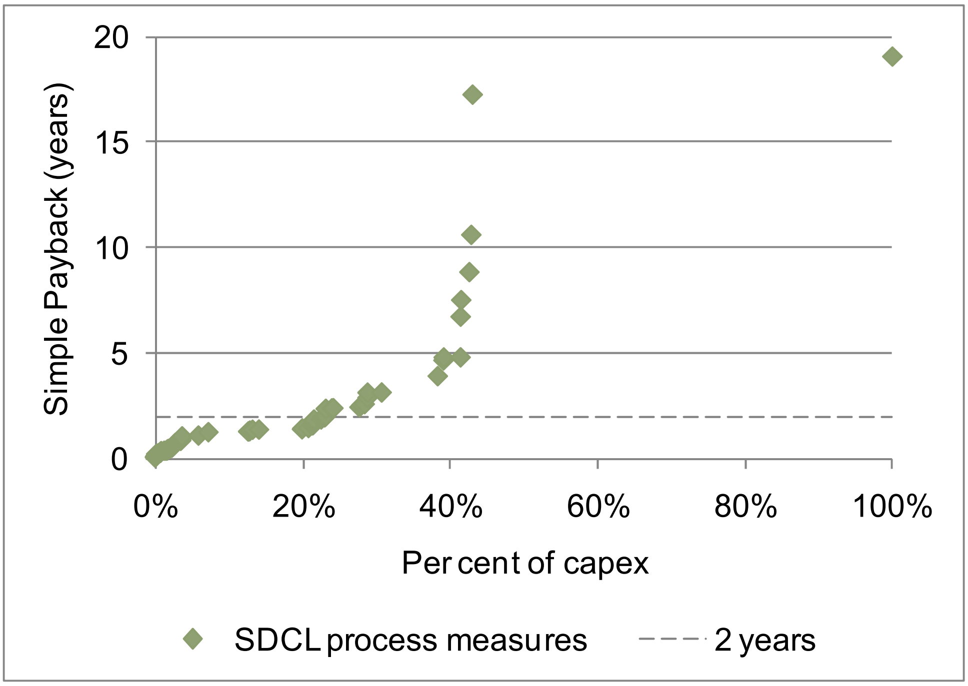


Source *Vivid Economics*

4.6.2 **The cost effectiveness of energy efficiency measures**

Energy efficiency investments are generally found to be cost-effective in engineering assessments and this has been observed across the data sets analysed for this study. Figure 28 presents the distribution of paybacks across the capital cost of the energy efficiency opportunity identified in SDCL's USA database and AEA Technology's database of the UK's six most carbon intensive industries. In general, large numbers of less expensive measures pay back quickly, with the majority of measures paying back within five years. Measures with paybacks longer than five years tend to be far more capital intensive and there tend to be few of these larger measures in the databases analysed. Figure 29 presents the analysis of the Carbon Trust SME database and finds, for SME's, that IRR's can be high. It corroborates the finding that there are a large number of small measures that payback quickly.

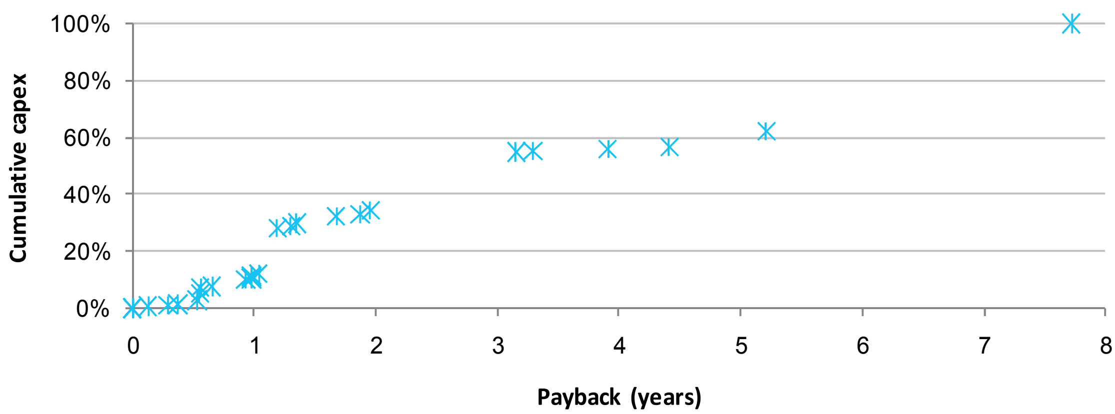
Figure 27. **A database of industrial energy efficiency measures from the USA shows that low capital cost measures pay back quickly, while a small number of measures require large investments with long pay-back periods**



Notes: each marker represents an instance in a sector from the database

Source: Sustainable Development Capital Limited & Vivid Economics analysis

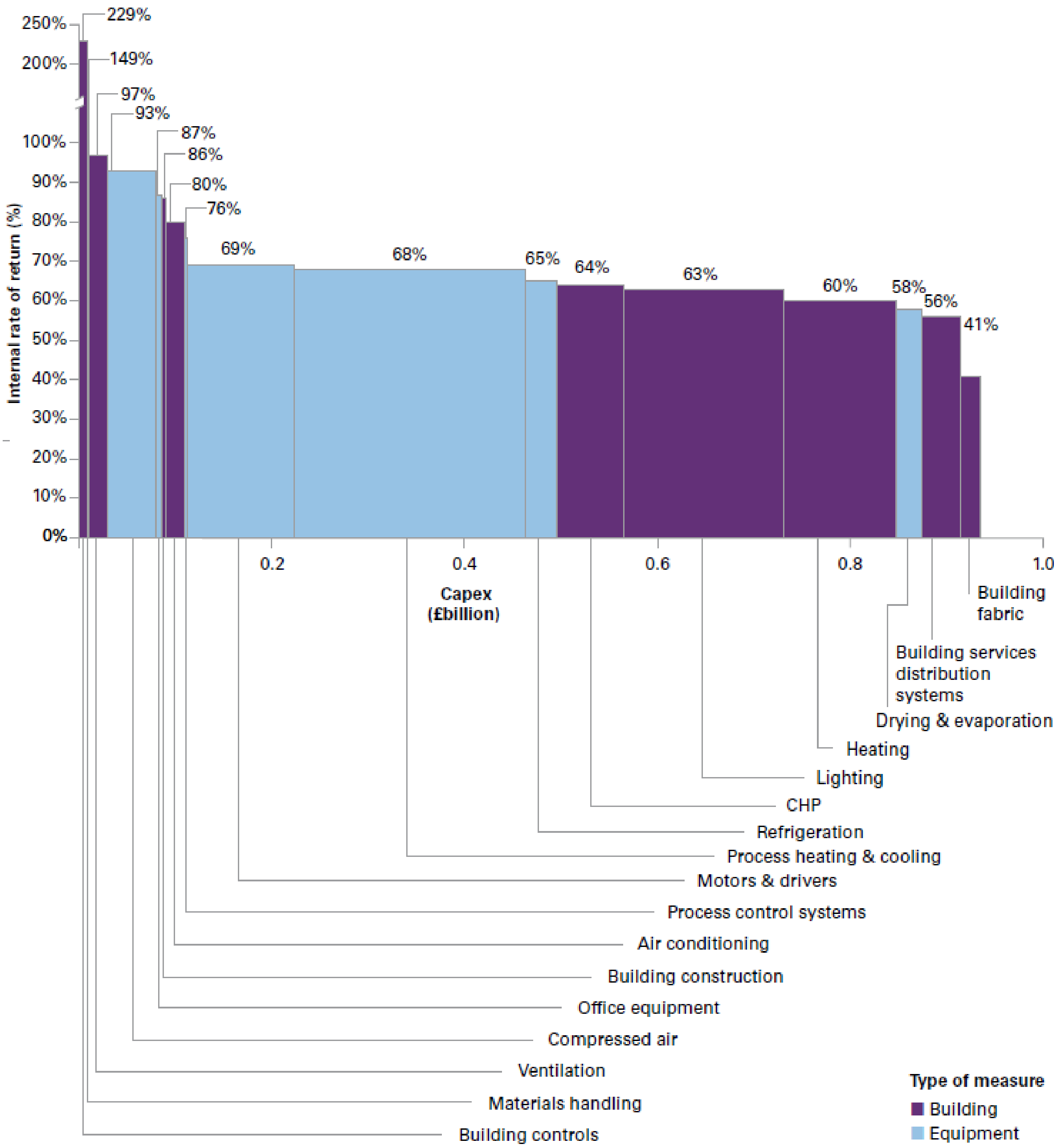
Figure 28. **Sixty per cent of the technical potential for energy efficiency in the UK's six most carbon intensive industries may pay back within five years**



Notes: each marker represents an instance in a sector from the database; data is only for the technical potential of energy-saving measures in the AEA Technology (2010) database, excluding two outlying measures

Source: AEA Technology (2010) & Vivid Economics analysis

Figure 29. **Analysis of a Carbon Trust database shows that for SME's the rates of return on energy efficiency investments are often above 50 per cent**



Source: Carbon Trust, Vivid Economics analysis.

Notes: data is only for measures that have an IRR>25 per cent and a capital cost > £3,000; data is scaled up from the Carbon Trust database to the whole economy

Source: Carbon Trust (unpublished)

4.6.3 Energy efficiency opportunities in Small and Medium sized Enterprises (SMEs)

Many small and medium sized Enterprises (SMEs) have a lower energy cost share. As a result of this energy efficiency tends not to be a priority and therefore a significant energy efficiency opportunity is thought to remain (Carbon Trust, unpublished). It is difficult to gauge the size of this opportunity precisely as data on SME activity is scarce. The Carbon Trust, using a database of energy efficiency measures recommended during energy assessments, estimates that there is £1 billion of capital expenditure to be made in SME's buildings and process-related energy efficiency measures, all of which have an IRR of more than 25 per cent and a capital cost of more than £3,000. Such an investment would save £0.7 billion per year in energy costs and 4.9 $MtCO_2$ of CO_{2e} (Carbon Trust, unpublished). In sectors with non-energy intensive SME's, such as public services and retail, 40 per cent of carbon savings identified came from energy management and 45 per cent from building-related measures. This suggests that the most effective ways of increasing the energy efficiency of SME's is to support behavioural change, either through information campaigns or increased energy prices, or to tackle energy efficiency in buildings. For sectors with energy-intensive SME's, such as chemicals, energy management still provides 20 per cent of carbon savings but 60 per cent of savings comes from improvements in process-related technologies.

4.6.4 Energy efficiency opportunities in non-domestic buildings

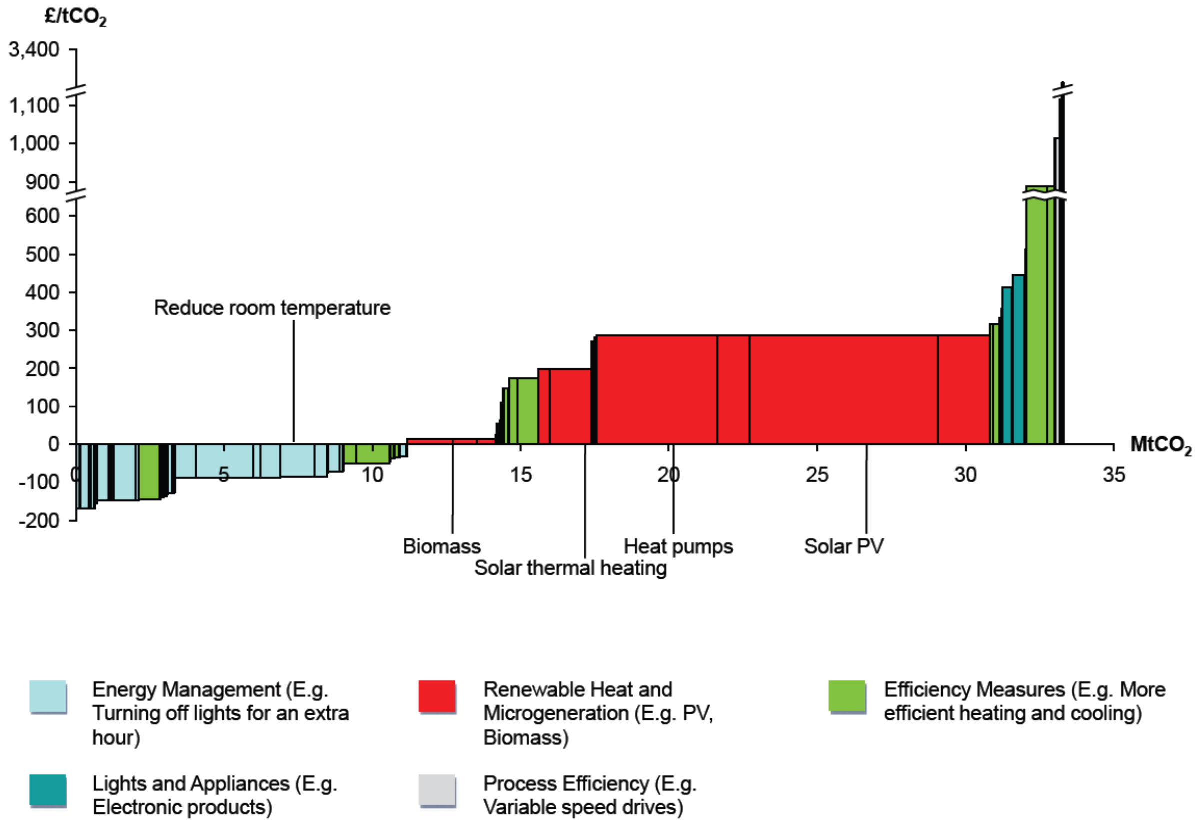
Non-domestic buildings consumed 205 TWh of energy in 2008, producing 64 $MtCO_2$[9]. The energy efficiency opportunity is thought to be large, with a 25 per cent reduction in direct emissions (5 $MtCO_2$ saving from 20 $MtCO_2$ of emissions) between 2008 and 2020 projected in the 4th carbon budget medium scenario of the Committee on Climate Change[10], while the Carbon Trust reckons that a 35 per cent reduction in total CO_2 emissions is feasible by 2020 (Carbon Trust, 2010). In addition, the Carbon Trust considers a 70 per cent reduction in non-domestic building CO_2 to be possible at no net cost, although the cost-effective abatement potential estimated by the Committee on Climate Change is lower, as shown in Figure 30.

