The Economics of Low Carbon Cities

A Mini-Stern Review for the Leeds City Region

Andy Gouldson, Niall Kerr, Corrado Topi,
Ellie Dawkins, Johan Kuylenstierna, Richard Pearce.

Centre for Low Carbon Futures 2050

Centre for Climate Change Economics and Policy

University of Leeds

The University of York

SEI Stockholm Environment Institute

leeds city region
intelligence driving growth

Contents

Tables, Figures and Appendices

The Economics of Low Carbon Cities

Today

10% of city-scale GDP leaves the local economy every year through payment of the energy bill. This is forecast to grow significantly by 2022.

10% of GDP leaks out of the economy

Tomorrow

Investing 1% of GDP p.a.

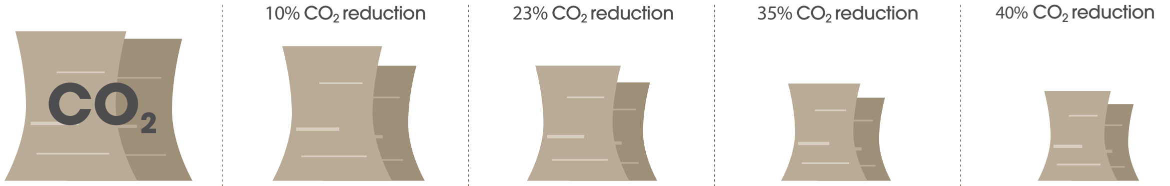
Leads to...

1% of GDP could be profitably invested, every year for ten years, to exploit commercially attractive energy efficiency and low carbon opportunities.

- **Energy**
  reductions in the energy bill equalling 1.6% of GDP
- **Financial viability**
  four years for measures to pay for themselves
- **Employment**
  more jobs and skills in low carbon goods and services
- **Wider economic benefits**
  energy security, increased competitiveness, extra GDP
- **Wider social benefits**
  reductions in fuel poverty, improvements in health

Typical Potential to reduce CO_2 emissions

1990	2022			
	10% CO_2 reduction	23% CO_2 reduction	35% CO_2 reduction	40% CO_2 reduction
	After responding to energy price increases	Plus supply of lower carbon electricity	Plus exploitation of the profitable options	Plus exploitation of the no net cost options



The Economics of Low Carbon Cities: A Mini Stern Review for the Leeds City Region

Executive Summary

What is the most effective and efficient way to decarbonise a city? There are hundreds of low carbon options available and, although they present a significant opportunity to reduce energy bills and carbon footprints, there is often a lack of reliable information on their performance. The higher levels of risk and uncertainty that emerge as a result of this lack of reliable information can be a major barrier to action, making it hard to develop a political, a business or a social case for investment in low carbon options.

The Leeds City Region is an area with a population of three million, an economy worth £52 billion a year and an energy bill of £5.4 billion a year.

In an attempt to address this problem, this report reviews the cost and carbon effectiveness of a wide range of the low carbon options that could be applied at the local level in households, industry, commerce and transport. It then explores the scope for their deployment, the associated investment needs, financial returns and carbon savings, and the implications for the economy and employment.

It does this for the Leeds City Region (LCR), an area with a population of three million, an economy worth £52 billion a year and an energy bill of £5.4 billion a year. Whilst highlighting the very significant and commercially viable opportunities for the decarbonisation of the Leeds City Region – and the potential economic benefits associated with these – the report also recognises the scale of the challenge, the need for investment and the requirement for investment vehicles and delivery mechanisms that can exploit the potential for significant change.

Executive Summary

Our Approach

Our approach has been to develop a robust model for assessing the costs and benefits of different levels of decarbonisation at the city region scale. We use UK Committee on Climate Change Data on the potential energy, cost and carbon savings from thousands of low carbon measures. We take into account changes in the economy and the wider energy infrastructure, but we focus primarily on the potential for the wider deployment of energy efficiency measures and small-scale renewables. We also assess the potential for their deployment and the rates at which they could be deployed at the local level.

We use realistic projections of the energy, cost and carbon savings emerging from different measures. Typical interest rates (8%) and energy prices are used and ambitious but realistic scenarios for the rate at which different technological and behavioural options are adopted. Projected savings are reduced to take into account implementation gaps. The scope for the adoption of different measures is adjusted to take into account hard to reach households and businesses.

The Potential for Carbon Reduction – Investments and Returns

We find that – compared to 1990 levels – the Leeds City Region could reduce its carbon emissions by 2022 by:

- 12.9% through cost effective investments that would pay for themselves (on commercial terms) over their lifetime. This would require an investment of £4.90 billion, generating annual savings of £1.19 billion, paying back the investment in 4.11 years but generating annual savings for the lifetime of the measures.
- 18.0% through cost neutral investments that could be paid for at no net cost to the Leeds City Region economy if the benefits from cost effective measures were captured and re-invested in further low carbon measures. This would require an investment of £11.57 billion, generating annual savings of £1.59 billion, paying back the investment in 7.3 years but generating annual savings for the lifetime of the measures.
- 18.8% with the exploitation of all of the realistic potential of the different measures. This would require an investment of £13.03 billion, generating annual savings of £1.71 billion, paying back the investment in 7.6 years but generating annual savings for the lifetime of the measures.

Impacts on Future Energy Bills

These figures are particularly significant in the context of projected energy price increases. We calculate that the 2011 LCR energy bill is £5.38 billion per year, but we forecast that this will grow to £7.24 billion by 2022 – a £1.86 billion increase in the LCR annual energy bill.

- With investment in all of the cost effective measures, this £1.86 billion increase in the annual energy bill could be cut by £1.19 billion (64% of the projected increase).
- With investment in all of the cost neutral measures, it could be cut by £1.59 billion (85% of the projected increase).
- With investment to exploit all of the realistic potential, it could be cut by £1.71 billion (92% of the projected increase).

The Leeds City Region could therefore insulate itself against projected energy price increases to a very large extent through investments in energy efficiency and low carbon options.

The 2011 Leeds City Region energy bill is £5.38 billion per year, but we forecast that this will grow to £7.24 billion by 2022.

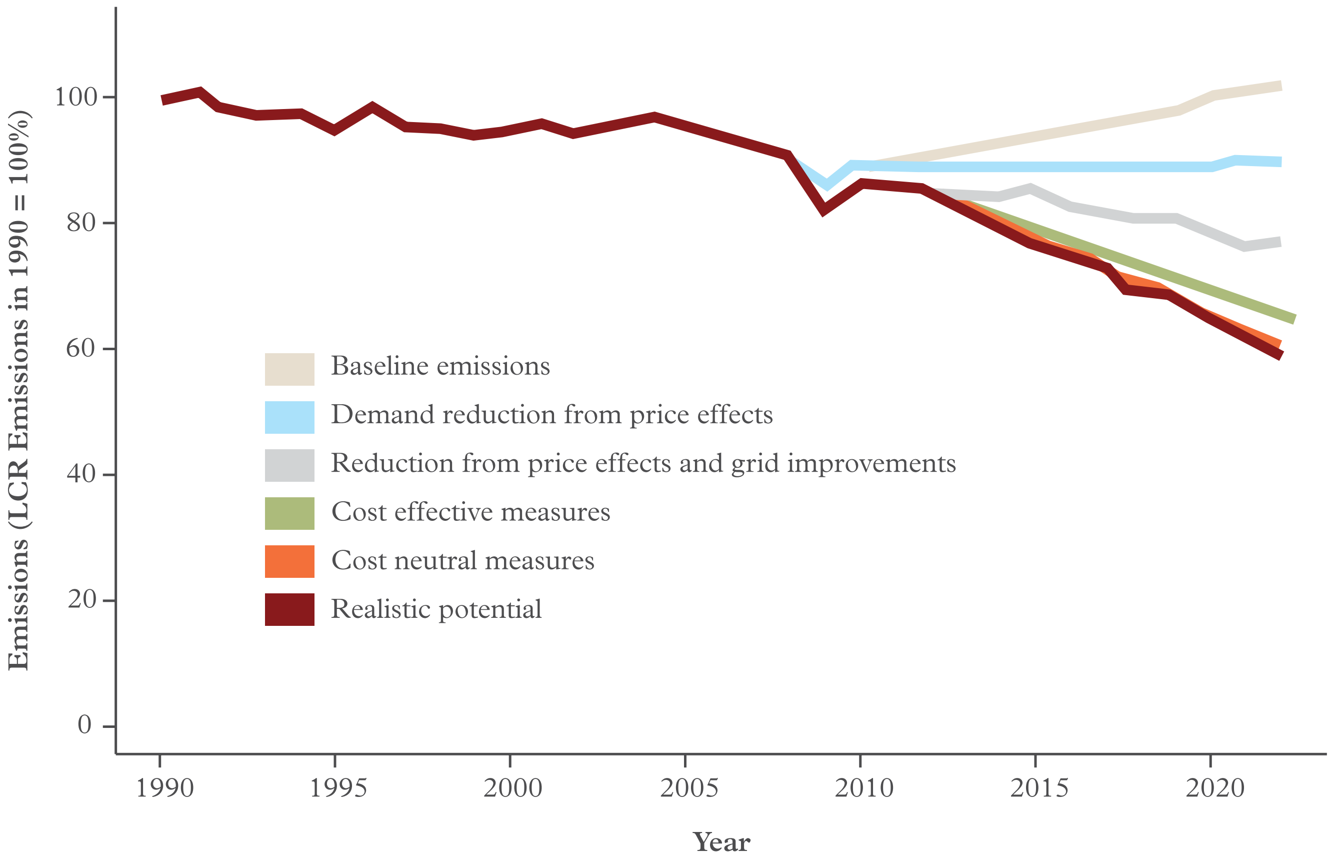
The Wider Context – Other Influences on LCR Carbon Emissions

To put these energy savings and carbon reduction figures into a wider context, we find that:

- With other things constant, background trends in economic growth combined with changes in the energy and carbon intensity of GDP will lead to a 2% increase in LCR carbon emissions between 1990 and 2022.
- Higher energy price increases will impact on demand, and this will lead to a 12% drop in LCR carbon emissions compared to the 1990 baseline by 2022. The total effect of the background trends plus the response to higher energy price will be a 10% drop in LCR emissions between 1990 and 2022.
- The decarbonisation of the national electricity system will lead to a 13% drop in LCR carbon emissions by 2022. The total effect of background trends, the impacts of price increases and the decarbonisation of the national electricity supply system will be a 23% drop in LCR emissions between 1990 and 2022.
- The total effect of all of the above plus the exploitation of all of the cost effective low carbon options will be a 36% drop in LCR carbon emissions between 1990 and 2022.
- The total effect of all of the above plus the exploitation of the remaining cost neutral options will be a 41% drop in LCR emissions between 1990 and 2022.
- The total effect of all of the above plus the exploitation of all of the remaining realistic potential will be a 42% drop in LCR carbon emissions between 1990 and 2022.

The impacts of these price effects, grid decarbonisation and cost effective, cost neutral and realistic potential are shown in the Figure below.