The capital required to achieve these savings is thought to be £1.2 billion for building related measures and £4.9 billion for lighting (McKinsey 2011, & also Carbon Trust 2010). It is also known that around 15 per cent of buildings may undergo a major refurbishment before 2020 (Carbon Trust, 2010). Overall, the buildings sector has significant energy efficiency potential.

[9] Committee on Climate Change, 2010, The Fourth Carbon Budget, supporting data, chapter 5, figure 5.12

[10] Ibid., figure 5.11

Figure 30. **The technical potential of abatement by 2020 in non-domestic buildings is 50 per cent of current emissions, although only half of this is cost-effective at the non-traded cost of carbon and most of these savings are due to energy management**



Source: Committee on Climate Change, 2008, 'Building a low-carbon economy', chapter 6, figure 6.19

4.6.5 Assessment of value for money

The net present value generated by a £1 billion investment in energy efficiency is estimated at between £300 million and £1,674 million. The variation is the result of varying the lifetime over which energy efficiency measures deliver both energy savings and CO_2 savings, with the lower bound representing a case where measures have a lifetime of 10 years and the upper bound where measures have a lifetime of 25 years. These results are presented in Figure 31 and in Table 42.

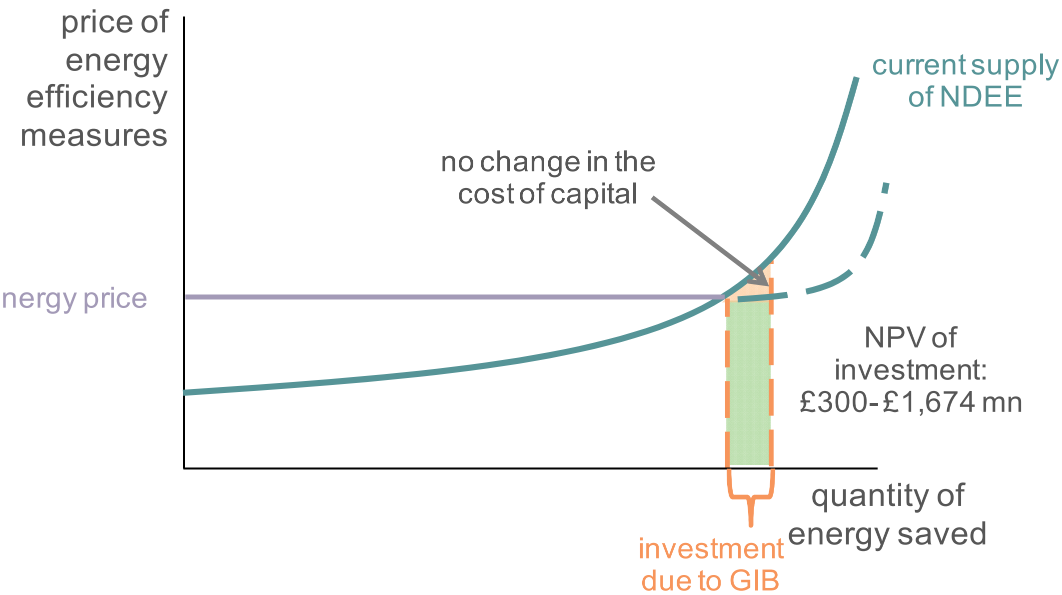
Table 42. **The value for money of a capital investment of £1 billion in non-domestic energy efficiency**

	Units	Measures persist for 10 years	Measures persist for 15 years	Measures persist for 20 years	Measures persist for 25 years
Capital invested	(£ millions, 2011)	1,000	1,000	1,000	1,000
IRR of investment	(per cent)	4.4%	12.7%	15.0%	15.8%
NPV of investment	(£ millions, 2011)	20	340	610	840
Investment as % of opportunity to 2020	(per cent)	6.7%	6.7%	6.7%	6.7%
Electricity saved in 2020	(TWh)	3.5	3.5	3.5	3.5
Non-traded CO2e saved in 2020	(thousand tonnes per annum)	330	330	330	330
Traded CO2e saved in 2020	(thousand tonnes per annum)	660	660	660	660
Total CO2e saved in 2020	(thousand tonnes per annum)	990	990	990	990
NPV of society	(£ millions, 2011)	320	840	1,310	1,640

Source: Vivid Economics

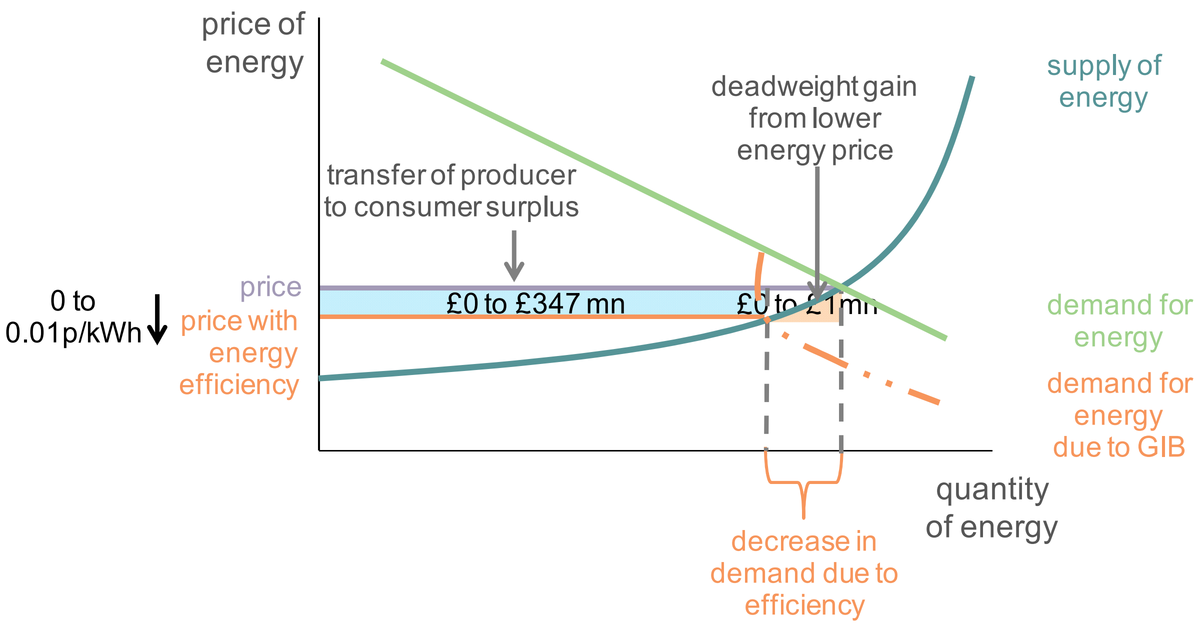
The improvement in energy efficiency reduces demand for energy. This could reduce the average price of electricity for non-domestic consumers by up to 0.01 p/kWh. The price of other fuels is assumed to be inelastic as it is set in wider markets. The decrease in electricity price generates a negligible present value gain of up to £1 million and a reduction in transfers between producers and consumers with a present value of up to £367 million. These figures are presented in Figure 32, and these are driven by an assumption, in the absence of empirical data, that the price elasticity of supply of electricity is unity.

Figure 31. **GIB investment in non-domestic energy efficiency can have a large positive NPV if the technology invested in has a long life time**



Source *Vivid Economics*

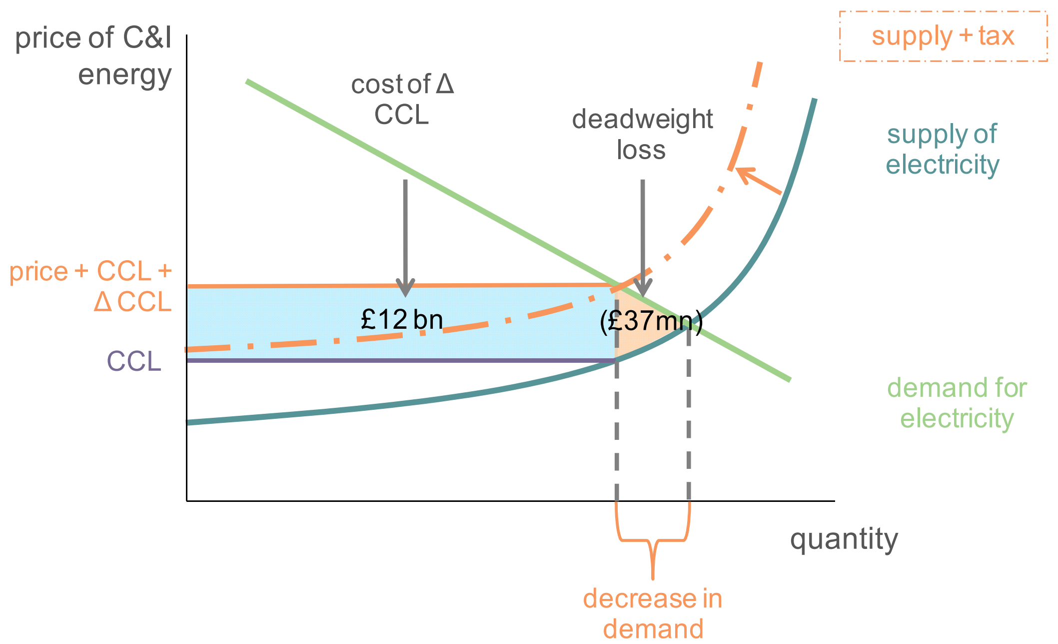
Figure 32. **The effect of the GIB intervention on the energy supply market**



Source *Vivid Economics*

Under the alternative policy, an increase in the Climate Change Levy, the price of non-domestic energy increases by £1.38/MWh. This creates a deadweight loss with a present value of £37 million, and results in transfer payments, in the form of higher taxes, with a present value of £12 billion, as shown in Figure 33.

Figure 33. **The effect of the alternative policy intervention on the energy supply market**



Source *Vivid Economics*

Under both policies, the effect on energy consumption and carbon dioxide savings is the same. By 2020, energy consumption falls by 3.5 TWh p.a. and emissions are lower by 1.1 mtCO_2pa.

Table 43. **Estimated value for money impact of £1 billion invested in non-domestic energy efficiency via the GIB**

Variable	Low	High
Net present value of energy efficiency measures (£ millions)	300	1,674
Deadweight gain from lower electricity price (£ millions)	0	1
Total (£ millions)	300	1,675
Transfers (£ millions)		367
Change in energy consumption in 2020 (TWh pa)		3.5
Change in carbon dioxide emissions in 2020 ($mtCO_2$ pa)		1.1

Source: Vivid Economics

Table 44. **Estimated value for money impact of energy taxation with the same energy saving effect**

Variable	Low	High
Net present value of energy efficiency measures (£ millions)	300	1,674
Deadweight cost of increased Climate Change Levy (£ millions)	(37)	(37)
Total (£ millions)	263	1,638
Transfers (£ millions)		12,000
Change in energy consumption in 2020 (TWh pa)		3.5
Change in carbon dioxide emissions in 2020 ($mtCO_2$ pa)		1.1

Source: Vivid Economics

4.7 Comparison of value for money across all sectors

4.7.1 **Brief overview**

In addition to the in depth analysis of value for money across the three main sectors (offshore wind, non-domestic energy efficiency, and commercial and industrial waste), a briefer review of value for money has been completed for a 13 further sectors. This sets up a framework of comparison across sectors and presents basic qualitative and quantitative results for all sectors together. A full quantitative approach was beyond the scope of this report except for the main sectors. The sectors considered are:

- carbon capture and storage;
- electric vehicle infrastructure ;
- flood defences;
- Green Deal (domestic energy efficiency and micro-renewables);
- marine;
- non-domestic energy efficiency;
- non-local authority commercial and industrial waste;
- nuclear;
- offshore wind;
- onshore wind;
- photovoltaics;
- renewable heat;
- rolling stock;
- smart meters (domestic);
- smart meters (non-domestic).

The GIB will find itself constrained in its available capital because of the large scale of the capital investment required in the low-carbon transition and in other areas of environmental improvement. Consequently, in order to maximise its value for money, thought must be given both to the private return on capital that it achieves, the environmental benefits and the social benefits which it generates. In addition there are operational considerations such as the timing of intervention and deal flow.

4.7.2 **Methodology**

Sectors are evaluated according to six factors. Of the first four, three are qualitative and include:

- complementarity with other government policies;
- market additionality (including capital mobilisation);
- timing and investability (with a preference for the period to 2020);
- green impact (value of lifetime emissions avoided or other green benefits per unit of GIB capital employed).

Each of the three factors are assessed and then given an attribute score on a five-point scale ranging from very good, through good, fair and poor to very poor. These are shown in the summary below as quarters of a shaded circle, with a fully shaded circle being good and an unshaded circle being very poor. This builds on the multi-attribute analysis prepared for BIS by McKinsey & Company during summer 2011.

The other two factors are quantitative:

- returns to society (net present value per £1 of capital invested);
- private returns to the GIB (return on capital employed).

The three quantitative factors are all normalised per unit of capital deployed. For green benefits, this is the carbon dioxide emissions avoided. For the private benefits, this is the return on capital. For the social benefits, this normalisation involves taking a rolled-up stream of future social benefits, where appropriate expressed as a present value, and dividing it by the capital costs of the projects. This normalisation concept was adopted from a value for money tool, the Transport Appraisal Guidance, developed by the Department for Transport, in which the value of benefits is normalised by the cost to the 'broad transport budget'. The analogy here is that the normalisation is by the GIB's capital allocation.

4.7.3 **Limitation of the analysis**

Within the scope of this report, no commentary is offered on the mobilisation of finance other than for the main three sectors. For those three sectors, individual investments offer a mobilisation factor of between 2 and 10 times, with portfolio of investments offering between 3.6 and 5.5 times according to McKinsey estimates (McKinsey & Co, personal communication).

4.7.4 **Data sources**

Data were collected on typical investments, covering capital costs, CO_2 savings and market benefits. The financial components were rolled up into a present value sum. The data come from Vivid Economics modelling results for the main sectors, and from a number of consultancy reports, government reports and regulatory impact assessments. A full list of sources is listed alongside the tables in this section.