Figure 1: Baselines and Analysis of Price Effects, Grid Decarbonisation and Cost Effective, Cost Neutral and Realistic Potential



Wider Impacts on Employment and Economic Growth

We also calculate that the levels of investment required to realise these reductions in energy bills and carbon footprints could have wider economic benefits within the Leeds City Region:

- Over the next ten years, the levels of investment needed to exploit all cost effective measures with employment generating capacity would lead (directly and indirectly) to the generation of 4,443 jobs and to growth in GVA of £211 million per year.
- Over the next ten years, the levels of investment needed to exploit the all of the cost neutral measures with employment generating capacity would lead (directly and indirectly) to a further 5,226 jobs and to GVA growth of £230 million per year.
- In total, therefore, we predict that the levels of investment needed to exploit all of the cost effective and cost neutral measures with employment generating capacity would lead to the generation of 9,669 jobs over the next ten years and to GVA growth of £442 million per year.

Low Carbon Investment: Supply and Demand

The analysis highlights that within the Leeds City Region there is considerable potential to reduce energy use and carbon footprints through cost effective and cost neutral investments on commercial terms. However, the fact that these opportunities exist on this scale is obviously not enough to ensure that they are actually exploited. Incentives – no matter how strong they are – have to be matched with appropriate capacities if progress is to be made. These relate both to the capacity to supply appropriate levels of investment and to the capacity to stimulate and sustain demand for such investments.

To stimulate the supply of the very significant levels of investment that are needed, we need to think about innovative financing mechanisms, based on new forms of cost recovery and benefit sharing and new ways of managing risk. And we need to develop new delivery vehicles that can stimulate and sustain demand for investment in low carbon options by overcoming the many potential barriers to change.

Conclusions and Recommendations

From a climate and carbon perspective, the analysis in this report suggests that the Leeds City Region has to exploit all of the cost effective measures and all of the cost neutral measures identified if it is to reduce its carbon emissions by 40% by 2022.

Decarbonising on this scale and at this rate should be possible. The technological and behavioural options are readily available, the energy and financial savings associated with these are clear (even based on conservative assessments), the investment criteria are commercially realistic, and the deployment rates have been judged by the independent Committee for Climate Change to be challenging but still realistic.

The economic returns on investment could be very significant indeed. Many of the measures would pay for themselves in a relatively short period of time, they would generate significant levels of employment and economic growth in the process, and if done well there may be a wider range of indirect benefits (not least from being a first mover in this field). The political and business case for very large investments in the low carbon economy is very strong indeed.

However, the transition depends on political and social capital as well as financial capital. The levels of ambition, investment and activity needed to exploit the available potential are very significant indeed. Enormous levels of investment are required, along with major new initiatives with widespread and sustained influence in the domestic, commercial and industrial sectors.

And, of course, we need to think about some major innovations, particularly in stimulating the supply of and the demand for major investment resources. We need to think about innovative financing mechanisms, based on new forms of cost recovery and benefit sharing and new ways of managing risk. And we need to develop new delivery mechanisms that can stimulate and sustain demand for investment in low carbon options by overcoming the many potential barriers to change.

Whilst this report provides some vital insights, we should recognise that economics is not the only discipline that has something useful to say on the transition to a low carbon economy/society. A wider analysis should also consider the social and political acceptability of the different options, as well as issues relating to the social equity and broader sustainability of the different pathways towards a low carbon economy and society. We also need to think about `future proofing' investments to consider their compatibility with the more demanding targets for carbon reduction and with the different levels of climate change that are likely to come after 2022.

Economics of Low Carbon Cities

What is the most effective and efficient way to decarbonise the Leeds City Region? There are hundreds of low carbon options available and, although they present a significant opportunity to reduce energy bills and carbon footprints, there is often a lack of reliable information on their performance. The higher levels of risk and uncertainty that emerge as a result can be a major barrier to action, making it hard to develop a political, a business or a social case for investment in low carbon options.

In an attempt to address this problem, this paper reviews the cost and carbon effectiveness of a wide range of the low carbon options that could be applied at the local level in households, industry, commerce and transport. It then explores the scope for their deployment in the Leeds City Region (LCR). On this basis, we identify least cost pathways towards different levels of decarbonisation within the Leeds City Region, and we examine the investment needs and payback periods associated with different levels of decarbonisation. We also consider the wider economic implications of such transitions – with a particular emphasis on the opportunities for job creation in the low carbon and environmental goods and services sector. It also explores the wider implications of these investments for employment and economic growth.

Whilst highlighting the very significant and commercially viable opportunities for the decarbonisation of the Leeds City Region – and the potential economic benefits associated with these – we also recognise the scale of the challenge, the need for investment and the requirement for policy innovations and delivery mechanisms that can create the potential for significant change. This is the first time that an analysis of the economics of low carbon cities has been carried out in this level of detail anywhere in the world.

The low carbon and environmental goods and services sector is estimated to be worth £3.2 trillion a year, and to be growing steadily through the recession (BIS, 2010).

There are some pressing reasons why we need to better understand how to decarbonise a city or a city region. Cities could be particularly exposed to the impacts of climate change (UN HABITAT, 2009) and as a result we might hope that cities would play a leading role in helping to avoid climate change. There is certainly evidence that many cities are doing just this (Bulkely and Betsil, 2005) – and a number of local authorities within the Leeds City Region have set ambitious targets for carbon reduction. But climate change is a collective action problem on a global scale, and in some instances the case for action on environmental grounds alone is not strong enough.

Fortunately, there are other drivers that might motivate cities to address issues of climate change – some of which appeal more to self interest than to collective concern. Incentives to invest in energy efficiency and energy security are going up: energy prices are high and are forecast to increase and possibly to become more volatile in years to come (IEA, 2009). Policy pressures are intensifying: in some settings, national governments have adopted ambitious carbon targets that seem likely to tighten further over time. And economic development opportunities are becoming more prominent: the low carbon and environmental goods and services sector has been estimated to be worth £3.2 trillion a year, to employ 28 million people worldwide and to be growing steadily through the recession (BIS, 2010).

These trends could have major social and economic implications for all – through their impacts on growth, competitiveness, employment, social welfare, fuel poverty and so on – but their effects are likely to be felt more acutely in cities. Globally, more than half of all economic output is generated in cities, and more than half of all people live in cities, but in urbanised countries these figures increase to around 80% (UN HABITAT, 2004; UNWUP, 2009). Further, it has been estimated that between 40 and 70% of all anthropogenic greenhouse gas (GHG) emissions are produced in cities, and that at least 70% of emissions can be attributed to the consumption that takes place within cities (UN HABITAT, 2011). Cities seem to be as exposed to attempts to reduce energy use and carbon footprints as they are vulnerable to the effects of climate change itself.

This paper considers how the Leeds City Region could most efficiently and effectively exploit the wide range of technological and behavioural opportunities to reduce its energy bill and carbon footprint. It considers how much it would cost to reach different levels of decarbonisation through the least cost route. Evidence is presented on the economics of decarbonising the domestic, commercial, industrial and transport sectors as well as the city region as a whole.

Approach to the Analysis

At the national level in the UK, information on the performance of a wide range of different low carbon options has been collated by the independent Committee on Climate Change (CCC). The CCC was established as part of the 2008 Climate Change Act, legislation that led the UK to become the first country in the world to set legally binding carbon reduction targets. The CCC has subsequently recommended, and the UK Government has adopted, legally binding targets of a 34% reduction on 1990 levels of greenhouse gas emissions by 2022 and a 50% reduction by 2027.

To inform the setting of these targets, the CCC modelled three key aspects of the transition to a low carbon economy/society:

- the scope to decarbonise national energy systems, for example through the incorporation of large scale renewables or new nuclear facilities;
- the potential to deploy smaller scale renewables such as solar PV or micro-wind turbines; and
- the potential for demand-side reductions through a range of technological and behavioural changes.

Throughout the research presented in this paper, we have collaborated closely with the secretariat of the CCC to downscale the national level data to make it relevant at the local level. Given our interest in measures that can be adopted at the local level, we focus only on demand side measures and small scale renewables, whilst taking account of changes in national energy infrastructure and the forecast decarbonisation of electricity supply.

Thereafter, we need to generate data on a range of variables, as set out in Table 1.

To collect or generate data on each of these variables, the methodology follows a number of stages:

1. Identifying a list of the applicable low carbon measures

The CCC data includes a list of the energy efficiency measures and small scale renewables that could be adopted in the domestic, commercial, industrial and transport sectors. To a large degree, we base our analysis on that list of measures. However, as the transport sector analysis only considers private road transport options, we expand it to consider a limited number public transport options. A full list of the measures included in the analysis is presented in Table 2. We do not claim that this list of measures is complete – indeed expanding it to include a wider range of (particularly behavioural) measures should be seen as a key priority – but it is the most detailed and extensive list that we have found that is underpinned by broadly comparable data sets.

Table 1: List of Variables

Baseline trends	Financial savings per measure
Range of applicable low carbon measures	Carbon savings per measure
Capital cost of each measure	Scope for deployment in the Leeds City Region
Operational costs of each measure	Rate of deployment in the Leeds City Region
Hidden and missing costs of each measure	Total costs and carbon savings
Energy savings per measure	Cost and carbon savings for different levels of investment, decarbonisation

Table 2: Lists of the Low Carbon Measures Considered

Domestic	Mini wind turbines (5kW) with FiT; Photovoltaic generation with FiT' Biomass boilers with RHI; Electronic products; ICT products; Integrated digital TVs; Reduced standby consumption; Reduce heating for washing machines; A++ rated cold appliances; A-rated ovens; Biomass district heating with RHI; Efficient lighting; A-rated condensing boiler; Insulate primary pipework; Glazing – old double to new double; Uninsulated cylinder to high performance; Glazing – single to new; Insulated doors; Reduce household heating by 1^0C; Induction hobs; Loft insulation 0 – 270mm; Cavity wall insulation for pre-76 houses; Improve airtightness; DIY floor insulation (suspended timber floors); Loft insulation (increase from 25 to 270mm); Loft insulation (increase from 50 to 270mm; cavity wall insulation for houses built between 1976 and 1983); A+ rated wet appliances; Loft insulation (increase from 75 to 270mm); Cavity wall insulation for houses built post-83; Turn unnecessary lighting off; Installed floor insulation (suspended timber floors); Loft insulation (increase from 100 - 270mm); Loft insulation (increase from 150 to 270mm); Room thermostat to control heating; Paper type solid wall insulation; Modestly insulated cylinder to high performance; Thermostatic radiator valves; Air source heat pump with RHI; Micro wind turbines (1kW) with FiT; Hot water cylinder thermostat; Solar water heating with RHI.
Commercial	Photocopiers – energy management; Printers – energy management; Monitors – energy management; Computers – energy management; Fax machine switch off; Vending machines – energy management; Most energy efficient monitor PC only; Most energy efficient monitor; Lights – turn off lights for an extra hour; Lights – sunrise-sunset timers; Lights – basic timer; Heating – more efficient air conditioning; Lights – light detectors; Stairwell timer; Compressed air; Presence detector; Heating – programmable thermostats; Heating – optimising start times; Heating – reducing room temperature; Biomass boilers with RHI; Most energy efficient fridge-freezer; Heating – TRVs fully installed; Most energy efficient flat roof insulation; Heating – most energy efficient boiler; Biomass district heating with RHI; Lights – metal halide floodlights; Lights – IRC tungsten-halogen – spots; Most energy efficient pitched roof insulation; Most energy efficient cavity wall insulation; Air source heat pump with RHI; Most energy efficient freezer; Most energy efficient fridge; Ground source heat pump with RHI; Lights – most energy efficient replacement 26mm; Motor – 4 pole motor – EFF1 replace 4 pole; Lights – HF ballast; Most energy efficient external wall insulation; Solar thermal (inc RHI) most energy efficient double glazing; Lights – most energy efficient replacement tungsten; Variable speed drives; Most energy efficient double glazing (replace old double).
Industrial*	Burners; Drying and separation; Refrigeration and air conditioning; Lighting; Compressed air; Heat recovery with RHI; Design; Low temperature heating; Renewable heat with RHI; Building energy management; Space heating; New food and drink plant; High temperature heating; Fabrication and machining; Operation and maintenance; Controls; Energy management; Process improvement; Ventilation; Information technology; Motors and drives; insulation.
Transport	Park and ride; Express bus network; Bus priority and quality enhancements; Smarter choices; Cycling; Demand management; Mild hybrid; Plug-in hybrid; Full hybrid; Biofuels; Micro hybrid; Electric; New railway stations; Rail electrification.

* *Industrial measures are based on the grouping of thousands of different measures into broader categories to aid analysis and presentation.*

2. Evaluating the cost and carbon performance of each applicable measure

Based on the CCC data set, we extract data on the costs of adopting one unit of each measure and the energy (and hence the financial and carbon) savings that can be expected over the lifetime of that measure. The costs we consider include the capital costs, running costs and any hidden or missing costs (i.e. the costs of searching for or adopting the measure). We take into account incentives designed to encourage take up of small scale renewable or energy efficiency measures, such as Feed-in Tariffs. Future energy costs are based on DECC energy price forecasts through to 2022 (see Appendix A). Savings are based on CCC evaluations of the energy saved or generated in different contexts over the lifetime of each measure. Conservative estimates of energy savings are used throughout and these are adjusted to take account of rebound effects (i.e. the degree to which consumption goes up as efficiency improves). Future carbon savings are based on projected falls in the carbon intensity of electricity in the period to 2022 (again see Appendix A). Carbon savings from demand reductions are based on the attribution of a share of national carbon emissions to the relevant form of final consumption at the local level (AEA, 2010).

3. Understanding the potential for the deployment of different measures within the LCR

We then relate this list of measures to the scope for their deployment at the city scale. Ideally, this process would use observed data to take into account the size, composition and energy efficiency of the domestic, industrial, commercial and transport sectors in each particular locality.

For the domestic sector, such data is available and hence we have a very detailed and highly realistic picture of the scope for saving energy and fitting small-scale renewables in households at the local level.

For industry, local level data is available on both the scale and the sectoral composition of the economy. However, no local or firm level data is available on levels of energy efficiency or up take of low carbon options. Our data therefore reflects the size and sectoral composition of industry within the Leeds City Region, taking into account 21 key industrial sectors, but more data is needed on the level of uptake of energy efficient and low carbon options in the area. In the absence of this, we assume here that each sector of local industry is as energy efficient and hence has the same potential to adopt low carbon measures as the same sector at the national level.

For the commercial sector, we adjust for scale of the sector to reflect capacities at the local level, using levels of floor space as the key indicator. Whilst we are able to identify the scope for decarbonisation in the public and private sectors, no further data is available on the sectoral composition or energy efficiency of the commercial sector at the local level. As with industry, we assume that the commercial sector is on average as energy efficient, and that it has the same potential to adopt low carbon measures, as the commercial sector at the national level.

For transport, the national data set developed by the CCC is limited to private road transport. For this sector, we take into account the number of vehicles registered at the local level, the fuel efficiency of the vehicle stock and the average number of miles travelled to develop a detailed picture of private road transport at the local level. However, we supplement the national data set with local data on public transport and demand management options. The options themselves and the carbon savings associated with them were identified in a recent report by Arup (Arup, 2009), with the cost benefit data being developed on the basis of further research on similar transport options in other contexts. A summary of the sources of data for this stage of the analysis is included in Table 3.

4. Understanding background trends, developing baselines and scenarios for deployment

The analysis focuses on the adoption of low carbon measures at rates over and above three key elements:

Background trends – the UK economy is forecast to grow and we take account of this by for this by factoring projected economic growth into the calculation of the baseline, based on the most recent HM Treasury forecasts (again see Appendix A for details). It is also expected to steadily (autonomously) decarbonise at a slow rate as a result of structural and technological changes – for example as we de-industrialise and adopt more efficient new technologies. We account for this by extrapolating from past trends in decarbonisation within the Leeds City Region, controlling for the impact of price changes as these are addressed separately.

The impact of future price increases – energy price increases (themselves reflecting carbon price increases) generally lead to reductions in demand and we account for these through the application of medium term price elasticities of demand for the different sectors (see Appendix A for details), applied to the price increases expected within DECC's energy price forecasts.

The future decarbonisation of energy supply – the UK has been, and plans to continue, investing in the replacement of its energy infrastructure with less carbon intensive alternatives. DECC forecasts carbon intensities for future energy supply through to 2022.

We therefore identify a baseline that reflects the impact of these background trends (but not future initiatives) in the period to 2022.

To consider the potential for the adoption of extra low carbon measures above this baseline, we then follow the CCC by assuming take up rates of low carbon measures that are based on a realistic proportion of the technical potential of each measure being exploited by 2022. These deployment rates take into account the impact of policies such as the EU Emissions Trading Scheme (ETS), the UK Carbon Reduction Commitment (CRC) and the UK Feed-in Tariffs (FiTs) for small-scale renewables. We also incorporate an evaluation of the impacts of the UK Renewable Heat Incentive (RHI), based on provisional incentive rates included in consultation documents (DECC, 2010). We assume that current and prospective rates of FiT and RHI stay in place through to 2022. The analysis does not account for the impact of the Green Deal or the Green Investment Bank – although these schemes could provide finance for some of the investments mentioned.

Table 3: Data Sources

Domestic: CCC data downscaled and compositionally adjusted using the Housing Energy Efficiency Database.
Transport: CCC data on vehicle stock and vehicle usage downscaled and compositionally adjusted using UK Department for Transport data, supplemented with behavioural measures identified by Arup and cost data on these measures drawn from related projects.
Commercial: CCC data downscaled using Office of National Statistics data on commercial floor space.
Industry: CCC data downscaled and compositionally adjusted using SIC data on the sectoral make up of the LCR economy from the Regional Econometric Model.

5. Identifying investment needs, financial returns and carbon savings for different levels of decarbonisation

Having worked out that each measure could be applied a particular number of times within the Leeds City Region, we calculate aggregated investment needs, payback periods and carbon savings under different conditions. We do this for both a social case and a business case for investment. In each case, there are two key issues in the analysis – the first relates to the selected discount/interest rate, and the second to the forecast energy prices.

Discount/interest rates – for the social case, we adopt the standard (i.e. HM Treasury Green Book recommended) discount rate of 3.5%. In terms of the business case analysis, for the main forecasts we adopt a commercially realistic interest rate of 8%. To turn a nominal interest rate into a real interest rate, we also have to adjust for inflation, and we assume a 3% inflation rate when generating business case projections.

Energy price forecasts – DECC produce energy price forecasts – including price forecasts at 'central', 'high' and 'high' levels (see Appendix A). Current prices are some way above those in DECC's 'high' price forecasts. Basing the main part of the analysis on the 'high' forecast ensures that the estimates of financial returns are quite conservative.

Of course, interest rates, energy prices and inflation rates can go up and down and this will affect financial returns. To account for this, we also conduct some sensitivity tests based on a more and less favourable scenarios. The more favourable scenario has the same interest rate as the central forecast (as interest rates are unlikely to drop below current rates) but is based on higher forecast energy prices – meaning that returns on energy saving investments would also be higher. The less favourable scenario has a higher interest rate (11%), but lower energy prices, meaning that returns on energy saving investments would be lower.

A summary of all of these aspects is included in Table 4.

As we want to examine the extent to which there is a commercially realistic business case for investment in low carbon options, in the main part of the analysis below we present the results of the analysis based on the central business case. However, we consider the implications of moving to a more or less favourable business case in a sensitivity analysis.

Table 4: The Different Scenarios

Scenario	Discount/interest rate	Inflation rate	Energy price
Social case	3.5%	0%	High, no tax
Central business case	8%	3%	High, with tax
More favourable business case	8%	3%	Very high, with tax
Less favourable business case	11%	3%	Central, with tax

6. Developing league tables and MAC curves

Having completed calculations of the costs and benefits of each option on the basis above, for the central business case we then prioritise options according to the extent that they pay for themselves over their lifetime (i.e. by their Net Present Value). This enables the identification of league tables of the most cost effective measures for the domestic, industrial, commercial and transport sectors and for the city region as a whole. These are presented both as league tables of the most cost and carbon effective measures, and as Marginal Abatement Cost (MAC) curves. for the domestic, commercial, industrial and transport sectors (see Appendices D-G).

We then identify the different levels of decarbonisation that could be achieved with different levels of investment, with a distinction drawn between three levels of investment:

The cost effective level – this includes all of the measures that would more than pay for themselves over their lifetime.

The cost neutral level – this includes all of the measures that could be afforded if the benefits from the cost effective measures were captured and reinvested in further low carbon options.

The realistic technical potential level – this includes all of the measures that could realistically be adopted, regardless of their cost effectiveness.

7. Calculating employment and wider effects on GVA

The final stage of the analysis focuses the effects that investments in decarbonising the Leeds City Region would have on employment and the wider LCR economy. To do this, we take the forecast levels of investment required to exploit those cost effective and cost neutral opportunities with employment generating potential under the central business case scenario. We assume even levels of investment per year over the period from 2012 to 2022, and assumptions about the amount of the investment retained within the LCR are made taking into account the strength of the supplier base and the level of competition from outside the LCR in particular sectors, based on a recently completed study of the low carbon goods and services sector within the LCR (see Quantum Strategy and Technology, 2010). Only those measures with employment generating potential are examined – some behavioural measures (i.e. adjusting thermostats) with no employment generating potential are not assessed. Thereafter, groups of measures are clustered together to create cross-cutting categories that could be assessed based on the insights from the recent work on the size, capacities, and employment intensity of the low carbon goods and services sector. The direct employment effects of major levels of investment in low carbon options are then forecast based on an expansion of current levels of employment per unit of GVA within the LCR low carbon goods and services sector, and direct economic effects are forecast based on an expansion of current levels of GVA per employee. Wider economic effects were then calculated using standard multipliers proposed by English Partnerships (see Appendix C for details).

The Key Findings

At the energy prices and interest rates encountered by households and businesses, how much would it cost to cut energy bills and carbon footprints and how quickly would investments be repaid? How many jobs could we create in the process of cutting energy bills and lowering carbon footprints? And to what extent is it possible to insulate the local economy from future energy price hikes?

The potential for carbon reduction – investments and returns

The results of the central business case analysis show that, compared to 1990, the Leeds City Region could reduce its carbon emissions by 2022 by:

- 12.9% through cost effective investments that would pay for themselves (on commercial terms) over their lifetime. This would require an investment of £4.90 billion. This would generate an annual savings of £1.19 billion, paying back the investment in 4.11 years but generating annual savings for the lifetime of the measures.
- 18.0% through cost neutral investments that could be paid for at no net cost to the Leeds City Region economy if the benefits from cost effective measures were captured and re-invested in further low carbon measures. This would require an investment of £11.58 billion, generating annual savings of £1.59 billion, paying back the investment in 7.3 years but generating annual savings for the lifetime of the measures.
- 18.8% if all of the realistic potential of the different measures was exploited. This would require an investment of £13.03 billion. This would generate an annual savings of £1.71 billion, paying back the investment in 7.6 years but generating annual savings for the lifetime of the measures.