4.7.5 **Assumptions**

The returns to GIB capital vary by financial product, as shown in Table 48. Equity returns vary greatly across sectors. In contrast, debt product returns are assumed to be the same across all sectors. Debt products offer returns of 6.75-8 per cent while equity returns are 10-25 per cent. These and the other return figures are taken from work carried out by McKinsey and Co (McKinsey & Co, personal communication). As a result of the properties of these returns, the GIB's private return will depend upon the mix of products it places in each sector. An illustrative mix has been assumed in this analysis, but should be revisited and not be relied upon in any subsequent decision-making by the GIB. The product mix assumptions are laid out in Table 48.

4.7.6 **Results**

4.7.6.1 Qualitative analysis

The qualitative analysis spans the three attributes: complementarity with other government policies; market additionality (including capital mobilisation); and timing and investability. These have been explored in the Sections 2 and 3 of this report, and are summarised here and given a score on a five-point scale.

First, consider timing. Of all the sectors, some are unlikely to be immediate priorities for the GIB. Marine energy is too early-stage in its development now, but might be suitable in a few years' time. Carbon capture and storage will not be suitable until it has completed its grant-funded demonstration phase towards the end of this decade.

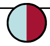
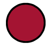
Second, additionality. For a number of sectors, there is likely to be private sector capital available and the only question is whether the private capital providers find their capital becoming exhausted. This applies to onshore wind, photovoltaics, rolling stock, nuclear power and local authority-collected waste.

Thirdly, policy complementarity. Flood defences are almost always publicly funded and there are alternative funding arrangements already in place already. Smart meters already have a clear regulatory framework but face possible competition for capital allocation by energy suppliers, and so should remain part of the assessment.

In addition, there is the attribute of green impact, in which the top five scoring sectors are materials recovery facilities, nuclear, carbon capture and storage, non-domestic smart meters, and non-domestic energy efficiency. Offshore wind is among the bottom three.

The sectors which emerge as suitable from the qualitative assessment screening are non-domestic energy efficiency, non-local authority-collected commercial and industrial waste including energy from waste, the Green Deal, offshore wind, smart meters and electric vehicle infrastructure.

Table 45. **Scoring of qualitative measures of value for money**

Sector	Complement and not duplicate other gov't policies	Market additionallity	Timing/investability (2020)
Offshore wind	 – RO scheme in place, feed-in tariff with contract for difference to be implemented following EMR which tackles prevailing externalities (GHGs, innovation spill over) – No other direct gov't financing interventions – GIB involvement more efficient/ targeted than increase in ROCs/FIT	 – Limited capital markets financing caused by high (perception of) risk – Limited financing from utilities given stretched balance sheets – Limited number of financial investors currently active – Potentially insufficient coordination of adjacent infrastructure in supply chain	 – Round 2 sites are already in planning and will require financing for construction – Important to ensure financing within next 4 years to remain on target for 2020 Renewable Energy Target – Some Round 3 sites likely to enter financing negotiations from 2014 onwards – Existing refinancing opportunity
Non-domestic energy efficiency (incl. CHP and onsite renewables)	 – Current policies include EU ETS, CCAs1 and CCL2 – GIB intervention would not duplicate these policies – no other material government EE financing programme	 – Sub-optimal investment levels due to market failures (e.g. management attention, agent-principal problems) – Small risk of crowding out private finance – GIB to manage	 – Opportunities to invest/support investments currently available throughout the UK economy to help to initiate new investments
Non-local authority commercial and industrial waste processing (EFW and MRF)	 – Landfill Tax in place – GIB intervention would not duplicate this policy – no other material government financing programme in this waste sector	 – Opportunity to increase investment held back by scale of projects (high impact of due diligence and other costs) – Some novel technology is risky	 – Technology and opportunities currently available – In C&I sector, approx £1bn could be invested
Energy from waste	 – RO scheme in place for various technologies e.g. pyrolysis, gasification – Landfill tax in place – GIB intervention would not duplicate these policies – no other material government financing programme in these sectors	 – Opportunity to increase investment held back by market failures (e.g., certainty of waste input, novel technologies – Only small risk of crowding out financing for larger projects using proven technologies – GIB to manage	 – Incineration technologies widely available and investable – Gasification and pyrolysis techniques are more novel and may be more limited investment opportunities, but overall a major opportunities

Green Deal (domestic energy efficiency and micro-renewables)	●	– Green Deal is a gov't intervention at household level, achieving significant GHG savings – Additional GIB intervention as aggregator of loans might be required to create market for investors	●	– Market interest in Green Deal unclear at this point – novel nature of security interest and untested economics likely to create risk aversion – Small scale of investments likely to require aggregator of loans to make sector more investable	◑	– Green Deal timing (2012) highly compatible – £100-200m investment likely to be sufficient to pump-prime a single market aggregator of debts
Marine	◑	– RO scheme in place – Current direct gov't intervention focused on venture capital and R&D – £20m DECC capital available for first arrays	●	– Limited private capital availability due to immature technology and lack of proven business model – Likely to require government financing support, due to high risks and capital intensive nature of investment	○	– Unlikely to be significant opportunities which meet GIB risk/ reward criteria prior to 2015 – Other sources of government funding likely to prove most attractive to developers
Flood defences	○	– Gov't direct intervention already forecast at more than £2bn to 2015, targeted to areas of most need – GIB could duplicate lending of Public Works Loan Board to local authorities; for private sector projects no risk of duplication	●	– Inherent public good nature not conducive to private financing – new revenue models required – Any GIB financing that meets criteria likely to be additional	○	– Unclear requirements/project availability within timeframe – Not likely that any privately financed flood defences constructed in period
CCS	◔	– UK government committed to support 3-4 demonstration projects – EU ETS and carbon price floor support – GIB support could be complementary, but probably not required pre 2015, and possibly not until after 2020	●	– Currently limited private capital investment – Significant technology risk aversion, as well as potential novel business model issues – likely to require GIB support	○	– Early stage technologies yet to be proven viable on commercial scale – Timing of demonstration plants unclear – Unlikely to be a need for GIB participation pre 2015, but medium term potential pre 2020
Smart meters	●	– Incentives already in place for roll out	◔	– Unlikely that GIB support required for this sector, but might release capital for deployment in other market segments	●	– Currently being rolled out
Onshore wind	◕	– RO scheme in place – GIB intervention would not be duplicative	○	– Private investors provide sufficient funding for new onshore wind projects – Unlikely to be any significant projects justifying GIB participation	●	– Opportunities currently available – subject to market additionality

Solar photovoltaics	– Feed-in tariff and RO scheme in place – GIB intervention would not be duplicative	– Private investors provide sufficient funding for new solar PV projects – Evidence that, even with lower FiT support, there would still be sufficient private funding	– Opportunities currently available
Electrical vehicle infrastructure	– No gov't support so far, aside early stage funding	– Little private investment, because of early stage	– Limited opportunities that are commercial and available in large enough scale – Timing of rollout unclear at this point
Rolling stock	– Government oversees procurement of rolling stock, as indirectly guarantees Train Operating Companies as provider of last resort – GIB support could be attractive to reduce cost of financing by increasing market capacity for major rolling stock procurement programmes	– Financing available, but not at potentially desirable accelerated pace – However, there are market alternatives to GIB participation	– Several major procurements of rolling stock to take place over period to 2015, including Cross Rail and Intercity Express replacement programme, worth several £bns – GIB role could be to either provide significant capital or to help take a smaller risk position
Nuclear	– EMR, EU ETS and carbon floor price aim to ensure financial viability with no direct support – Historically government supported projects but all future projects intended to be planned, financed, constructed, and operated by private sector	– Over period to 2015, likely that utilities will finance nuclear power projects on balance sheet – Possible additional role if balance sheets become stretched	– Majority of capital likely to be financed on utility balance sheets – Scale of GIB financing likely to be minimal over the period- although could be a significant priority over the medium term
Local authority collected municipal waste	– Local Authorities play a significant financing role through PFIs – However, some potential for GIB to assist in financing of new technologies or merchant capability to provide additional infrastructure	– Already large amount of private capital, given relative safety of PFI arrangements – However, there may be some new technologies or investments which are beyond PFI financing	– Technology already mature; large amount of landfill diversion already occurring to MRFs – However, medium potential for additional build-out of new plant over period to 2015
Renewable Heat	– Renewable Heat Premium Payment provides one-off grants to households. – Renewable Heat Incentive provides long-term tariff support	– Small risk of crowding out of private finance – Low level of investment due to a variety of market failures	– Opportunities currently available.

Source: McKinsey & Co based on Vivid Economics analysis

4.7.7 Quantitative analysis

The quantitative analysis allows a clearer ranking of sectors. They are ranked on three attributes, which are listed in Table 46 to Table 48. In each of these tables, the best-performing sector is shown at the top of the list, and the worst performer is placed at the bottom. A visual summary of the scores is presented in Figure 34.

Nuclear power, carbon capture and storage and smart meters top the table of green impact per unit of capital deployed meanwhile flood defences, offshore wind and the Green Deal fairly poorly on this metric.

On social returns, flood defence is the best performer, accompanied by smart meters, nuclear power and non-domestic energy efficiency. Marine energy, photovoltaics and carbon capture and storage languish at the bottom of the table.

The best private returns to GIB investment are offered by the equity-rich opportunities such as electrical vehicle infrastructure, marine energy and carbon capture and storage. Photovoltaics, renewable heat and non-domestic energy efficiency and waste offer debt returns only. Note that these returns are not risk-adjusted which is why the scores are biased in favour of the riskier investments.

Table 46. **Estimated green impact, tCO_2 saved per £m of capital investment, in descending order**

Sector	tCO2 saved per £m capital investment
MRF (materials recovery facility)	96
Nuclear	66
Carbon capture and storage (capture)	71
Smart meters (non-domestic)*	40
Onshore wind	25
Non-domestic energy efficiency	23
Renewable heat *,[a]	18
EFW (energy from waste)	10
Marine	9
Domestic energy efficiency/Micro-renewables (via Green Deal)*	5
Offshore wind	5
Smart meters (domestic)	3
Photovoltaics	2
Flood defences	N/A
EV infrastructure	N/A
Rolling stock	N/A

*Notes: *Green impact is calculated as tCO_2 per £m total project costs;*

[a] Based on the DECC Impact Assessment. Using Arup (2011), as typical renewable heat project, such a ground source heat pump, has a green impact factor of around 6.

Sources: Vivid Economics calculations, Arup (2011), DECC Impact Assessments, DTI (2007), Defra (2010a), Ernst and Young (2010), Pöyry (2007).

Table 47. **Estimated social return, net present value per £m of capital investment, in descending order**

Sector	**NPV per £m capital investment**
Flood defences	12.45
Smart meters (non-domestic)*	6.02
Nuclear	2.82
Non-domestic energy efficiency	1.51
MRF	0.92
Domestic EE/Micro-renewables (via Green Deal)*	0.48
Smart meters (domestic)*	0.44
Onshore wind	0.15
Renewable heat*	-0.30
Offshore wind	-0.44
EFW	-1.13
Carbon capture and storage	-1.56
Photovoltaics	-1.78
Marine	-1.85
EV infrastructure	N/A
Rolling stock	N/A

*Note: * includes the value of untraded CO_2. Since the price of untraded CO_2 is lower than the price of traded CO_2 these figures are likely to be underestimated.*

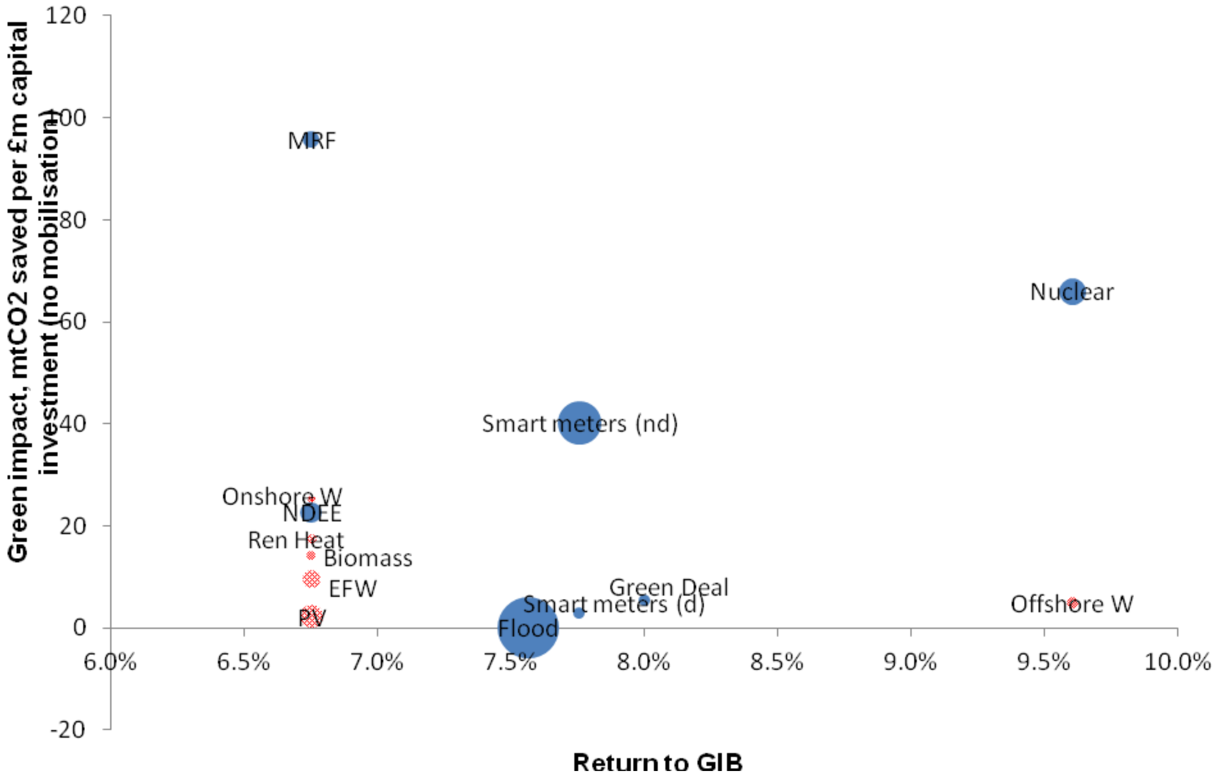
Source: Vivid Economics calculations based on Vivid modelling, Arup (2011), DECC Impact Assessments, DTI (2007), Defra (2010a), Ernst and Young (2010), Pöyry (2007).

Table 48. **Estimated returns on assets for GIB products, by sector**

Sector	Financing mix: Equity	Financing mix: Subordinated debt	Financing mix: Senior Debt	Return on: Equity	Return on: Subordinated debt	Return on: Senior debt	Risk-adjusted return to GIB
Electric vehicle infrastructure	50%		50%	25%	8%	6.75%	15.9%
Marine	33%	16%	50%	20%	8%	6.75%	11.3%
CCS	50%	25%	25%	15%	8%	6.75%	11.2%
Offshore wind	33%	16%	50%	15%	8%	6.75%	9.6%
Nuclear	33%	16%	50%	15%	8%	6.75%	9.6%
Green Deal (domestic energy efficiency and micro-renewables)		100%		10%	8%	6.75%	8.0%
Smart meters (domestic)	33%		66%	10%	8%	6.75%	7.8%
Smart meters (non-domestic)	33%		66%	10%	8%	6.75%	7.8%
Flood defences	25%		75%	10%	8%	6.75%	7.6%
Non-local authority commercial and industrial waste processing (EFW and MRF)			100%	25%	8%	6.75%	6.8%
Non-domestic energy efficiency			100%	10%	8%	6.75%	6.8%
Renewable heat			100%	10%	8%	6.75%	6.8%
Photovoltaics			100%	10%	8%	6.75%	6.8%
Onshore wind			100%	15%	8%	6.75%	6.8%
Rolling stock			100%	12%	8%	6.75%	6.8%

Source: Vivid Economics calculations based on Vivid modelling, Arup (2011), DECC Impact Assessments, DTI (2007), Defra (2010a), Ernst and Young (2010), Pöyry (2007).

Figure 34. **Comparison of sector scores on green impact, return to GIB and social net present value**



Note: Size of the bubble represents the return to society, see Table 47. Blue bubbles indicate positive return, red bubbles indicate a negative return

Source Vivid Economics calculations based on Vivid modelling, Arup (2011), DECC Impact Assessments, DTI (2007), Defra (2010a), Ernst and Young (2010), Pöyry (2007).

The assessment may change when data on mobilisation become available.

Table 49. **Overall value for money assessment across sectors**

Sector	Complementarity to govt policy	Timing and Investability	Market additionality	Green impact	Return to society	Return to GIB
Green Deal (domestic energy efficiency and micro-renewables)*	●	◑	●	◔	◕	◑
Electrical vehicle infrastructure*	●	◔	◔			●
Non-domestic energy efficiency*	◑	●	◕	◕	◕	◔
Non-Local Authority commercial and industrial waste (EFW)*	◕	◕	◕	◑	◔	◔
Non-Local Authority commercial and industrial waste (MRF)*	◕	◕	◕	●	◕	◔
Offshore wind*	◑	●	●	◔	◔	◕
Renewable heat	◕	●	◕	◕	◑	◔
Smart meters (domestic)*	●	●	◔	○	◑	◑
Smart meters (non-domestic)*	●	●	◔	◕	●	◑
Carbon capture and storage	◔	○	●	●	○	●
Flood defences	○	○	●	○	●	◑
Marine	◑	○	●	◔	○	●
Nuclear	◔	◔	◔	●	●	◕
Onshore wind	◕	●	○	◑	◔	◔
Rolling stock	◔	◕	◔			
Solar PV	●	●	○	○	○	◔

*Note: * indicates that the sector passed the qualitative assessment*

4.7.8 Conclusions

The value for money assessment set out above establishes a framework for the GIB to consider its capital allocation across its portfolio. It is a preliminary assessment and in some cases not exhaustive. Other government departments might be invited to offer further detail to improve the robustness of the assessments of each sector.

The results using the data collected here indicate that not all sectors are worthy of GIB involvement in the period to 2020, and fewer still in the first period to 2015. Of those that merit support by the GIB, non-domestic Smart Meters, materials recovery facilities, non-domestic energy efficiency and the Green Deal offer the greatest returns to society. If green impact is the primary concern, then the portfolio would be weighted in favour of waste (materials recovery facilities) and non-domestic energy efficiency. If returns to the GIB took primacy, then the portfolio would emphasise offshore wind and electric vehicle infrastructure.

5 Implications for economic growth

The GIB has a positive, but probably small impact on economic growth

Section Contents:

Section Summary

There is unlikely to be any discernable impact on economic growth in the UK in the short term, but there might be benefits in the long term. The origin and scale of benefits depend on the opportunity foregone in any alternative use of the public funding allocated to the GIB, or the risk of a negative effect on growth from increased spending. They also depend upon the net returns from the re-allocation of capital across sectors.

The GIB might enhance economic growth in the longer term if its investments (i) offer higher social returns than the alternative use of the public and private funds (not all of which might be captured in changes to Gross Domestic Product), (ii) generate greater technology spillovers, or (iii) create greater disruptive competition. The first of these is identifiable by a high net present value and benefit-cost ratio, a property which some, but not all of the sector investments examined here possess. Three positive examples are: energy efficiency which improves the supply side productivity of the economy; smart meters which enhance the productivity of the power infrastructure; and, materials recovery facilities which enhance materials resource efficiency. Offshore wind and direct combustion energy from waste are counter-examples: they generate market outputs of lower value than their input costs, and so record a negative impact on GDP, but nevertheless contribute towards environmental targets. The potential for technology spillovers is difficult to identify but is greatest for the most rapidly innovating sectors. Finally, disruptive technologies which increase innovation in competing technologies might include electric vehicles and their effect on internal combustion engines.

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5.1 Four pillars of growth

Better use and an expansion of resources are the keys to growth

5.1.1 **Introduction**

The creation of a Green Investment Bank (GIB) is potentially likely to have small growth effects in the longer term, given the expected size of the bank. However, at the margin it could stimulate both aggregate demand and aggregate supply in both the short term and the long term, thereby increasing measured GDP growth rates. It is helpful to categorise the range of potential impacts according to the broad mechanism by which growth could be affected (Bowen and Fankhauser 2011):

- A boost to aggregate demand in the short run: a 'Keynesian' mechanism (after John Maynard Keynes);
- An increase in the level of potential supply over the short to medium term due to the correction of market and policy failures, increasing the measured growth rate during the adjustment period: a 'Pigovian' mechanism (after Arthur Pigou);
- An increase in the growth rate of potential supply over the medium term due to a boost to the drivers of endogenous growth, particularly innovation: a 'Schumpeterian' mechanism (after Joseph Schumpeter);
- An increase in the growth rate of potential supply in the long term due to the relaxation of resource constraints: a 'Georgian' mechanism (after Henry George, the American political economist and critic of Thomas Malthus).

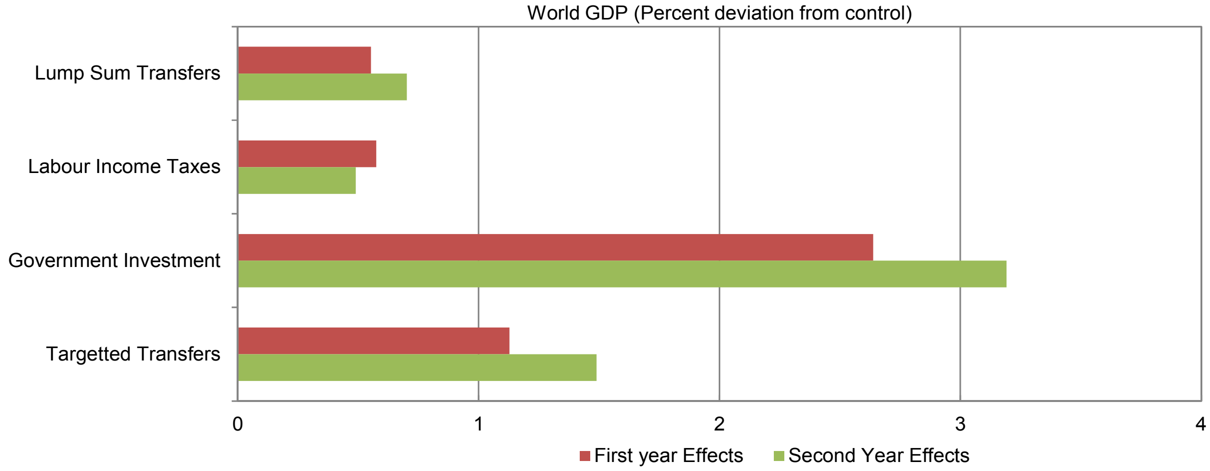
5.1.2 **The 'Keynesian' mechanism**

If there are spare resources available in the economy, investment could increase GDP, and hence in the short run, GDP growth, through a Keynesian multiplier effect. The size of such multiplier effects is controversial. The literature has focused on increases in government spending but the principles can be extended to induced increases in private investment spending. IMF research and surveys such as Hemming et al (2002) suggest that the impact of fiscal expansions has varied widely across countries and time. This is not surprising given the range of shocks triggering downturns and the market failures responsible for prolonging them. The authors conclude that certain common features can be identified, consistent with macroeconomic theory, and that expansions have been more effective when:

- there was excess capacity;
- the economy was relatively closed;
- the spending stimulus was accompanied by monetary expansion.

Furthermore, IMF modelling suggests that a pound spent on government investment has a bigger cumulative effect on GDP than a pound spent on transfers targeted on 'hand-to-mouth' households whose consumption is determined by their current disposable income. These targeted transfers are in turn more effective than equal lump-sum transfers to all households or labour tax cuts (Freedman et al., 2009). The Freedman et al. simulations for public investment could be used to calculate effective multipliers for induced total public and private investment at a time when monetary policy is accommodative, i.e. when interest rates do not rise to counteract increases in spending, and capital and labour in the sectors benefiting from GIB-financed investment are underutilised. The simulation experiment is not a straightforward single pulse of spending in one year, but the charts show in Figure 35 suggest that the medium-term multiplier could be around two.

Figure 35. **Effects of global stimulus with monetary accommodation**



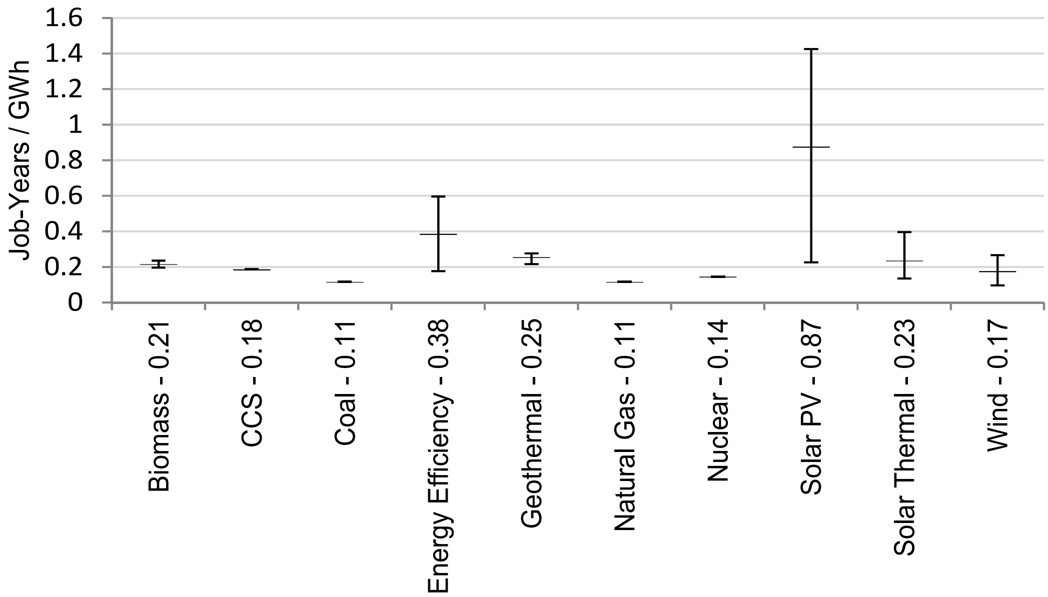
Source: Freedman et al. (2009)

Job creation depends on the labour intensity of the investment spending. Barbier (2010), for example, draws attention to the range of employment consequences of any given amount of green fiscal stimulus spending in Korea. Various US reports have used input-output tables and assumed fixed labour-output ratios to calculate employment creation following a targeted fiscal stimulus (e.g. Pollin et al., 2008; Pollin et al., 2009). These estimates could also be used to project the impact of induced private investment spending. Different types of power generation utilise different amounts of labour per kWh of energy produced, with renewable energy sources requiring more labour hours per kWh produced over the lifetime of the generating plant. Wei et al. (2010) has a good discussion of all the quantitative renewables/jobs studies that the authors could identify, Figure 36.

At the current juncture, the assumption of underutilised resources seems reasonable, and a period of global economic slowdown is a promising time to ramp up expenditure on 'green' objectives, as discussed in Bowen and Stern (2010). Nevertheless, it would take time for a GIB to get off the ground and for the projects it finances to come on line. So the key question is, what will be the extent of spare capacity in the economy when that happens?

Slowdowns associated with banking crises tend to last longer than others but, in the absence of further adverse shocks, the global output gap is likely to close by the middle of this decade, although there might still be spare capacity in the euro area and especially the UK (IMF WEO, 2010; WEO, 2011; OECD, 2010; Office for Budget Responsibility, 2010). At that point, increasing expenditure on more labour-intensive activities is likely to crowd out other investment, by diverting saving flows, and reduce the labour productivity of the economy at full employment. This could have possible adverse consequences for real returns on capital, too, if the demand for labour increases relative to the demand for real capital and the equilibrium share of labour is thereby significantly increased[11].