Impacts on future energy bills

These figures are particularly significant in the context of projected energy price increases. We calculate that the 2011 LCR energy bill is £5.38 billion per year, but we forecast that this will grow to £7.24 billion by 2022 – a £1.86 billion increase in the LCR annual energy bill.

- With investment in all of the cost effective measures, this £1.86 billion increase in the annual energy bill could be cut by £1.19 billion (64% of the projected increase).
- With investment in all of the cost neutral measures, it could be cut by £1.59 billion (85% of the projected increase).
- With investment to exploit all of the realistic potential, it could be cut by £1.71 billion (92% of the projected increase).

The Leeds City Region could therefore insulate itself against projected energy price increases to a very large extent through investments in energy efficiency and low carbon options.

Table 5: Main Results

LCR sector	Capital cost in 2012	Annual cost saving in 2022	Annual carbon saving in 2022	Payback	LCR carbon cut in 2022 (above trend, 1990 base)
	£bn	£bn	KTCO2	yrs	%
			Cost effective measures		
Domestic	£1.11	£0.40	907.81	2.78	3.81%
Transport	£0.85	£0.13	213.84	6.33	0.90%
Commercial	£1.87	£0.34	937.08	5.58	3.93%
Industry	£1.07	£0.32	1022.90	3.31	4.29%
Total	**£4.90**	**£1.19**	**3081.63**	**4.11**	**12.93%**
			Cost neutral measures		
Domestic	£3.57	£0.56	1266.77	6.41	5.32%
Transport	£2.21	£0.26	606.32	8.50	2.54%
Commercial	£3.41	£0.45	1163.76	7.64	4.88%
Industry	£2.38	£0.32	1260.78	7.34	5.29%
Total	**£11.58**	**£1.59**	**4297.63**	**7.29**	**18.04%**
			Realistic technical potential		
Domestic	£3.57	£0.56	1266.77	6.41	5.32%
Transport	£3.67	£0.39	780.47	9.52	3.28%
Commercial	£3.41	£0.45	1163.76	7.64	4.88%
Industry	£2.38	£0.32	1260.78	7.34	5.29%
Total	**£13.03**	**£1.71**	**4471.78**	**7.61**	**18.77%**

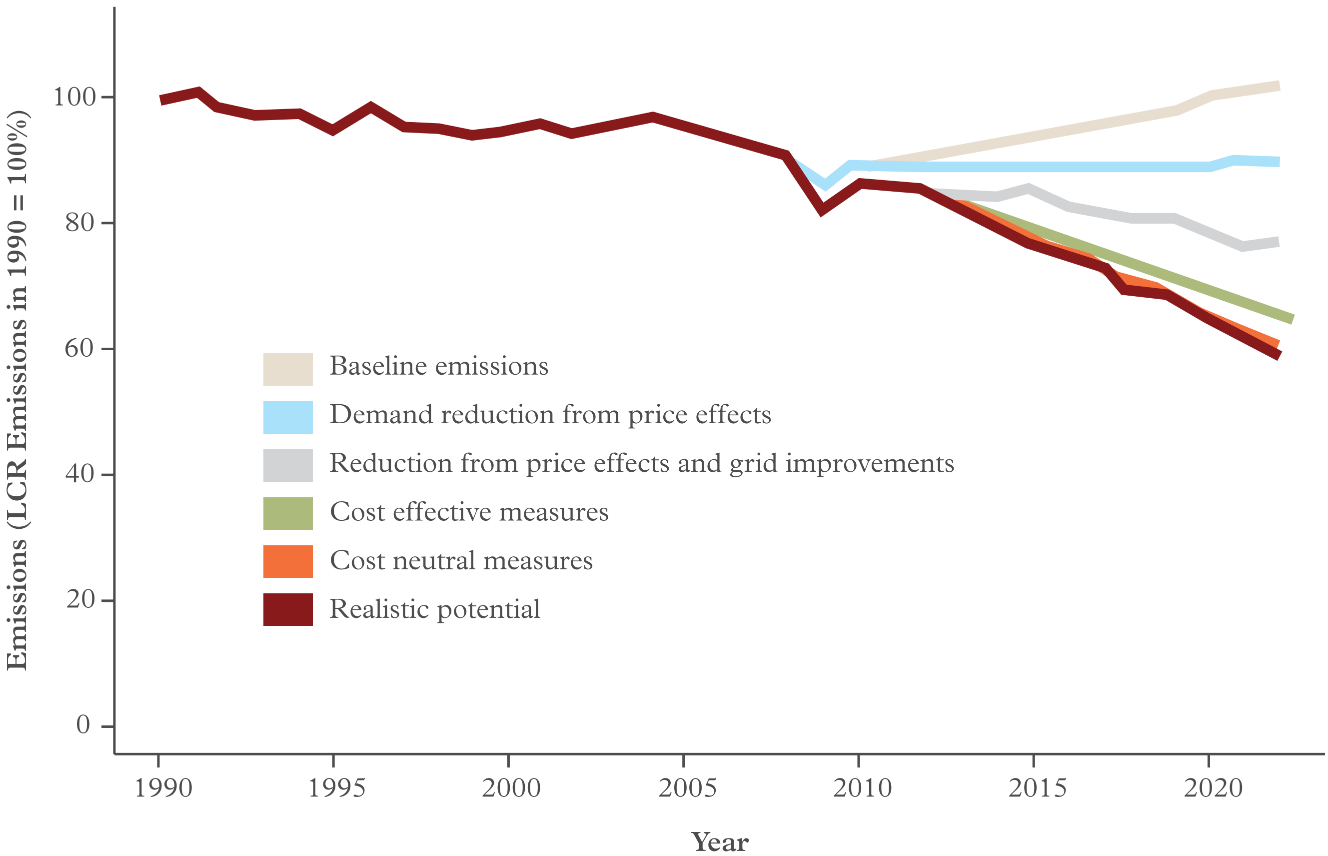
The wider context – other influences on LCR carbon emissions

It is critically important to note that these figures relate to the impacts of investments that are over and above a continuation of background trends, the ongoing impacts of current policies, the impacts of future increases on energy prices and the impact of a continuing decarbonisation of national energy supply. The combined impacts of all of these factors are reflected in Figure 1.

As is shown in Figure 1, we forecast that:

— With other things constant, background trends in economic growth combined with changes in the energy and carbon intensity of GDP will lead to a 2% increase in LCR carbon emissions between 1990 and 2022.
— Higher energy price increases will impact on demand, and this will lead to a 12% drop in LCR carbon emissions compared to the 1990 baseline by 2022. The total effect of the background trends plus the response to higher energy price will be a 10% drop in LCR emissions between 1990 and 2022.
— The decarbonisation of the national electricity system will lead to a 13% drop in LCR carbon emissions by 2022. The total effect of background trends, the impacts of price increases and the decarbonisation of the national electricity supply system will be a 23% drop in LCR emissions between 1990 and 2022.

Figure 1: Baselines and Analysis of Price Effects, Grid Decarbonisation and Cost Effective, Cost Neutral and Realistic Potential

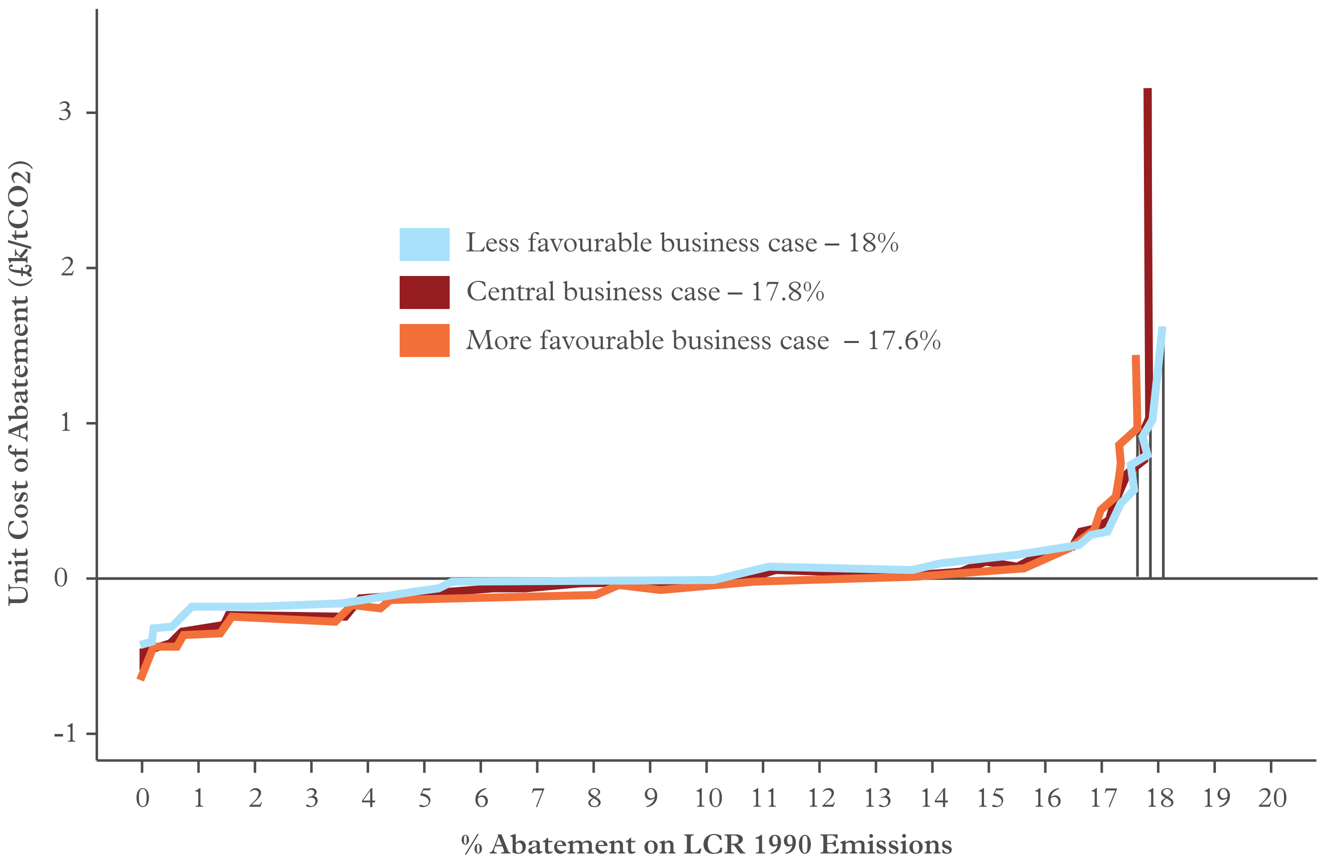


— The total effect of all of the above plus the exploitation of all of the cost effective low carbon options will be a 36% drop in LCR carbon emissions between 1990 and 2022.
— The total effect of all of the above plus the exploitation of the remaining cost neutral options will be a 41% drop in LCR emissions between 1990 and 2022.
— The total effect of all of the above plus the exploitation of all of the remaining realistic potential will be a 42% drop in LCR carbon emissions between 1990 and 2022.

Sensitivity analysis

Based on a sensitivity analysis, these results appear to be very robust. When compared to scenarios that, in terms of returns on investment, are either more (the same interest rate, higher energy prices) or less (higher interest rates, lower energy prices) favourable, there is little change in the results. As is shown in Figure 2, the different made to the realistic potential under the different scenarios is limited to +/- 0.2% on a central projection of 17.8%. Wider analysis suggests returns on investment are more sensitive to changes in energy prices than interest rates, but the broader conclusion is that they are not that sensitive to changes in either of these key variables.

Figure 2: Sensitivity Analysis



Wider impacts on employment and economic growth

In terms of the wider economic implications of the different levels of investment, we estimate that implementation of the cost effective and cost neutral measures in the domestic, non-domestic, industrial and transport sectors will result in the creation of a total of about 9,670 additional jobs/annum and additional GVA of £442 million/annum in Leeds City Region (LCR) over the 10 year period (or £4.4 billion in total).

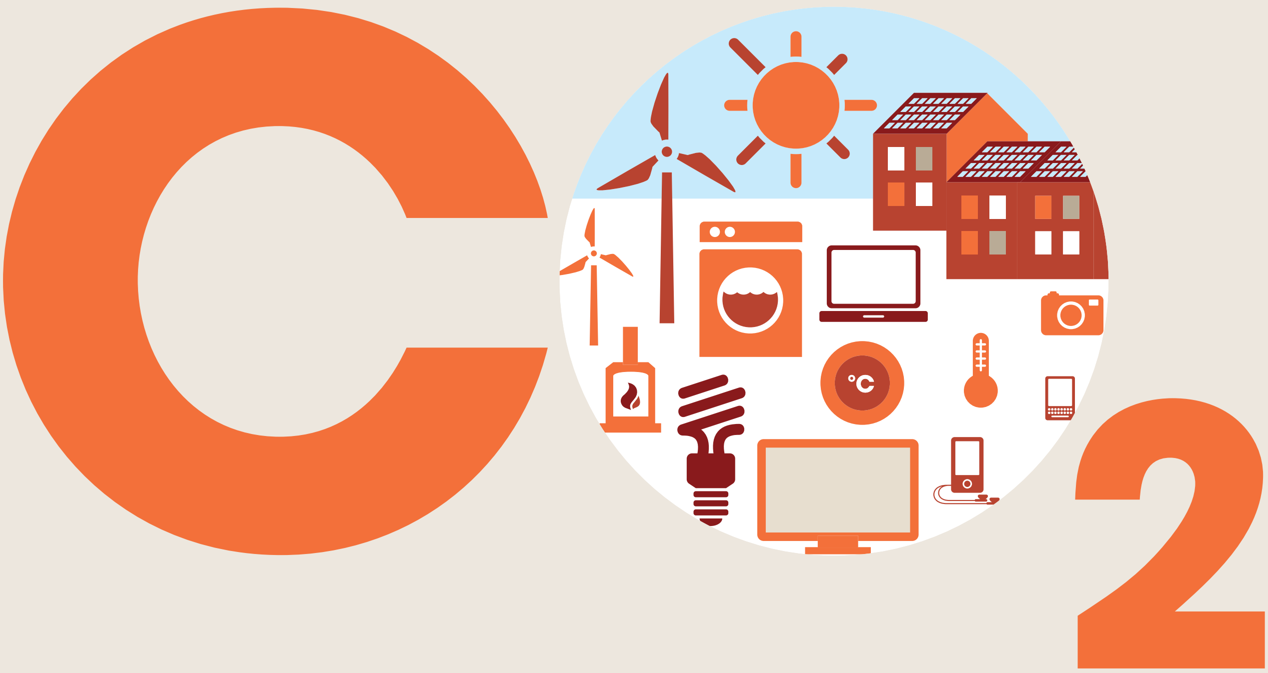
These totals include the direct impacts of the required levels of investment in employment and GVA and indirect effects based on supply chain and income (or consumption) multipliers. A summary of the estimates by sector is provided in Table 6.

Table 6: Summary of the Economic Benefits

Sector	Measures	Total investment to 2022 (£000)	LCR direct jobs p.a.	LCR direct GVA p.a. (£000)	LCR total jobs p.a.	LCR total GVA p.a. (£000)
Domestic	Cost effective	961,302	698	32,812	978	45,905
	Cost neutral	2,121,230	1,757	77,273	2,720	119,818
	Sub-total	**3,082,532**	**2,455**	**110,085**	**3,698**	**165,723**
Commercial	Cost effective	1,388,586	1,020	45,334	1,596	70,986
	Cost neutral	1,471,380	1,074	46,676	1,541	67,139
	Sub-total	**2,859,966**	**2,093**	**92,010**	**3,137**	**138,125**
Industrial	Cost effective	233,922	116	7,560	116	7,569
	Cost neutral	130,259	63	3,778	94	5,667
	RH Measures	795,965	584	25,511	871	37,976
	Sub-total	**1,160,146**	**763**	**36,858**	**1,140**	**54,997**
Transport	**Sub-total**	**n/a**	**1,168**	**58,168**	**1,753**	**87,252**
Total	Cost effective	2,583,810	3,003	143,883	4,443	211,711
	Cost neutral	4,518,834	3,477	153,238	5,226	230,600
	All measures	**7,102,644**	**6,480**	**297,121**	**9,669**	**442,312**

Sector Focus

The Domestic Sector



Main Findings
The Domestic Sector

Cost effective opportunities

- There are £1.1 billion worth of cost-effective, energy efficient and low carbon investment opportunities available in the domestic sector in the Leeds City Region.
- Exploiting these would generate annual savings of £400 million a year.
- At commercial rates, these investments would pay for themselves in under 3 years, whilst generating annual savings for the lifetime of the measures.
- If exploited, these investments would reduce Leeds City Region carbon emissions by 3.8% by 2022, compared to 1990.

Cost neutral opportunities

- There are £3.6 billion of cost-neutral, energy efficient and low carbon investment opportunities available in the domestic sector in the Leeds City Region.
- Exploiting these would generate annual savings of £556 million a year.
- At commercial rates, these investments would pay for themselves in 6.4 years, whilst generating annual savings for the lifetime of the measures.
- These investments would reduce Leeds City Region carbon emissions by 5.3% by 2022, compared to 1990.

Table 7: League Table of the Most Cost Effective Measures for the Domestic Sector

	Central business case	£/TCO2
1	Mini wind turbines (5kW) with FiT	-457
2	Biomass boilers with RHI	-325
3	Electronic products	-245
4	Information and communication technology products	-244
5	Integrated digital TVs	-228
6	Reduced standby consumption	-228
7	Reduce heating for washing machines	-209
8	A++ rated cold appliances	-180
9	A rated ovens	-175
10	Biomass district heating with RHI	-155
11	Efficient lighting	-153
12	A-rated condensing boiler	-145
13	Insulate primary pipework	-132
14	Glazing – old double to new double	-123
15	Uninsulated cylinder to high performance	-122
16	Glazing – single to new	-120
17	Insulated doors	-118
18	Reduce household heating by 1°C	-111
19	Induction hobs	-110
20	Loft insulation 0 - 270mm	-79
21	Pre '76 cavity wall insulation	-73
22	Improve airtightness	-71

FiT = Feed in Tarriff. RHI = Renewable Heat Incentive. Correct as at 1/1/2012

Cost effective

Cost neutral

Discussion

There are numerous opportunities for reducing the energy use and carbon footprints of households within the Leeds City Region. This could be done through investments in the fabric of the built environment (i.e. through loft and wall insulation, double glazing), through investments in more energy efficient appliances (computers, TVs, fridges, freezers etc) or through changes in behaviour (turning off appliances, turning down thermostats etc). The league tables of the most cost and carbon effective measures are included in Table 7.

23	DIY floor insulation (susp. timber floors)	-70
24	Loft insulation 25 - 270mm	-69
25	Loft insulation 50 - 270mm	-59
26	76-83 cavity wall insulation	-56
27	A+ rated wet appliances	-54
28	Loft insulation 75 - 270mm	-52
29	Post '83 cavity wall insulation	-30
30	Turn unnecessary lighting off	-28
31	Installed floor insulation (susp. timber frames)	-25
32	Loft insulation 100 - 270mm	-8
33	Glazing (to best practice)	-4
34	Ground source heat pump with RHI	2
35	Solid wall insulation	9
36	Loft insulation 125 - 270mm	11
37	Loft insulation 150 - 270mm	59
38	Room thermostat to control heating	59
39	Paper type solid wall insulation	76
40	Modestly insulated cylinder to high performance	90
41	Thermostatic radiator valves	135
42	Photovoltaic generation with FiT	180
43	Air source heat pump with RHI	340
44	Micro wind turbines (1kW) with FiT	639
45	Hot water cylinder 'stat	671
46	Solar water heating with RHI	1173

Table 8: League Table of the Most Carbon Effective Measures for the Domestic Sector

	Central business case	KTCO2
1	Reduce household heating by 1°C	201.15
2	Solid wall insulation	198.03
3	Biomass boilers with RHI	153.76
4	Pre '76 cavity wall insulation	101.64
5	Electronic products	84.59
6	Biomass district heating with RHI	79.66
7	Ground source heat pump with RHI	77.05
8	Information and communication technology products	55.49
9	Efficient lighting	51.90
10	Air source heat pump with RHI	45.87
11	Loft insulation 0 - 270mm	18.38
12	A+ rated wet appliances	16.98
13	DIY floor insulation (susp. timber floors)	14.71
14	Mini wind turbines (5kW) with fit	12.69
15	Glazing – single to new	12.37
16	Reduce heating for washing machines	12.32
17	Photovoltaic generation with fit	12.20
18	Uninsulated cylinder to high performance	11.14
19	Loft insulation 100 - 270mm	11.10
20	Solar water heating with RHI	10.68
21	Reduced standby consumption	10.40
22	Improve airtightness	9.77

FiT = Feed in Tarriff. RHI = Renewable Heat Incentive. Correct as at 1/1/2012

The analysis shows that bigger domestic wind turbines and solar photovoltaics (both with FiTs) are the most cost effective measures, but the aggregated carbon saving potential from this measure is relatively small across the Leeds City Region. Biomass boilers (with RHI) are the next most cost effective measure, and they are also an option with one of the largest potential carbon savings at the LCR scale. Other options that are cost effective but that have relatively small carbon savings relate to the adoption of more efficient appliances. Solar PV (with FiTs) has a relatively small carbon saving potential at the LCR scale, but reducing household heating levels by one degree has a very significant level of cost-effective carbon saving potential, as does the wider deployment of energy efficient lighting and investments in loft insulation cavity wall for the oldest and least well insulated houses. The biggest aggregate carbon saving available for any domestic sector measure relates to solid wall insulation – investments in this measure are cost neutral over their life time.

In terms of the wider employment and economic effects, domestic measures represent 38% of the total jobs and GVA that could be created within the LCR through investments in cost effective and cost neutral low carbon measures. Within this sector the measures which result in the most jobs/GVA are loft and cavity wall insulation, solid wall insulation, PV generation, mini wind turbine and renewable heat such as heat pumps, biomass boilers and solar thermal.