Figure 36. **Generation of job-years per GWh over the life of plant**



Source: Wei et al. (2010)

Estimates of aggregate output gaps can obscure varying mismatches of demand and potential supply across regions and industry sectors. These mismatches are important because capital and, even more, labour cannot be instantly and without costs transferred among regions and sectors, even for new projects. The scope for GIB-financed projects to increase aggregate demand without driving up prices and crowding out other spending is larger if those projects are located in areas of high unemployment and utilise plant and equipment in otherwise underused factories. This is true so as long as the spending does not worsen the problems responsible for regional/sectoral differences in unemployment in the first place, such as inappropriately high nationally negotiated pay or inadequate, overstretched local infrastructure. This mechanism is greatly dependent upon where orders for equipment are placed and so a good deal of empirical information is needed before judgements on its effectiveness can be made accurately.

Although government spending can be growth enhancing in the right circumstances, the UK is currently running a large budget deficit and its public debt is a high proportion of GDP. The Government has to take care to move to greater fiscal balance and a lower level of public debt otherwise lenders may ask for higher interest rates, with negative impacts on growth.

[11] This might happen relative to a counterfactual case where there is additional investment in high-carbon power generation, as renewables are less capital-intensive; but if the alternative is investment in public works generally, or other less capital-intensive activities, one would not expect the share of labour to be increased.

5.1.3 The 'Pigovian' mechanism

The recent OECD review of the UK economy (OECD, 2011, pages 149-150) argues that market failures and lack of full climate policy credibility over the long term may warrant government intervention in the form of a GIB. It notes that:

> *'Financial markets may not be prepared to take on all the risks associated with new low-carbon technologies, given their novelty and the dependence of their success on future policies and provision of infrastructure, so that in the absence of further government intervention insufficient finance would be available at the scale and pace needed to meet decarbonisation goals. Private investment in this area is contingent on the credibility of the government's long-term commitment to carbon pricing and other climate-change policies; subscription of government capital helps build that credibility. This will help to redirect saving flows to low-carbon investments more generally.'*

Market failures in the process of financial intermediation are particularly acute at the moment because of the realisation on the part of banks that asymmetric information, as well as affecting their relationships with end-borrowers, is a more serious problem within the financial system than had been thought. That has inhibited new syndicated project finance arrangements. Banks can be thought of as a means by which borrowers' behaviour is monitored on behalf of the ultimate investors. That monitoring has been revealed to be less effective than previously assumed. In any case, it is more difficult when the end-borrowers' activities are more novel, as in the case of the transition to low carbon.

The correction of market and public policy failures should increase wellbeing. The effect on UK GDP growth depends on the nature of the failure. Some of the benefits of intervention will not be in the form of increased market output, but instead through measures not captured in market measures, such as improved ecosystem services or increased life expectancy. Also, some will not be obtained until the far future, for example averted climate-change impacts. Some of the benefits may be accompanied by reductions in measured output (as with averted climate-change impacts in models that generate positive mitigation costs). And some of the benefits will accrue overseas (e.g. public subsidies for energy R&D may help to raise global innovation closer to its optimal level but many of the benefits will spill over to producers in other countries). Firms and households will adjust their behaviour in response to corrective interventions so that general equilibrium feedbacks should in principle be considered.

The value of correcting a market failure could be obtained in principle by using a parameterised model of the economy that specifies precisely the nature of the market failure and compares the value of output when this failure is operative (i.e. when firms and households decide on their market transactions given market prices) with the value when the allocation of productive resources is optimised (a 'social planner' makes the decisions). Few actual economic models allow this, because they do not model the market failures explicitly in the first place. Some Integrated Assessment Models used by climate-change economists have experimented with one or two externalities on top of the central greenhouse gas externality e.g. the WITCH model (Bosetti et al. 2009) considers the benefits of tackling the externalities from the production of knowledge. Deriving a sense of the magnitude of the benefits from correcting market and public policy failures could be done by:

- Assuming that the negative-net-cost carbon abatement opportunities or 'free lunches' identified in abatement cost curve exercises are the result of market failures, estimating how many would be taken up (and how fast) if a GIB were introduced and converting these into a monetary amount reflecting the increase in the value of potential output (this would in principle be reflected in GDP data in due course);
- Valuing marginal emissions reductions achieved by GIB investments at the prevailing carbon price (this would not necessarily affect conventionally measured GDP, at least for a long time, but the carbon price at a point in time should in principle measure the value that society puts on achieving emissions reductions at that time).

5.1.4 The 'Schumpeterian' mechanism

Empirical endogenous growth models lay emphasis on the contributions of human and physical capital to output, both directly and via enhanced technological progress. There may be increasing returns to human capital, knowledge accumulation and investment, because of the positive externalities that can be generated. Aghion and Howitt (1998) discuss the theoretical underpinnings of this framework at length. Bouis et al. (2011) contains a useful discussion of empirical work in this area and also reports the authors' recent panel regressions attempting to account for differences in countries' growth rates:

- Extending past work to a larger range of countries, they confirm that long-run GDP per capita levels are increased inter alia by education policies, trade openness, R&D expenditures and policy frameworks that are conducive to low inflation, although the estimated effect of education is implausibly large.
- Using a new growth regression framework that explicitly models technology diffusion and allows the exploration of growth effects from a wider set of policies and institutions, while alleviating some of the constraints of the usual 'pooled mean group estimator' method, they find that the estimated return to education is more in line with available evidence from microeconomic studies.
- Regulatory barriers to entrepreneurship, explicit barriers to trade and – especially – patent rights protection appear to be fairly robust determinants of long-run cross-country differences in technology.
- Some other policies and institutions such as trade liberalisation are found to speed up technology convergence.
- There is limited evidence that the effects of policies and institutions vary depending on countries' level of development.
- Drawing on the work of Levine on the importance of well-developed financial markets for economic growth (King and Levine, 1993; Levine, 2005), the authors find that the IMF index of financial liberalisation helps to explain GDP growth (although it is difficult to separate out with confidence the effects of different policies and institutions).

According to OECD research (Egert *et al.*, 2009):

> *'Time-series results reveal a positive impact of infrastructure investment on growth. They also show that this effect varies across countries and sectors and over time. In some cases, these results reveal evidence of possible over-investment, which may be related to inefficient use of infrastructure…. infrastructure investment in telecommunications and the electricity sectors has a robust positive effect on long-term growth (but not in railways and road networks).*

> *Furthermore, this effect is highly nonlinear as the impact is stronger if the physical stock is lower.'*

That suggests that GIB-supported investment in innovative capital assets and knowledge building could raise the UK growth rate. The Egert *et al.* study contains regression results that could be used to obtain a ballpark estimate of the size of the effect.

A more qualitative approach is taken by Perez and the neo-Schumpeterians (e.g. Perez, 2010), who emphasise the transformative effect of some key innovations (e.g. railways, the internet) – a 'techno-economic paradigm shift' – and the scope for a new (sixth) Industrial Revolution. Stern (2011) has drawn on this tradition, noting that the transformation necessary of energy supply, energy efficiency, means of transport, buildings and land use certainly constitutes a revolution in the usual sense of the word.

However, it is very difficult to see how to estimate the marginal contribution of a GIB to such a transformation, which by its very nature is not a phenomenon susceptible to marginal analysis – either an economy goes down the revolutionary path or it does not, and no one action alone is likely to be the trigger for the choice of a different path. Nevertheless, one could argue that new methods of finance are a necessary but not sufficient condition for a 'green' industrial revolution, given the obstacles to traditional private financial intermediation, particularly at present.

There are also some reasons to doubt whether the switch to a low-carbon development path would meet the criteria for a Schumpeterian stimulus:

- Is the size of the industry sector at the heart of the transformation big enough and with sufficient links to the rest of the economy? In terms of its contribution to GDP, the energy sector in the UK is less important than manufacturing, business services, financial intermediation or transport (sectors at the centre of previous industrial revolutions). Electricity is a homogenous good, offering no scope for product innovation, and renewables do not improve the reliability or cost of power.
- Will high-carbon innovation and lower fossil-fuel rents discourage low-carbon deployment? In the nineteenth century, the advent of steamships triggered a burst of innovation in the sailing fleet, and the tea-clippers fended off the new technology for several decades. This 'sailing ship effect,' boosting innovation in previously mature industries set in their ways, could be seen in areas such as coal-fired electricity generation and the internal combustion engine. The prospect of high carbon prices in the future could lead low-cost fossil-fuel producers to extract resources more rapidly in the near term, forsaking some of their rents, driving down the relative price of fossil fuels and thus undermining the impact of carbon pricing. (And should one count as a benefit of 'green' climate-change policies lower oil prices that counteract the policies' objective, even if GDP growth is stimulated?)
- Is the Schumpeterian mechanism – intensified entrepreneurial competition leading to a plethora of competing novel products, stimulating both potential supply and demand, followed by failure of the unsuccessful innovators – going to work with energy, which from the point of view of the end-user will still be supplied in traditional forms (especially electricity) and often by monopolistic regulated utilities?

One way of thinking about this issue is to consider the impact of past transformative innovations such as the railway. Exercises in quantitative economic history (in the sub-discipline of cliometrics) have tended to attribute surprisingly low increments of GDP to apparently transformative innovations such as the railway (see Crafts, 2010; Fogel, 1964). But the definition of the counterfactual case in which the innovation is not introduced is problematic. The tools of cliometrics do not lend themselves easily to studying cases where increasing returns and network externalities allow initially small innovations to lead to big changes in the path followed by an economy.

5.1.5 **The 'Georgian' mechanism**

The main resource constraint that green investments will remove is that placed on the British economy by its commitment to reduce its output of carbon by 80% by 2050. Without the ability to power industry and make things in a green manner, then the UK will quickly become constrained by its commitments under international treaties and the Climate Change Act.

There are also less important resource constraints which may be relaxed by policies on waste and recycling for example, which may allow us to make better use of water and materials which would otherwise have been thrown away.

Importantly green investments would largely not relax any kind of fossil fuel constraint on the future growth of the UK economy. This is because for practical purposes there is a limitless amount of fossil fuel under the earth and certainly far more than we could burn over the next 30 or 40 years. This is certainly the case for gas and for coal, however there is a chance that liquid hydrocarbons will become prohibitively expensive as they become scarcer in the years to come, and that a decrease in the reliance of the economy on oil could therefore relax a resource constraint. This may present a future role for electric vehicles for example.

The debate about the 'limits to growth' following Meadows et al. (1972) also indicated that increasing efficiency of resource use in response to relative price increases may allow continued growth despite physical limits on resource endowments (although this depends on the pace of technical progress and the degrees of substitutability in production and consumption) – and the limits themselves may respond to economic stimuli. In the context of the GIB however making better use of the resource constraint is to a large extent the aim of the policy.

5.2 Analysis of impacts on growth

The is little evidence that growth would be enhanced significantly

5.2.1 **Potential of the Keynesian mechanism to deliver growth**

A key factor is the amount of spare capacity in the economy when the stimulus is delivered, since without spare capacity a stimulus crowds out private investment and reduces the productivity of an economy.

On the one hand, it will take some time for the GIB to be set up and by the time the investments it funds are commissioned, the UK may have substantially closed its output gap. Moreover, some of the GIB's programme may involve long term commitments which are not consistent with standard demand stimulus spending and may employ products manufactured outside the UK, with little stimulating effect.

On the other hand, recessions from banking crises tend to be long-lasting, and so it may be 2017–18 before the current 3 per cent GDP output gap is closed, according to the Office for Budget Responsibility (OBR, 2011). What is true for the UK as a whole may not be true at a regional level. Some areas of the country were not operating at full capacity before the recession, and they may gain more from stimulation.

Set against the weak evidence that the GIB could act as a stimulus is the fact that the public sector debt and fiscal deficit need to be brought down through tighter public budgeting and higher taxation. If the GIB were to contribute to greater public borrowing, it could have a growth-reducing effect, by raising the risk of a rise in the cost of public borrowing.

5.2.1.1 Investments which may have a Keynesian effect

Offshore wind may have a regional Keynesian effect. More than 95 per cent of employment is concentrated in the construction of turbines and ships, rather than in operation and maintenance (Wei et al., 2010). At the moment the UK has ship manufacturing facilities, and will have offshore wind turbine manufacturing facilities, and there may be underemployment in some of the coastal regions.

Non-domestic energy efficiency may have a Keynesian effect where new plant is purchased while the economy has an output gap. There may also be a regional dimension with industrial regions benefiting the most.

Electric vehicle infrastructure by its nature has high capital costs dispersed in proportion to population. Only if installation begins swiftly is there an economy-wide benefit.

Non-Local Authority commercial and industrial waste may have a general Keynesian effect if, as may be the case, it is possible to get projects underway relatively quickly. Site installation costs will be a major component, employing labour locally, which may improve the Keynesian effect.

Flood defence is similar to waste in that it could be started quickly and employs most of its labour locally.

Rolling stock is unlikely to have a general Keynesian effect because of the timing of new stock manufacture. There may be a regional effect in the manufacturing sector, dependent on which firm builds the trains, and it is possible that orders will be placed outside the UK. For example, the Thameslink extension has four remaining bidders of which one is British and one other would manufacture in the UK[12].

Smart meters require the installation of meters in all areas of the country and manufacturing which could take place in the UK or elsewhere. There may therefore be a general Keynesian impact.

Photovoltaics is a labour intensive method of electricity production with 0.87 job years/GWh compared to 0.11 job years/GWh for coal (Wei et al., 2010). Wei states that more than 97% of the employment is in the construction and installation process. The cells themselves may be manufactured abroad, removing much of the Keynesian effect. Due to the greater solar potential of the South East of the country much of the spending will occur in the part of the country likely to come out of the recession fastest.

5.2.1.2 Investments unlikely to have a Keynesian effect

Marine, nuclear and carbon capture and storage are all unlikely to have a Keynesian effect as they will not be implemented while the effects of the current recession are still felt. Smart grid infrastructure is also unlikely to have an effect since it will largely be drawn from refurbishment and expansion budgets and so is not deficit spending in the usual sense.

5.2.2 Potential of the Pigovian mechanism to deliver growth

This is the most important mechanism for delivering growth effects for the GIB, as explained by the Green Investment Bank Commission in its report. It applies where the externality affects the UK in the short term, and so has little effect for greenhouse gas emissions abatement.

The OECD concurs, arguing in a recent review of the UK economy that market failures and lack of full climate policy credibility over the long term may warrant government intervention:

> *'Financial markets may not be prepared to take on all the risks associated with new low-carbon technologies, given their novelty and the dependence of their success on future policies and provision of infrastructure, so that in the absence of further government intervention insufficient finance would be available at the scale and pace needed to meet decarburization goals.'*

The GIB might contribute to growth via this mechanism where it mobilises additional private investment or crowds out inefficient private investment.