Cost effective

Cost neutral

23	Glazing (to best practice)	9.31
24	Loft insulation 75 - 270mm	9.01
25	Glazing – old double to new double	8.21
26	76-83 cavity wall insulation	6.70
27	Modestly insulated cylinder to high performance	6.45
28	Loft insulation 50 - 270mm	4.89
29	Room thermostat to control heating	3.98
30	Post '83 cavity wall insulation	3.71
31	Turn unnecessary lighting off	3.17
32	Thermostatic radiator valves	2.09
33	Insulate primary pipework	1.64
34	Paper type solid wall insulation	1.24

35	Integrated digital TVs	1.12
36	Micro wind turbines (1kW) with fit	1.07
37	A++ rated cold appliances	1.03
38	Loft insulation 25 - 270mm	0.97
39	Hot water cylinder 'stat	0.31
40	A rated ovens	0.00
41	A rated condensing boiler	0.00
42	Insulated doors	0.00
43	Induction hobs	0.00
44	Installed floor insulation (susp. timber frames)	0.00
45	Loft insulation 125 - 270mm	0.00
46	Loft insulation 150 - 270mm	0.00

For those investments with employment creating potential:

— Total capital expenditure for the selected measures over the 10 years is £3.6 billion (31% for cost effective measures and 69% for cost neutral measures);

— Total average number of jobs/year created is about 3,700 (26% for cost effective measures and 74% for cost neutral measures). This total comprises 2,460 direct jobs and 1,240 indirect jobs based on composite supply chain and income (or consumption) multipliers;

— Total average annual GVA is about £166 million (28% for cost effective measures and 72% for cost neutral measures). This equates to a cumulative total of £1.66 billion over the 10 year period.

A breakdown of the jobs per year for the cost effective measures is given in Figure 3.

This shows that microgeneration technologies (PV generation, biomass and mini wind) account for 62% of the total jobs for cost effective measures and insulation measures account for 30% of the total. Other measures include efficient lighting and energy efficient (A+ and A++ rated) appliances.

A breakdown of the jobs per year for the cost neutral measures is given in Figure 4.

Solid wall insulation accounts for 43% of the total jobs for cost neutral measures and renewable heat technologies (air source and ground source heat pumps and solar thermal) account for 54% of the total. Other measures include heating controls and micro wind.

We estimate that around 250 direct additional jobs and £17.5m GVA/annum could be created in LCR associated with the delivery of whole house survey by energy advisors (375 jobs and £26m GVA/annum if indirect jobs are included).

Figure 3: Breakdown of Total Jobs for Cost Effective Domestic Measures

(Total jobs/annum – 978)

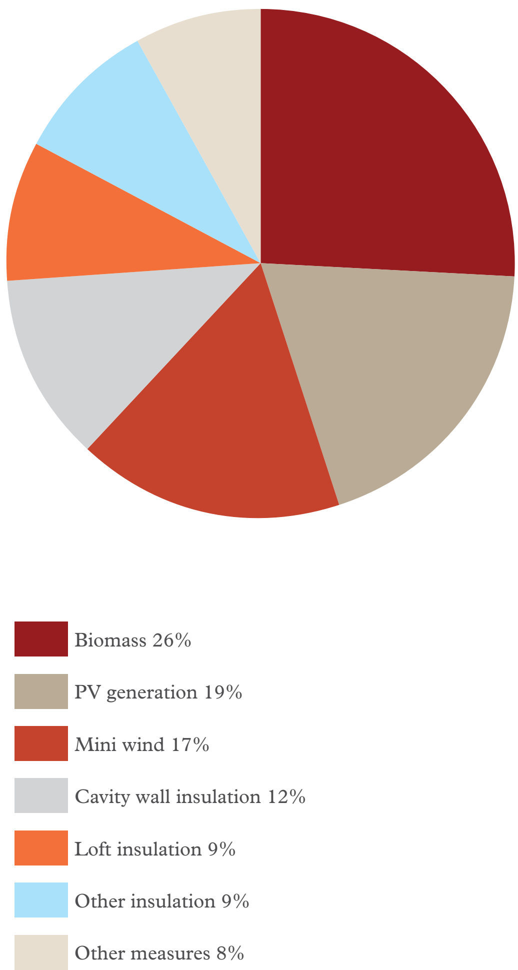
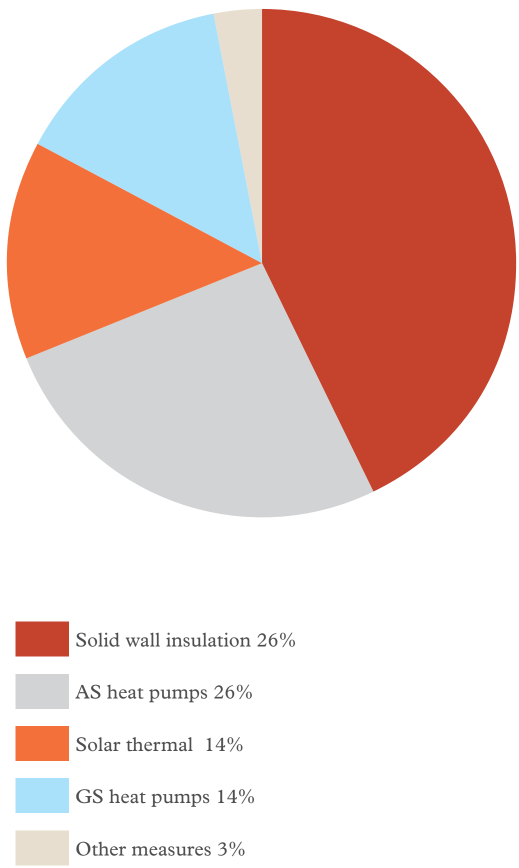


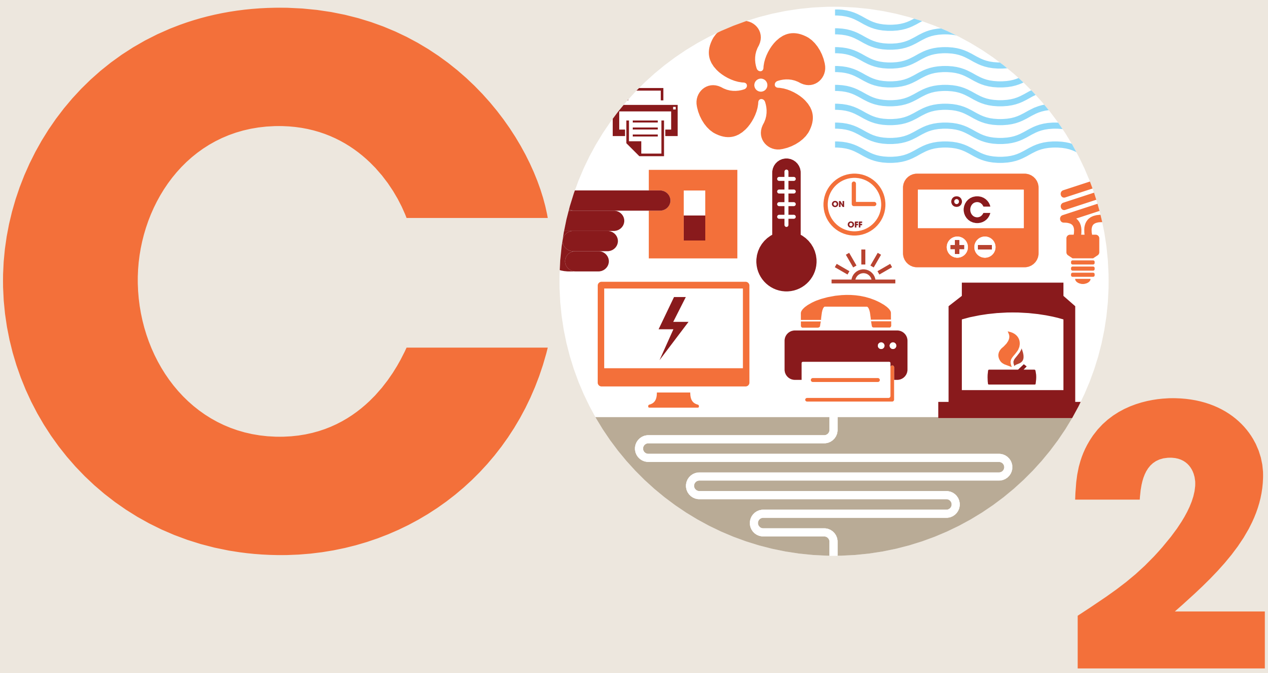
Figure 4: Breakdown of Total Jobs for Cost Neutral Domestic Measures

(Total jobs/annum – 2,720)



Sector Focus

The Commercial Sector



Main Findings
The Commercial Sector

Cost effective opportunities

- There are £1.9 billion of cost-effective, energy efficient and low carbon investment opportunities available in the commercial sector within the Leeds City Region.
- Exploiting these would generate annual savings of £335 million a year.
- These investments would pay for themselves in 5.58 years, whilst generating annual savings for the lifetime of the measures.
- If exploited, these investments would reduce Leeds City Region carbon emissions by 3.9% by 2022, compared to 1990.

Cost neutral opportunities

- There are £3.4 billion of cost-effective, energy efficient and low carbon investment opportunities available in the commercial sector within the Leeds City Region.
- Exploiting these would generate annual savings of £447 million a year.
- Collectively, these investments would pay for themselves in 7.64 years, whilst generating annual savings for the lifetime of the measures.
- Collectively, these investments would reduce Leeds City Region carbon emissions by 4.9% by 2022, compared to 1990.

Table 9: League Table of the Most Cost Effective Measures for the Commercial Sector

	Central business case	£/TCO2
1	Office equipment – fax machine switch off	-500.11
2	Photocopiers – energy management	-500.11
3	Monitors – energy management	-500.11
4	Computers – energy management	-500.11
5	Printers – energy management	-500.11
6	Vending machines – energy management	-500.11
7	Office equipment – most energy efficient monitor PC only	-462.94
8	Office equipment – most energy efficient monitor	-436.54
9	Lights – turn off lights for an extra hour	-422.63
10	Lights – sunrise-sunset timers	-422.35
11	Lights – basic timer	-422.16
12	Heating – more efficient air conditioning	-420.26
13	Lights – light detectors	-414.59
14	Stairwell timer	-401.69
15	Compressed air	-343.71
16	Presence detector	-283.64
17	Heating – programmable thermostats high	-257.85
18	Heating – optimising start times	-255.15
19	Heating – reducing room temperature	-251.48
20	Biomass boilers with RHI	-243.03
21	Most energy efficient fridge-freezer	-221.49

FiT = Feed in Tarriff. RHI = Renewable Heat Incentive. Correct as at 1/1/2012

Cost effective

Cost neutral

Discussion

Again, there are numerous energy efficient and low carbon options available to the commercial sector, including many forms of more energy efficient appliance (computer monitors, photocopiers etc), various different types of energy saving equipment (light detectors, thermostats etc) and some behavioural measures (turning lights off for an extra hour). A range of small scale-renewables could also be adopted and there are various ways in which buildings could be better insulated. The league tables of the most cost and carbon effective measures are included below.

22	Heating – thermostatic radiator valves fully installed	-205.74
23	Most energy efficient flat roof insulation	-161.18
24	Heating – most energy efficient boiler	-120.99
25	Biomass district heating with RHI	-115.64
26	Lights – metal halide floods	-108.45
27	Lights – IRC tungsten-halogen – spots	-103.65
28	Most energy efficient pitched roof insulation	-80.47
29	Most energy efficient cavity wall insulation	-41.78
30	Air source heat pumps with RHI	-1.99
31	Most energy efficient freezer	39.44
32	Most energy efficient fridge	61.40
33	Ground source heat pumps with RHI	68.11
34	Lights – most energy efficient replacement 26mm	98.16
35	Motor – 4 Pole motor – EFF1 replace 4 Pole	156.60
36	Lights – high frequency ballast	160.00
37	Most energy efficient external wall insulation	288.06
38	Solar water heating with RHI	679.15
39	Most energy efficient double glazing	779.40
40	Lights – most energy efficient replacement tungsten	911.53
41	Variable speed drives	917.51
42	Most energy efficient double glazing (replace double)	3170.37

Table 10: League Table of the Most Carbon Effective Measures for the Commercial Sector

	Central business case	KTCO2
1	Air source heat pumps with RHI	154.79
2	Heating – most energy efficient boiler	139.46
3	Heating – programmable thermostats high	135.57
4	Biomass boilers with RHI	88.08
5	Heating – reducing room temperature	82.47
6	Ground source heat pumps with RHI	75.24
7	Biomass district heating with RHI	69.11
8	Most energy efficient double glazing	49.64
9	Heating – optimising start times	46.46
10	Lights – basic timer	37.65
11	Heating – more efficient air conditioning	33.51
12	Heating – thermostatic radiator valves fully installed	24.88
13	Lights – most energy efficient replacement 26mm	24.37
14	Solar water heating with RHI	23.63
15	Lights – turn off lights for an extra hour	20.48
16	Monitors – energy management	17.49
17	Lights – high frequency ballast	16.25
18	Most energy efficient external wall insulation	15.37
19	Most energy efficient flat roof insulation	13.86

FiT = Feed in Tarriff. RHI = Renewable Heat Incentive. Correct as at 1/1/2012

The analysis shows that the most cost effective measures all involve replacing office equipment with more energy efficient alternatives. However, at the LCR scale, these measures would not lead to very significant amounts of carbon reduction. The biggest carbon savings from cost effective measures come from the installation of biomass boilers, biomass district heating schemes and air source heat pumps (all taking into account the effect of RHIs). Thereafter, the biggest carbon savings from cost effective measures come from installing programmable thermostats, optimising start times for heating, installing basic timers on lighting systems and adopting more energy efficient air conditioning.

Commercial measures (i.e. in public and private sector buildings) represent about 32% of the total jobs and GVA that could be generated through cost effective and cost neutral investments in low carbon measures. Within this sector, the measures which result in the most jobs/GVA are more efficient boilers and air-conditioning, heating and lighting controls, renewable heat and the most energy efficient double glazing.

Cost effective
Cost neutral

20	Presence detector	10.96
21	Most energy efficient cavity wall insulation	10.81
22	Most energy efficient pitched roof insulation	10.09
23	Computers – energy management	7.46
24	Variable speed drives	6.98
25	Stairwell timer	6.96
26	Lights – most energy efficient replacement tungsten	5.77
27	Office equipment – most energy efficient monitor PC only	5.31
28	Lights – IRC tungsten-halogen – spots	4.76
29	Most energy efficient freezer	4.56
30	Lights – sunrise-sunset timers	4.00
31	Lights – light detectors	3.97
32	Most energy efficient double glazing (replace double)	3.03
33	Compressed air	2.79
34	Printers – energy management	1.95
35	Lights – metal halide floods	1.92
36	Most energy efficient fridge	1.49
37	Photocopiers – energy management	1.08
38	Office equipment – fax machine switch off	0.57
39	Vending machines energy management	0.41
40	Motor – 4 Pole motor – EFF1 replace 4 Pole	0.35
41	Most energy efficient fridge-freezer	0.14
42	Office equipment – most energy efficient monitor	0.07

- Total capital expenditure for the selected measures over the 10 years is £3.4 billion (56% for cost effective measures and 51% for cost neutral measures);
- Total average number of jobs/year created is about 3,140 (51% for cost effective measures and 49% for cost neutral measures). This total comprises 2,090 direct jobs and 1,050 indirect jobs based on composite supply chain and income (or consumption) multipliers; and
- Total average annual GVA is about £138 million (51% for cost effective measures and 49% for cost neutral measures). This equates to a cumulative total of £1.38 billion over the 10-year period.

A breakdown of the jobs per year for the cost effective measures is given in Figure 5.

Air source heat pumps account for 43% of the total jobs for cost effective measures, followed by heating controls with 16%, energy efficient lighting and controls with 11% and energy efficient boilers with 11% of the total. Other measures include insulation, efficient air-conditioning and compressed air.

A breakdown of the jobs per year for the cost neutral measures is given in Figure 6.

Ground source heat pump measures accounts for 40% of the total jobs for cost neutral measures, followed closely by solar thermal with 38%. Insulation contributes 15% and lighting contributes 5% of the total jobs. Other measures include variable speed drives and more efficient electric motors.

Figure 5: Breakdown of Total Jobs for Cost Effective Commercial Measures

(Total jobs/annum – 1,600)

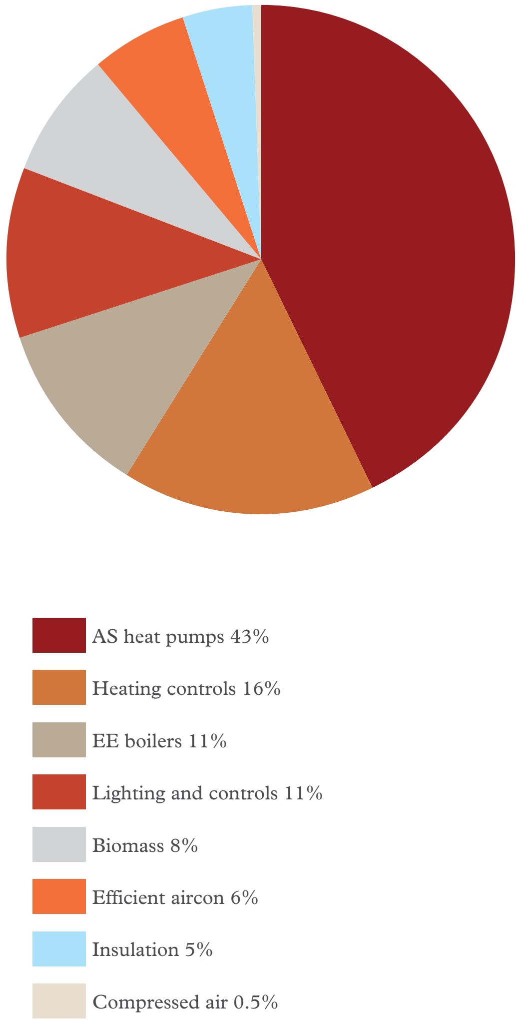
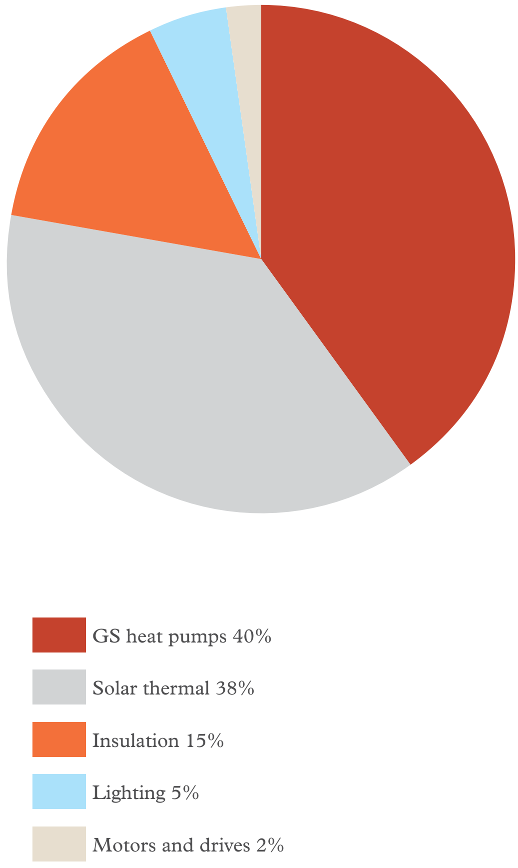


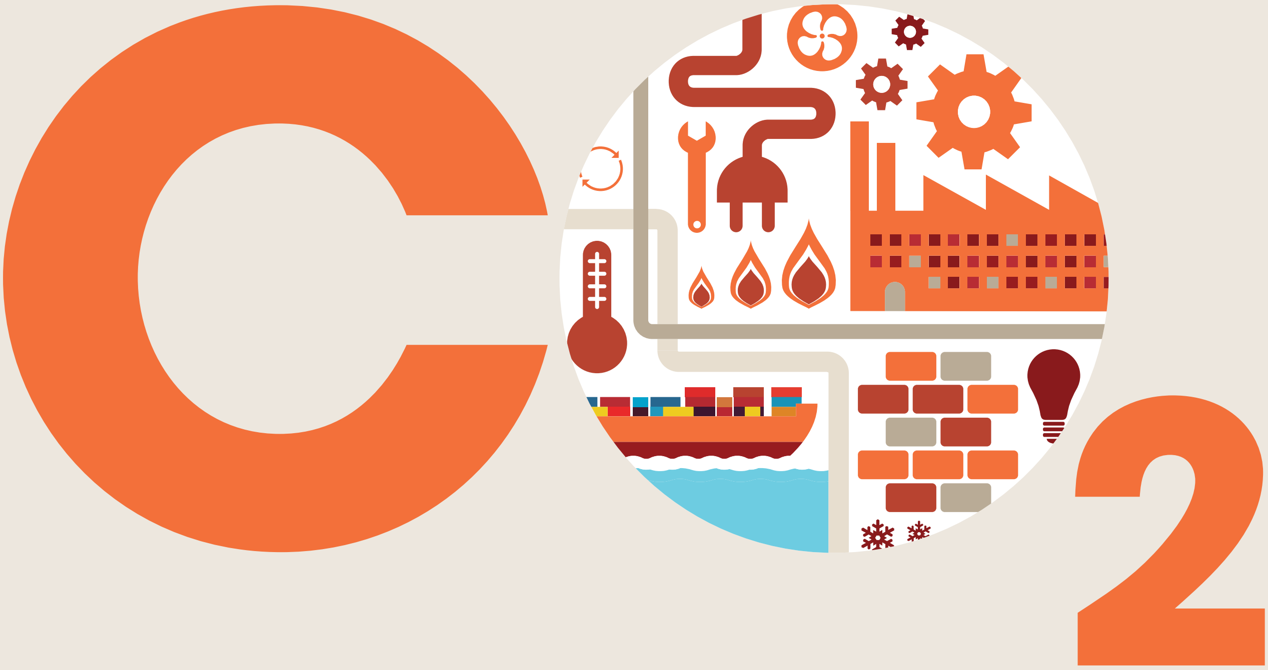
Figure 6: Breakdown of Total Jobs for Cost Neutral Commercial Measures

(Total jobs/annum – 1,540)



Sector Focus

The Industrial Sector



Main Findings
The Industrial Sector

Cost effective opportunities

- There are £1.07 billion of cost effective, energy efficient and low carbon investment opportunities available in industry in the Leeds City Region.
- Exploiting these would generate annual savings of £323 million a year.
- At commercial rates, these investments would pay for themselves in 3.31 years, whilst generating annual savings for the lifetime of the measures.
- If exploited, these investments would reduce Leeds City Region carbon emissions by 4.3% by 2022, compared to 1990.