5.2.2.1 Investments which may have a Pigovian effect

Non-domestic energy efficiency: Markets may fail to allocate capital efficiently to off-balance-sheet projects where the investment is in novel assets (energy efficiency performance contracts), meanwhile managers working within balance sheets may not face appropriate incentives to control costs and energy costs in

[12] Source Department for Transport website in the national archives;
http://webarchive.nationalarchives.gov.uk/+/http://www.dft.gov.uk/pgr/rail/pi/thameslinkrollingstock/thameslinkbidders

particular. Furthermore, small firms may face high transaction costs of borrowing and may have low capitalisation as a result. Correction of these market failures could lead to more efficient production and hence growth.

Offshore wind and marine: the GIB's involvement could help to expand the pool of capital gaining experience of the sectors, spreading learning among financial intermediaries.

Electric vehicle infrastructure: Electric vehicles and their charging network are complements. One will not develop without the other. There is a substantial network externality and there is room for government intervention to correct this market failure.

Flood defence is a classic example of a public good since it is non-rivalrous and partly non-excludable. This presents a classic case for government intervention and would reduce the growth (and human) impact of extreme events.

5.2.2.2 Investments unlikely to have a Pigovian effect

For waste, the unpriced carbon benefits of recycling materials are a global rather than UK benefit. For rolling stock and smart meters, which are proven technologies, there are no appreciable market failures where investors can appropriately price risk and invest within well-defined sectoral legislation. There may be innovation spillovers, but the evidence suggests that these are usually small (Jaffe and Palmer, 1997).

5.2.3 **Potential for the Schumpeterian mechanism to deliver growth**

The Schumpeterian mechanism boosts the rate of investment or innovation. This is the first of the mechanisms to boost growth in the long term.

5.2.3.1 Investments which may have a Schumpeterian effect

Offshore wind: There may be the possibility of a progressive or a sailing ship effect from offshore wind, but the offshore wind industry would have to demonstrate credibility as a major source of energy for the UK if it is to pose a challenge to conventional power generation.

Non-domestic energy efficiency: The adoption of efficient industrial methods by some firms may encourage rivals to follow suit, and result in lower prices and an expansion of demand. If the GIB can speed up this effect then it may contribute to economic growth

Non-Local Authority commercial and industrial waste: It is possible that the GIB can help a market in solid recovered fuel to develop, making waste disposal of some waste streams obsolete and expanding the geographical and sectoral coverage of energy recovery from waste.

Renewable heat: The same line of argument can be used for renewable heat as for waste, with the potential for a convergence of solid fuel markets.

Electric vehicle infrastructure may offer a sailing ship effect. It is conceivable that electric vehicles act as a threat to internal combustion engines, and that coupled with high fuel costs conventional road transport reacts by becoming far more efficient. This is on top of the progressive effect which will result if greater investment in the research and development of electric vehicles occurs as a result of government intervention.

Smart grid and electric vehicles may interact, changing the character of the electricity market. With the addition of millions of electric accumulators to the electricity grid, mass electricity storage could become available for the first time. This would allow better matching of supply and demand, reducing the amount of time that renewable or nuclear energy generation is constrained, lowering the average price of electricity, and improving generation asset utilisation.

Marine energy: This technology may have a progressive and a sailing ship effect if it can produce cheap electricity, but it is too early to say whether it will ever be able to exert this competitive pressure on other forms of power production.

Carbon capture and storage: It is a demonstration technology at present, and may create learning benefits which have applications in other fields. As a mainstream carbon abatement technology it is, for the time being, high cost. Yet, there may be demand to adopt it very widely globally in the future.

Smart meters: This may have a progressive impact since it may lead to more efficient use of energy and may also change the time profile of use, and in so doing, bring down the cost of electricity.

Photovoltaics: Like other renewable energy technologies, there is the potential for a progressive and a sailing ship effect with respect to solar PV, if and only if the technology can become a great deal less expensive and more efficient.

5.2.3.2 Policies unlikely to have a Schumpeterian effect

Flood defence, rolling stock and nuclear have been excluded from the list of investments which are likely to have a Schumpeterian effect since they are not new or innovative enough to have transformative effects or sailing ship effects on other policies, and neither are they integral enough to the running of the economy to have a noticeable progressive effect.

5.2.4 **Potential of the Georgian mechanism to deliver growth**

The Georgian mechanism is reliant on relaxing constraints on the long term ability of the economy to grow, such as emissions, availability of hydrocarbons, infrastructure and supply of some raw materials.

5.2.4.1 Investments which may have a Georgian effect

Industrial energy efficiency, offshore wind and renewable heat could all help to relieve the emissions constraint to some degree.

Non-Local Authority commercial and industrial waste: In waste disposal there is scope to make greater use of energy embedded in waste, or to avoid the use of energy in the processing of virgin materials.

Electric vehicle infrastructure may help to relax the resource constraint from liquid hydrocarbons and, if the electricity infrastructure becomes less carbon intensive, may help to address the emissions constraint too.

Electric vehicle infrastructure: When electric vehicle infrastructure is combined with a smart grid it may mean that the power system becomes more efficient, with consequently lower emissions intensity.

Marine energy, like other renewable technologies, may help the economy escape from the emissions resource constraint.

Rolling stock may reduce capacity constraints on the rail network. Less un-sprung weight over the wheels may decrease maintenance on the track and planned capacity outage. New stock is also more efficient, with greater acceleration, increasing the work rate of a network.

Carbon capture and storage and *nuclear* may relieve the emissions constraint.

5.2.4.2 Investments unlikely to have a Georgian effect

Photovoltaics has not been included in the list of projects that are likely to have a Georgian impact due to its high (if falling) cost and small size, relative to the UK electricity market, making it unlikely that it will make a significant contribution to emissions reduction.

Flood defence is unlikely to relax any resource constraints, since it is mainly built to defend existing infrastructure.

Smart meters have not been included in the list since although they will have a marginal effect on resource constraints.

5.2.5 Summary of potential growth effects

Table 50. **There exists a range of potential growth effects resulting from the GIB in different industries**

	Keynesian	Pigovian	Schumpetarian	Georgian
Offshore wind	✓		✓	✓
Non-Local Authority commercial and industrial waste	✓		✓	✓
Non-domestic energy efficiency	✓	✓	✓	✓
Renewable heat			✓	✓
Low-carbon projects within the Green Deal	✓			✓
Nuclear				✓
Photovoltaics	✓		✓	
Marine renewables			✓	✓
Carbon capture and storage		✓	✓	✓
Onshore wind	✓			✓
Smart meters	✓		✓	
Electric vehicle infrastructure	✓	✓	✓	✓
Rolling stock	✓			✓
Flood defence	✓	✓		

Source: Vivid Economics

This paper does not seek to assess any potential distortions of competition. Such analysis will need to be undertaken, as part of the consideration of State aid, once all of the evidence is available.

6 Conclusions

The evidence built up in this work supports the case for the GIB as an enduring but responsive institution, offering value for money through its involvement in a variety of sectors over time. It is expected to accelerate the flow of capital into novel activities, achieve a modest level of immediate direct leverage of additional private capital, and contribute towards the achievement of policy goals.

Role in accelerating the flow of capital

The GIB's role is to address market failures which prevent capital being deployed as necessary to meet priority environmental policy objectives. Its strength lies in tackling imperfections in financial markets, imperfections which are not targeted by complementary industrial, environmental and fiscal policies.

The financial markets are still feeling the effects of the recent and ongoing crisis, but this is not a focus for the GIB. These issues are expected to resolve themselves within the next few years. The objective of the GIB is to address structural, rather than cyclical, issues that affect the availability of credit. The GIB improves the functioning of the financial markets, in particular in arranging capital, sharing risk and disseminating information.

There are two recurrent properties of the 15 sectors which have been examined as current or future potential targets for the GIB's activities. They are: (i) novelty of technology or business model; and, (ii) sustained rapid pace of investment needed in the policy context of a transition to a green economy.

The first of these properties, novelty, causes financial markets to under-allocate capital. Novelty implies insufficient information about the risk and returns of new types of assets, combined with rapid learning. Examples include more ambitious distant offshore wind farms, businesses trading solid recovered fuel or biomass, and energy efficiency projects that might be structured as paid-from-savings contracts. The returns to the party who invests in new information are lower than the returns the market (or society) makes in aggregate when the information becomes public. This leads to under-investment. The GIB may help to build expertise, create and share information. It can do so by becoming involved as an investor in the early stages of the deployment of novel projects, and as the project matures by actively seeking to widen capital participation. This process might occur naturally and slowly without the GIB. The GIB may speed it up and in doing so contribute to the adoption of innovations and potentially help drive economic growth in the long term .

The second of these properties, sustained rapid pace of investment, may exceed the capacity of the natural principal sponsors to supply capital. This is because firms typically supply capital from retained earnings, and sustained demand for capital investment (beyond the need to renew assets) can reduce earnings growth and payments to shareholders. The investment in green infrastructure may need to be as high as £20 – 50 billion (nominal) per annum to 2020, much higher than typical targets for organic growth. The GIB can help by participating in the capital structure of projects and working to achieve earlier refinancing after construction. Refinancing releases equity for the principal sponsors, allowing them to recycle it, thereby achieving a faster and more sustainable growth path.

Related to the issue of novelty, information costs, which are like fixed costs, can lead to imperfect competition and deter other investors. The GIB's activities may help to stimulate competition among capital providers by making information more accessible, for example by developing new contracts, stimulating deal flow or releasing historical performance data. It will have to balance these benefits with the commercial confidentiality which it needs to maintain as a credible financial intermediary.

Also related to novelty, the act of lending to a project is a signal to other lenders, a form of externality, that the project is viable. Thus the GIB may act as a pioneer lender and through its participation, mobilise capital from other providers.

Related to the issue of pace of investment, capital investment may be slowed down by path dependence, that is a propensity to maintain past lending patterns. There may also be ineffective coordination within a supply chain, for example between wind farm developers and their network providers or turbine manufactures. This is because each part of the supply chain needs to plan its level of output, and output depends upon the decisions of other players. This interdependence causes uncertainty, and leads to underinvestment. In some industries the issue is solved through vertical integration, but in sectors such as offshore wind, waste and energy efficiency vertical integration may not be possible or desirable because networks have multiple users and specialist manufacturers of intermediate goods have multiple customers. The GIB may help by providing strategic coordination between the players and so reduce uncertainty.

This work also considered whether the GIB might write long tenor loans written to firms, since most commercial lending is less than ten years' tenor. However, no clear market failure was discovered which suggests that the GIB may not set up long-term loan products at this time.

The types of opportunities for the GIB outlined above are likely to be a feature of low-carbon infrastructure in general over the next 40 years, for two reasons. First, carbon prices have only recently been introduced to parts of the economy. Second, the level of ambition in decarbonisation (and associated prices) will incentivise massive investment in assets which financial markets regard as exotic or novel. The green investment programmes will move in phases through parts of the economy decade by decade for several decades. The flows of capital will be very large in total and encompass a series of novel technologies. This programme extends at least until 2050, which is the long-term date for reducing greenhouse gas emissions from the UK economy by 80 per cent against 1990 levels.

Leverage of private capital

Given its size, the GIB's impact will depend on its ability to mobilise and leverage additional private capital. How much private sector capital could be mobilised by £1 of GIB capital is not easy to estimate, but something can be said about the character of success in this area.

Whilst leveraging will occur with all its products, GIB is most clearly having a leverage effect when it enables the refinancing of projects that would otherwise remain fully financed by their sponsors. The GIB's goal is to facilitate wider capital participation: to bring in new third party private capital, expanding the pool of capital available. The provision of £1 of GIB capital may introduce a further £1 to 3 of private capital.

Products

The three sectors which have been examined in detail – offshore wind, non-Local Authority commercial and industrial waste and non-domestic energy efficiency – may be those which the GIB might focus on initially, although not to the exclusion of other sectors. These three sectors offer immediate opportunities for investment in policy areas of high priority, characteristics of novelty in all three cases, and rapid scale-up in two out of three.

In **offshore wind**, the utility companies are currently the main sponsors of projects and there are many calls on their resources as Europe upgrades its power generation assets and networks. The GIB's action allows constructors to recycle a proportion of their project equity a few years earlier than would have otherwise been the case. This gives them the option to reinvest in new offshore wind construction, and may boost the rate of construction. The GIB may do this through deployment of equity and mezzanine debt, and so may catalyse the process by which offshore wind farms become established as a mainstream asset category. This is all assuming that the assets perform as expected.

In **waste**, the assessment has focused on non-Local Authority commercial and industrial waste. This segment features no long-term contracts for the management of waste, and so projects are financed on balance sheet. The sector has increased processing capacity in this way substantially over recent years, but the rate of change has been limited by several factors, most importantly the relative economics of waste recovery and disposal, the investment rate which shareholders are willing to accommodate, stickiness in adjustment of market structure between firms, and management skills within firms in response to higher capital intensity. Forthcoming higher rates of Landfill Tax will make new projects economically viable.

The GIB may provide co-investment equity or senior debt to new merchant facilities, allowing firms to grow their merchant businesses more quickly, and smaller firms who may have more restricted access to debt are among the most likely to be receptive to this proposal. It may also allow firms to deploy more novel advanced conversion technologies (such as pyrolysis and gasification).

In **industrial energy efficiency and large non-domestic buildings**, several independent data sets corroborate high returns on an engineering cost basis, with most projects paying back in less than five years. Interviews have confirmed that large companies finance energy efficiency projects in the same way as any other capital investment.

There are four areas which the GIB might target in this sector: the most promising are industrial energy efficiency; large commercial buildings; large on-site heat or power generation projects; and, energy efficiency in smaller firms. In each area, pilot products may be appropriate in the GIB's initial period of operation.

Receivables finance in this area is novel and likely to be challenging to establish. Again the GIB may play the role of first time lender.

The GIB may wish to get involved in large energy projects, such as combined heat and power and biomass energy, if it is more comfortable with novel fuel supply and heat off-take risks than other lenders. These projects have a unit size of around £2.5 – 50 million apiece, but there are some examples of larger projects. The market is limited to a handful of projects in a year, so the GIB is likely to be involved in no more than several transactions in its first few years of operation.

Finally, the GIB may continue the government's energy efficiency lending programme to small and medium sized enterprises. It would not sell the loans itself, but could make funds available to retail banks at commercial rates for on-lending to firms. This is a model used by international financial institutions like the European Bank of Reconstruction and Development and the European Investment Bank. It is not possible to say how much appetite there would be among firms or retail banks for these products. Of all the products, this one has the least evidence of market demand. A second concern is how well the economics of the lending will work out. Lending costs may be high due to the small loan size and high credit risk of small firms.

As noted above, the GIB may become involved in a **wide range of sectors**. Of all those examined in this study, only two, flood defences and onshore wind, offer no rationale for GIB intervention. These are rejected in both cases because finance is currently available, in the former case, from a statutory agency of the Treasury, and in the latter case, from the market.

More equitable outcomes and other benefits

The economic rationale for the GIB is based on two sources of value creation. The first way in which the GIB may add value is that it may help the Government to meet its policy targets (e.g. on renewable energy) and may do so in a way that is more equitable and often more efficient than alternative interventions. By bringing forward projects earlier and in greater number, the GIB will have impact measured in terms of physical progress towards policy objectives.

The second way in which the GIB may add value is by supporting projects that generate benefits for the UK in excess of their costs. The evidence collected shows that the value of the GIB's intervention is mainly because it is a more targeted instrument than alternative policies, which bring with them the inequitable and costly features of taxes.

The assessment of value for money shows that value characteristics vary by sector. Weighing the benefits of changes in net present value, redistribution, market appetite and contribution to policy targets might be required.

In addition, there is the GIB's impact on competition and trade distortion, which has to be weighed in the balancing test applied by the European Commission.

An enduring role

The areas for GIB intervention will evolve over time. Novelty and rapid scaling up are not persistent features of any market. Over time, novelty is replaced by standardisation, and as scale is reached the rate of growth eventually slows. The GIB will have to respond to evolving needs, operating in several sectors at one time. Once a small portfolio of successful projects has been achieved for a sector or market segment once the initial markets, market failures, needs and constraints change or disappear, the GIB may move on to deploy its capital in a catalytic fashion in another sector or segment, and so it will have a passing presence in individual sectors and market segments, but an enduring rolling programme of involvement in an ever-changing mix of sectors. Offshore wind, commercial and industrial waste and industrial and commercial energy efficiency could be prominent initial sectors though others are possible, giving the GIB's portfolio diversity, tackling areas of policy need, and deploying capital where it can immediately be put to use.

In each sector, the GIB may follow a product life cycle. For example, it may start with equity-like first-loss participation and perhaps progress to mezzanine debt as the projects establish themselves. It may then build relationships with private capital providers and help to facilitate refinancing of established projects. By building these relationships, it might introduce new, large pools of capital, including from institutional providers (such as insurers and pension funds), which bring with them different appetites for risk and return and much larger scale funding than sector firms, for example utility companies, can offer from their limited retained earnings.

Timing, as with all successful investments, is crucial. If the GIB arrives too late to a sector, its effect may no longer be additional to private capital. If it arrives too early, projects will not be available or their performance will be too erratic. The sweet spot for the GIB in terms of timing is the early stages of deployment and rapid up-scaling.

Thus the task for the GIB will be to manage a portfolio of sectors throughout its life cycle of involvement. It will focus on stimulating, and certainly not crowding out or competing with, private sector investment. It will build a pipeline of new market segments to move into, exiting maturing ones, and may evaluate its performance and learning as it progresses.

References

ABI (2010), *Massive rise in Britain's flood damage bill highlights the need for more help for flood vulnerable communities says ABI*, press release 58/10, 24th November 2010

AEA Technology (2010), *Analysing the Opportunities for Abatement in Major Emitting Industrial Sectors*, ED56369, November.

AEA Technology (2011), *UK and Global bioenergy resources and prices*, Report for DECC

AEA Technology (2011a), *Review of technical information on renewable heat technologies*

Aghion, P. and P. Howitt (1998), *Endogenous Growth Theory*, Cambridge, CUP

Aghion, P., Boulanger J., and E. Cohen (2011). *Rethinking industrial policy,*. Bruegel Policy Brief 2011/04, June

AREVA (2011a), *The EPR Reactors under Construction Worldwide*

Arup (2011), *Review of the generation costs and deployment potential of renewable electricity technologies in the UK*, Report prepared for DECC

Auerbach A. J. and K. A. Hassett (2003), 'On the marginal source of investment funds', *Journal of Public Economics*, Vol. 87(, No. 1), pp. 205-232

Bank of England (2010), *Quarterly Bulletin*, 2010 Q2, Vol. 50, No. 2)

Barbier, E. B.(2010), *A Global green new deal: rethinking the economic recovery,* Cambridge University Press, Cambridge, UK

BERR (2008b), *Meeting the energy challenge – a white paper on nuclear power*, January, Department for Business Enterprise & Regulatory Reform

Bertoldi P. and S. Rezessy (2005), *Energy service companies in Europe: status report 2005*, Institute for Environment and Sustainability, Italy

Bertoldi P., Boza-Kiss B., and S. Rezessy (2007), *Latest development of energy service companies across Europe*, Institute for Environment and Sustainability, Italy

BIS and DECC (2009), *The UK Low Carbon Industrial Strategy*, July, Department for Business, Innovation and Skills and Department of Energy and Climate Change

Bosetti, V., Tavoni, M., De Cian, E., and A. Sgobbi (2009), *The 2008 WITCH Model: New Model Features and Baseline*, FEEM Working Paper 2009.085

Bouis, R., Duval, R., and F. Murtin (2011), *The policy and institutional drivers of economic growth across OECD and non-OECD economies,* OECD Economics Department Working Paper No. 843, OECD, Paris

Bowen, A. and S. Fankhauser (2011), *The Green Growth Narrative. Paradigm Shift or Just Spin?*, in Agder, N., Brown, K., and D. Conway: *Global Environmental Change*, Elsevier.

Bowen, A., and N. Stern (2010), *Environmental policy and the economic downturn,* Oxford Review of Economic Policy, Vol. 26, No. 2, pp. 137-63

BP (2011), *BP Statistical Review of World Energy June 2011*

Brealey R.A. and S. C, Myers (1996), *Principles of corporate finance*, McGraw-Hill

British Energy (2008), *Annual reports and accounts*

Butcher, L. (2011), *Railways: rolling stock,* Parliamentary Note, House of Commons Library, June.

Carbon Trust (2009), *Focus for success – a new approach to commercialising low carbon technologies*

Carbon Trust (2010), *Building the Future, Today,* June

Carbon Trust (2011a), *Marine Renewables Green Growth Paper*, May

Carbon Trust (unpublished), *Breaking through: harnessing energy efficiency to cut costs and carbon emissions in business and the public sector*

CEC (2005), *Biomass action plan*, Communication from the Commission, December

Committee on Climate Change (2008), *Building a low carbon economy – the UK's contribution to tackling climate change*, December

Committee on Climate Change (2010), *The CRC energy efficiency scheme – advice to Government*, September

Committee on Climate Change (2010a), *Potential for the application of CCS to UK industry and natural gas power generation*

Committee on Climate Change (2010b), *The Fourth Carbon Budget – Reducing emissions through the 2020s*, December.

Committee on Climate Change (2011), *The renewable energy review*, May

Committee on Climate Change (2011a), *Meeting Carbon Budgets –3rd Progress Report to Parliament*, June

Conrad, K. (1999), *Resource and Waste Taxation in the Theory of the Firm with Recycling Activities*, Environmental and Resource Economics, Vol. 14, No. 2, pp. 217-242

Crafts, N. (2010), *The contribution of new technology to economic growth: lessons from economic history,* Centre for Competitive Advantage in the Global Economy Working Paper No. 1, Department of Economics, University of Warwick, March

Crown Estate (2011a), Wave and tidal information from website

DCLG (2011), *Zero carbon homes: impact assessment*

De Canio, S. J. (1994a), '*Why do profitable energy-saving investment projects languish?*', Journal of General Management, Vol. 20, No. 1, pp. 62-71

De Canio S. J (1994b), '*Agency and control problems in US corporations: the case of energy-efficiency investments'*, Journal of the Economics of Business, Vol. 1(, No. 1, pp.), 105-123

De Canio S. J. and Watkins W. E. (1998), '*Investments in energy efficiency: do the characteristics of firms matter?*', Review of Economics and Statistics, Vol. 80, No. 1, pp. 95-107

DECC (undated), *Onshore wind Q&A*

DECC (2007), *Cost of biomass*

DECC (2009), *Carbon Capture Readiness (CCR), A guidance note for Section 36 Electricity Act 1989 consent applications*

DECC (2009c), *Impact assessment of UK renewable energy strategy*

DECC (2010), *2050 pathway analysis*, July

DECC (2010a), *Energy consumption in the United Kingdom*, data tables

DECC (2010b), *Table of past and present UK nuclear reactors*

DECC (2010c), *Consultation on an updated waste transfer pricing methodology for the disposal of higher activity waste from new nuclear power stations*, December

DECC (2010d), Digest of UK energy statistics

DECC (2010e), *Marine Energy Action Plan*

DECC (2010f), *Developing carbon capture and storage (CCS) infrastructure*, December

DECC (2010g), *Updated energy projections*, June 2010

DECC (2011), *Renewable Heat Incentive*

DECC (2011a), *Digest of UK Energy Statistics 2011*

DECC (2011b), *Renewable Heat Incentive, Impact assessment*

DECC (2011c), *UK renewable energy roadmap*

DECC (2011d), *The Green Deal, a summary of the Government's proposals*

DECC (2011e), *Energy Bill, Green Deal Impact Assessment*

DECC (2011f), *2009Final UK greenhouse gas emissions*: data tables

DECC (2011g), *Estimates of home insulation levels in Great Britain*

DECC (2011h), *Meeting energy demand – nuclear*

DECC (2011i), *Nuclear,* http://www.decc.gov.uk/en/content/cms/meeting_energy/nuclear/nuclear.aspx

DECC (2011j), *New nuclear - supply chain and skills,* http://www.decc.gov.uk/en/content/cms/meeting_energy/nuclear/new/supply_skills/supply_skills.aspx

DECC (2011k), personal correspondance

DECC (2011l), *New Nuclear*, http://www.decc.gov.uk/en/content/cms/meeting_energy/nuclear/new/new.aspx

DECC (2011m), *Feed in tariff capacity: monthly update*, July

DECC (2011n), *Fast-track review of feed-in tariffs for small scale low carbon electricity*, Impact Assessment 0059, March

DECC (2011o), *The national renewable energy action plan*

DECC (2011p), *Inter-departmental analyst group toolkit*, tables 1-29

DECC (2011q), *Office of Carbon Capture & Storage,* http://www.decc.gov.uk/en/content/cms/emissions/ccs/occs/occs.aspx

DECC (2011r),*Cutting edge UK energy projects in running for EU funding*, press release

DECC (2011s), *Sustainability standards for biomass,* http://www.decc.gov.uk/en/content/cms/meeting_energy/bioenergy/sustainability/sustainability.aspx

DECC (2011t), Press release, 9/6/2011

DECC (2011u), Onshore wind, http://www.decc.gov.uk/en/content/cms/meeting_energy/wind/onshore/onshore.aspx

DECC (2011v), *Eligible Renewable Sources and Banding Levels*, http://www.decc.gov.uk/en/content/cms/meeting_energy/renewable_ener/renew_obs/eligibility/eligibility.aspx

DECC (2011w), *Planning our electric future (energy market reform white paper)*

DECC (2011x), Office for Renewable Energy Deployment (ORED), http://www.decc.gov.uk/en/content/cms/meeting_energy/renewable_ener/ored/ored.aspx

DECC (2011y), *Smart meter rollout for the domestic sector (GB) - Impact Assessment*

DECC (2011z), *Smart meter rollout for the small and medium non-domestic sector (GB) – Impact Assessment*

DECC/Ofgem (2011), Smart Metering Implementation Programme. Response to Prospectus Consultation. Supporting Document 2 of 5. Rollout Strategy, March.

Dechezleprêtre A. and Martin R. (2010), *Low carbon innovation in the UK, evidence from patent data*, Report for the Climate Change Committee, Grantham Research Institute, London School of Economics

Defra (2003), *A study to estimate the disamenity costs of landfill in Great Britain*, February

Defra (2007a), *Analysis of the UK potential for combined heat and power,* October

Defra (2007b), *Waste strategy for England 2007*, May

Defra (2010), Future Funding for Flood and Coastal Erosion Risk Management – Impact Assessment

Defra (2010), *Survey of commercial and industrial waste arisings 2010 – final results*, December.

Defra (2010a), *UK Market value of the low carbon goods and services sector*, 2007/08

Defra (2011), personal communication, March

Defra (2011a) *Government Review of Waste Policy in England 2011*, June

Defra (2011b) *The Economics of Waste and Waste Policy*, Waste Economics Team, June

Defra and EA (2011), *Understanding the risks, empowering communities, building resilience: The national flood and coastal erosion risk management strategy for England,* The Department for Environment, Food and Rural Affairs and the Environment Agency, May

Department for Business, Enterprise and Regulatory Reform, and Department for Transport (2008), *Investigation into the scope for the transport sector to switch to electric vehicles and plug-in hybrid vehicles*

Department for Business, Innovation and Skills (2009), *An independent report on the future of the automotive industry in the UK*

Department for Transport (2008) UK Transport and Climate Change Data, Factsheet.

Department for Transport (2011), Making the connection, the plug-in vehicle infrastructure strategy

Department of Trade and Industry (2007), UK Biomass Strategy 2007- Working Paper 1 – Economic analysis of biomass energy, Energy Technologies Unit, May.

DfT/ORR (2011) *Realising the Potential of GB Rail. Final Independent Report of the Rail Value for Money Study. Detailed Report*, May.

Dhanju, A., Whitaker, P. and S. Burton (2005), *Assessment of Delaware Offshore Wind Project*, College of Marine Studies, University of Delaware.

Dixit A.K. and R.S. Pindyck (1994), *Investment under uncertainty*, Princeton University Press, Princeton

DTI (2007), Nuclear Power Generation Cost Benefit Analysis

E.ON (2009), *E.ON UK plc, Annual report and accounts*

EDF (2009), *EDF Energy plc annual report and financial statements,* December

Egert, B., Kozluk, T., and D. Sutherland D. (2009), *Infrastructure and growth,* OECD Economics Department Working Paper No.685, OECD, Paris

Element Energy (2009a), *Design of feed-in tariffs for sub-5MW electricity generation in Great Britain*, DECC, Table 12

Element Energy (2009b), *Strategies for the uptake of electric vehicles and associated infrastructure implications*, report for the Committee on Climate Change

Energy Technologies Institute (2009), *Plug-in Ultra Low Carbon Vehicles: Accelerating market growth for plug-in vehicles by enabling effective collaboration*

Environment Agency (2009a), *Flooding in England: a national assessment of flood risk*

Environment Agency (2009b), *Investing for the future: Flood and coastal risk management in England*

Environment Agency (2011b), *Adapting to climate change: advice for flood and coastal erosion risk management authorities*

Environment Agency Wales (2010), *Future flooding in Wales: flood defences, possible long-term investment scenarios*

EPIA (2011), *Global market outlook for photovoltaics until 2015*

Ernst & Young (2010), *Cost of financial support for wave, tidal stream and tidal range generation in the UK,* a report for DECC and Scottish Government

Ernst & Young (2011), *The UK 50 kW to 5 MW solar PV market*

Eumonia (2006), Impacts of Unit-based Waste Collection Charges, Report for OECD, May

European Commission (2010a), C*ommission sets up system for certifying sustainable biofuels*, Press Release

European Commission (2010b), *Commission adopts biomass sustainability report*, Press Release.

European Patents Office (2010), *Patents and clean energy: bridging the gap between evidence and policy*

Fershtman C. and K. Judd (1984), 'Equilibrium incentives in oligopoly', *American Economic Review*, Vol. 77, No. 5, pp. 927-940

Fogel, R.W. (1964), *Railroads and American economic growth*, Baltimore, Johns Hopkins University Press

Freedman, C., Kumhof, M., Laxton, D., and J. Lee (2009), *The case for global fiscal stimulus,* IMF Staff Position Note 09/03, March

Freeman, C. (1982), *The economics of industrial innovation*, Frances Pinter, London

Generation IV International Forum (2011), *Framework agreement*

Gertler, M. (1988), 'Financial structure and aggregate economic activity: an overview', *Journal of Money, Credit and Banking*, Vol. 20, No. 3, pp. 559-88

Gillingham K., Newell R.G., and K. Palmer (2009), *Energy efficiency economics and policy*, National Bureau of Economic Research Working Paper 15031, June

Gordon M.J. (1959), *Dividends, Earnings and Stock Prices*, Review of Economics and Statistics, Vol. 41, No. 2, pp. 99-105

Greenpeace and EPIA (2011), *Solar Generation 6, solar photovoltaic electricity empowering the world*

Hall, B.H. (1992), *Investment and research and development at the firm level: does the source of financing matter?*, University of California at Berkeley, Working paper 92-194, May

Hemming, R., Mahfouz, S., and A. Schimmelpfennig (2002), *Fiscal policy and economic activity during recessions in advanced economies,* IMF Working Paper 02/87, May

HM Government (2004), *Energy Act 2004*

HM Government (2009), *Electricity, England and Wales, The Renewables Obligation Order 2009,* No. 785, April

HM Government (2010), *Marine Energy Action Plan 2010*

HM Government (2010), *The Flood and Water Management Act 2010*

HM Revenue and Customs (2011), *Climate Change Levy – introduction, HMRC*, April

HM Treasury (2003), *The Green Book: appraisal and evaluation in central government*, HM Treasury, TSO, London

HM Treasury (2011), *Carbon price floor consultation: the Government response*

House of Commons Environment, Food and Rural Affairs Committee (2010), *Future flood and water management legislation, First Report of Session 2010-11,* December

Innovas (2009), *Low Carbon and Environmental Goods and Services: an industry analysis*, report prepared for BERR

Institute of Mechanical Engineers (2011), *Electric vehicle recharging infrastructure*

Inter-departmental Analysts Group (2010), *Valuation of energy use and greenhouse gas emissions for appraisal and evaluation,* June

International Energy Agency (2009). 'UK National Survey Report on PV'. Prepared by DECC

International Energy Agency (2010), Technology Roadmap – Nuclear Energy, International Energy Agency

International Energy Agency (2010a), Technology roadmap - Solar Photovoltaic Energy, OECD

International Energy Agency (2011), Electricity/heat data for United Kingdom

International Energy Agency (2011a) Energy Statistics of OECD Countries – 2011 edition

International Monetary Fund (2010), *World Economic Outlook*, Washington DC

Jaffe A.B. and R. N. Stavins (1994), *Energy-efficiency investments and public policy*, *Energy Journal*, Vol. 15, No. 2, pp. 43-65

Jaffe, A. B. and K. Palmer (1997), *Environmental Regulation and Innovation: A Panel Data Study*, Review of Economics and Statistics, Vol. 79. No. 4, pp. 610-619.

King, R., and R. Levine (1993), *Finance and growth: Schumpeter might be right,* Quarterly Journal of Economics, Vol. 108, No. 3, pp. 717–738

Kinnaman, T. C. and D. Fullerton (1999), The Economics of Residential Solid Waste Management, National Bureau of Economic Research Working Paper 7326, August.

K-Matrix (2011), *Low Carbon and Environmental Goods and Services Report (LCEGS) 2009/10*

Kreab & Anderson (2010), *Wave and tidal investor survey*

Levine, R. (2005), *Finance and growth: theory and evidence*, in Aghion, P., and S. Durlauf (eds.) *Handbook of Economic Growth*, Vol.1B, North-Holland, Amsterdam

Lintner, J. (1956), *Distribution of incomes of corporations among dividends, retained earnings, and taxes*, American Economic Review, Vol. 46, No. 2, pp. 97-113

Manufacturing Advisory Service (2011a), *Nuclear new build supply chain*

Manufacturing Advisory Service (2011b), *Nuclear – supply chain opportunities*

Martin, A. and I. Scott (2003), *The Effectiveness of the UK Landfill Tax*, Journal of Environmental Planning and Management, Vol. 46, No. 5, pp. 673-689

Mayor of London (2009), *An electric vehicle delivery plan for London*

McKinsey & Co (2011), database of abatement opportunities in the UK, personal communication

Meadows, D.H., Meadows, D.L., Randers, J., and W.W. Behrens III (1972), *The limits to growth,* Universe Books, New York

Merton R.C. (1992), *Financial innovation and economic performance*, Journal of Applied Corporate Finance, Vol 4, No. 4, pp. 12-22

Miller M. and F. Modigliani (1961), *Dividend policy, growth and the valuation of shares*, Journal of Business, Vol. 34, No. 4, pp. 411-433

Morris, J., Penning-Rowsell, E., and J. Chatterton, (2010), *The costs of the summer 2007 floods in England*, joint Defra/Environment Agency Flood and Coastal Erosion Risk Management Research and Development Programme.

Mott MacDonald, 2010, *UK Electricity Generation Costs Update,* June

Myers, S.C., *The capital structure puzzle*, Journal of Finance, Vol. 34, No. 3, pp. 575-592

National Grid (2011), *Operating the electricity transmission networks in 2020 – update*, June

National Renewable Energy Laboratory (2009), *Opportunities and challenges for development of a mature concentrating photovoltaic power industry*

Natural England (2011), *Energy crops scheme,* http://www.naturalengland.org.uk/ourwork/farming/funding/ecs/default.aspx

NERA and AEA Technology (2010), *Decarbonising Heat: Low-Carbon Heat Scenarios for the 2020's*, Report for the Committee on Climate Change (CCC), June

Nuclear Decommissioning Authority (2010), *Annual report and accounts*

Nuclear Industry Association (2008), *The UK capability to deliver a new nuclear build programme – 2008 Update*

Nuclear Industry Association (2011), *UK nuclear industry map*

OECD (2011), *OECD Economic surveys United Kingdom,* March

Office for Budget Responsibility (2011), *Economic and fiscal outlook*, March

Office of Science and Technology (2004), *Foresight future flooding*

Ofgem (2009) Project Discovery: Energy Market Scenarios, Office of Gas and Electricity Markets

Ofgem (2010) The Renewables Obligation Buy-out Price and Mutualisation Ceiling 2010-2011

Ofgem (2011), Carbon Emissions Reduction Target Update, Issue 13, September.

Ofgem (2011a), Feed-in tariff update, issue 4

Ofgem (2011b) Renewables Obligation: Guidance for generators

Ofwat (2009), *Future water and sewerage charges 2010-2015: final determination*

ONS & DECC(2011), *Domestic energy consumption in the UK since 1970*

Palmer, K. and M. Walls (1997), *Optimal policies for solid waste disposal: Taxes, subsidies, and standards*, Journal of Public Economics, Vol. 65, No. 2, pp. 193-205

Parliamentary Office of Science and Technology (2011), Carbon Footprint of Electricity Generation, June

Parsons Brinckerhoff (2010), *Powering the nation update 2010*

Parsons Brinckerhoff (2011), *Electricity generation cost model – 2011 update*, report prepared for DECC, June

Perez, C. (2010), *Technological revolutions and techno-economic paradigms,* Cambridge Journal of Economics, 34: pages 185-202

Pizer, W.A., Harrington, W., Kopp, R.J., Morgenstern, R.D. and J. Shih (2001), *Technology Adoption and Aggregate Energy Efficiency*, Resources for the Future Discussion Paper 01-21, Resources for the Future, Washington, DC

Pollin, R., Garrett-Peltier, H., Heintz, J., and H. Scharber (2008), *Green recovery: a program to create good jobs and start building a low-carbon economy*, PERI and the Center for American Progress, September

Pollin, R., Heintz, J., and H. Garrett-Peltier (2009), *The economic benefits of investing in clean energy*, PERI and the Center for American Progress, June

Pöyry (2007), *Analysis of carbon capture and storage cost-supply curves for the UK*, DTI, January

Pöyry (2009), *Carbon capture and storage: milestones to deliver large scale deployment by 2030 in the UK*

Pöyry (2009a), *Timeline for wind generation to 2020 and a set of progress indicators*, Report to the Committee on Climate Change, July

REN21 (2010), Renewables 2010, global status report

RenewableUK (2010), *Rebirth of UK manufacturing*, March

RenewableUK (2010a), *The economic value of wind to Wales – A survey*, May

RenewableUK (2010b), *Wind energy generation costs*, June

RenewableUK (2010c), *Channelling the energy, a way forward for the UK wave and tidal industry towards 2020*

RenewableUK (2011), *Working for a greener Britain*, February

RenewableUK (2011a), *Wave and tidal energy in the UK*, state of the industry report

RenewableUK (2011b), *UK Wind Energy Database*, http://www.bwea.com/ukwed/index.asp

RenewableUK (2011c), *Working for a greener Britain*: Vol 2, July

RenewableUK (2011d), *Small wind systems UK market report* 2010, April

RenewableUK (2011e), *Onshore wind technology*, http://www.bwea.com/ref/tech.html

RenewableUK (2011f), *Annual review 2010 – inspiring excellence*, undated

RenewableUK (2011g), *Rebirth of UK manufacturing*: Volume 2, February

RenewableUK(2011h), *Operational wind farms,* http://www.bwea.com/ukwed/operational.asp

RenewableUK and The Marine Energy Programme Finance Group (2011b), *Why the green investment bank should support the UK's wave & tidal energy*

Satchwell A., Goldman C., Larsen P., Gilligan D., and T. Singer (2010), *A survey of the US ESCO industry: market growth and development from 2008 to 2011*, Berkeley National Laboratory, US

Scottish and Southern Energy, (2010), *Scottish and Southern Energy plc annual report 2010*

Scottish Environment Protection Agency (2010), *Introducing the new approach to flood risk management,* together with Scottish Flood Forum, COSLA, Scottish Water and the Scottish Government

Scottish Environment Protection Agency (2011), *The Floodline Service, A guide to Scotland's flood warning and informing service*

Simon, H. A. (1972), *Theories of Bounded Rationality*, in McGuire C. B. and R. Radner (eds.), *Decision and Organisation*, Chapter 8, pp. 161-176

SKM Enviros (2010), *Modelling the 2013-18 cap for the CRC Energy Efficiency Scheme,* July

Smith, W.J. (2007), *Mapping the development of UK biorefinery complexes: literature review*

Sorrell, S. (2007), *The economics of energy service contracts*, Energy Policy, Vol. 35, No. 1, pp. 507-521

Stern, N. (2011), *The low-carbon industrial revolution*, presentation at LSE in the 'LSE Works' series, 17 March

Stiglitz, J. E. (1999), *Economics of the public sector*, 3rd edition, Norton, New York

Stiglitz, J. E., Jaramillo-Vallejo, J., and Y. Chal Park (1993), *The role of the state in financial markets,* World Bank Research Observer, Annual Conference on Development Economics Supplement, pp. 19-61

Technopolis (2009), *Low Carbon – Carbon Capture and Storage¸* November.

Transport Committee (2004), *The future of the railway (seventh report of session 2003-04)*, HC 145, 1 April.

Tufano, P. (1989), 'Financial innovation and first mover advantages', Journal *of Financial Economics*

UK Trade and Investment (2010), *UK Nuclear: powering the future*

Vlieghe, G.W. (2010), *Imperfect credit markets: implications for monetary policy*, Bank of England working paper no.385

Wei, M., Patadia, S., and D.M. Kammen (2010), *Putting renewables and energy efficiency to work: How many jobs can the clean energy industry generate in the US?* Energy Policy, Vol. 38, No. 2, pp. 919–931

Welsh Assembly Government (2011a), *Consultation on the development of a national strategy for flood and coastal erosion risk management in Wales, summary of responses,* March

Welsh Assembly Government (2011b), *Written statement by the Welsh Assembly Government, Flood and Coastal Erosion Risk Management in Wales,* Jane Davidson, Minister for Environment, Sustainability and Housing

Westinghouse (2011), *AP1000 – international construction*

World Nuclear Association (2011), *WNA reactor database*

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