Cost neutral opportunities

- There are £2.38 billion of cost neutral, energy efficient and low carbon investment opportunities available in industry in the Leeds City Region.
- Exploiting these would generate annual savings of £324 million a year.
- Collectively, these investments would pay for themselves in 7.34 years, whilst generating annual savings for the lifetime of the measures.
- Collectively, these investments would reduce Leeds City Region carbon emissions by 5.3% by 2022, compared to 1990.

Discussion

There are thousands of energy efficient and low carbon measures that could be adopted in different sectors of industry and that have been analysed in this research. For simplicity, we have clustered these together in a smaller number of categories of measures which includes more energy efficient burners, motors and drives, fabrication and machining, refrigeration and air conditionings, lighting, heat recovery, ventilation and so on. The league tables of the most cost and carbon effective measures are included below.

Table 11: League Table of the Most Cost Effective Measures for the Industrial Sector *

	Central business case	£/TCO2
1	Burners	-805.96
2	Refrigeration and air-conditioning	-243.94
3	Compressed air	-229.77
4	Lighting	-195.92
5	Fabrication and machining	-166.62
6	Design	-147.74
7	Building energy management	-129.87
8	Operation and maintenance	-120.46
9	Heat recovery	-120.23
10	Drying and separation	-119.03
11	Low temperature heating	-118.92
12	New food and drink plant	-118.90
13	Space heating	-111.22
14	High temperature heating	-93.80
15	Renewable heat	-91.03
16	Controls	-86.10
17	Process improvement	-71.72
18	Energy management	-51.50
19	Ventilation	267.37
20	Others	271.90
21	Information technology	339.14
22	Motors and drives	411.12
23	Insulation	618.82

Cost effective
Cost neutral
Realistic technical potential

Table 12: League Table of the Most Carbon Effective Measures for the Industrial Sector *

	Central business case	KTCO2
1	Renewable heat	516.84
2	Process improvement	101.55
3	Drying and separation	101.18
4	High temperature heating	93.24
5	Others	79.44
6	Motors and drives	74.73
7	Controls	57.39
8	Heat recovery	45.26
9	Low temperature heating	42.33
10	Operation and maintenance	40.23
11	Energy management	35.54
12	Space heating	17.72
13	Fabrication and machining	11.26
14	Ventilation	11.22
15	Refrigeration and air-conditioning	8.91
16	Building energy management	6.28
17	Insulation	4.96
18	Compressed air	4.55
19	Design	3.06
20	New food and drink plant	1.90
21	Lighting	1.52
22	Burners	1.27
23	Information technology	0.40

** Industrial measures are based on the grouping of thousands of different measures into broader categories to aid analysis and presentation. Average carbon effectiveness figures are presented for all measures within each category.*

The analysis shows more energy efficient burners are highly cost effective, but as the scope for their deployment in the LCR is low their aggregated potential to reduce carbon is also low. Thereafter, a number of measures are cost effective, but as (on average) they are not highly cost effective the incentives for their adoption are not necessarily high. The cost effective measure that stands out as having by far the highest potential to reduce carbon from industry is renewable heat.

In terms of their wider economic impact, industrial measures represent around 12% of the total jobs and GVA that could be generated through cost effective and cost neutral investments in low carbon measures. The measures which result in the most jobs/GVA are associated with motors and drives, high temperature heating, heat recovery, drying and separation, process improvements and renewable heat.

— Total capital expenditure for the measures with employment creating potential over the 10 years is about £2.4 billion (20% for cost effective, 11% for cost neutral and 69% for renewable heat measures);
— Total average number of jobs/year created is about 1,140 (15% for cost effective, 8% for cost neutral and 77% for renewable heat measures). This total comprises 760 direct jobs and 380 indirect jobs based on composite supply chain and income (or consumption) multipliers; and
— Total average annual GVA is about £55 million (21% for cost effective, 10% for cost neutral and 69% for renewable heat measures). This equates to a cumulative total of £550 million over the 10-year period.

A breakdown of the jobs per year for the cost effective measures is given in Figure 7.

Process improvement accounts for 38% of the total jobs for cost effective measures, followed by drying and separation with 32%, high temperature heating with 11% and heat recovery with 9% of the total. Other measures include burners, space heating, motors and drives and insulation.

A breakdown of the jobs per year for the cost neutral measures is given in the Figure 8.

High temperature heating accounts for 40% of the total jobs for cost neutral measures, followed by heat recovery with 25%, motors and drives with 11%, process improvement with 8% and energy management with 7% of the total. Other measures include fabrication and machining, low temperature heating, compressed air and insulation.

It should be noted that the categories of measures are the same as for the cost effective measures since they have been combined across a wide range of industry sectors, i.e. measures can be cost effective in some sectors and cost neutral in others.

A breakdown of the jobs per year for the renewable heat measures is given in Figure 9 which shows that biomass accounts for 45% of the total jobs, followed by air source heat pumps with 33% and ground source heat pumps with 22%.

Figure 7: Breakdown of Total Jobs for Cost Effective Industrial Measures

(Total jobs/annum – 175)

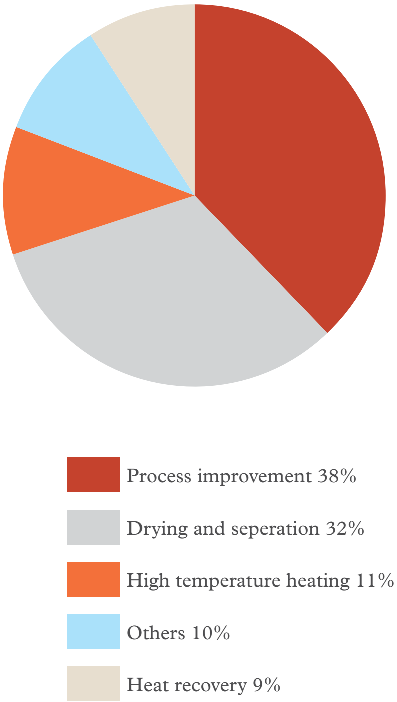


Figure 8: Breakdown of Total Jobs for Cost Neutral Industrial Measures

(Total jobs/annum – 94)

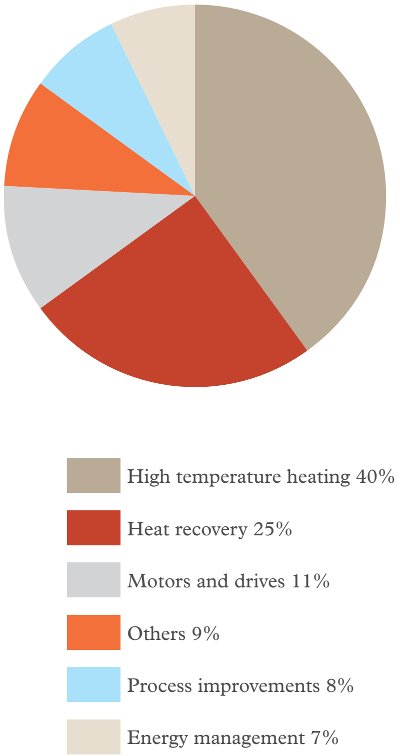
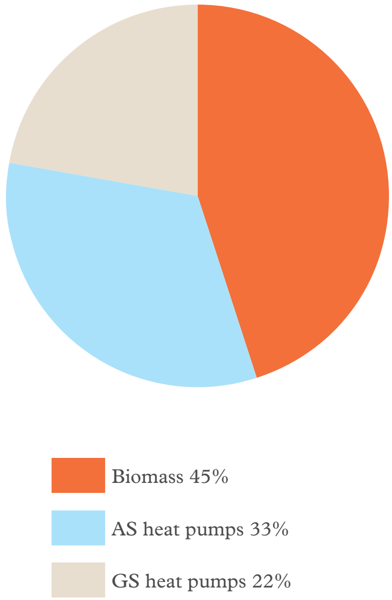


Figure 9: Breakdown of Total Jobs for Renewable Heat Industrial Measures

(Total jobs/annum – 871)



Sector Focus

The Transport Sector

Main Findings
The Transport Sector

Cost effective opportunities

- There are £847 million of cost effective, energy efficient and low carbon investment opportunities available in the transport sector in the Leeds City Region.
- Exploiting these would generate annual savings of £133 million a year.
- These investments would pay for themselves in 6.3 years, whilst generating annual savings for the lifetime of the measures.
- These investments would reduce Leeds City Region carbon emissions by 0.9% by 2022, compared to 1990.

Cost neutral opportunities

- There are £2.21 billion of cost neutral, energy efficient and low carbon investment opportunities available in the transport sector in the Leeds City Region.
- Exploiting these would generate annual savings of £260 million a year.
- Collectively, these investments would pay for themselves in 8.5 years, whilst generating annual savings for the lifetime of the measures.
- Collectively, these investments would reduce Leeds City Region carbon emissions by 2.5% by 2022, compared to 1990.

Discussion

The list of low carbon measures available in the transport sector is less extensive than the lists for the other sectors. Clearly there are other measures that could be included. Nonetheless, there are significant opportunities for reducing the energy use and carbon footprints of transport within the Leeds City Region. These include investments in park and ride schemes, smarter choices, cycling and demand management as well as investments in more fuel efficient and hybrid vehicles. League tables of the most cost and carbon effective measures are included in Tables 13 and 14.

Analysis

The analysis shows that park and ride schemes are the most cost effective low carbon transport option but that in aggregate across the LCR they do not have the highest level of transport related carbon saving potential. Express bus networks are also very cost effective over their life time, and they have significant carbon saving potential across the LCR, as do smarter choices and demand management. However, the carbon savings available through the widespread adoption of hybrid and electric vehicles are by far the most significant.

Table 13: League Table of the Most Cost Effective Measures for the Transport Sector

	Central business case	£/TCO2
1	Park and ride schemes	-370.03
2	Express bus/coach network	-370.03
3	Bus priority and quality enhancements	-316.54
4	Smarter choices	-315.17
5	Cycling	-261.97
6	Mild hybrid vehicles	-53.45
7	Demand management	-49.44
8	Plug-in hybrid vehicles	-43.73
9	Full hybrid vehicles	4.91
10	Biofuels	53.11
11	Micro hybrid vehicles	214.47
12	Electric	290.71
13	New railway stations	1429.09
14	Rail electrification	1448.29

Cost effective

Cost neutral

Realistic technical potential

In terms of their employment creating potential, transport measures represent 18% of the total jobs and GVA that could be generated through cost effective and cost neutral investments in low carbon measures. The measures which result in the most jobs/GVA are concerned with modal shift from cars to public transport.

- Total number of jobs/year created is about 1,750. This total comprises 1,170 direct jobs and 580 indirect jobs based on composite supply chain and income (or consumption) multipliers;
- About 69% of the jobs would be created in the rail transport sector, 24% in the bus sector and 7% in the cycling industry; and
- Total average annual GVA is about £87 million. This equates to a cumulative total of £870 million over the 10-year period.

These are mainly associated with modal shift from cars to more sustainable forms of transport such as buses, rail, and cycling, which would lead to a significant reduction in carbon emissions according to a report by Arup for LCR (Arup, 2009).

A report by Ekosgen on employment in sustainable transport (Ekosgen, 2010) shows that a shift from cars to rail, bus and cycle transport would also lead to an increase in jobs due to their higher job densities per km traveled. It concludes that between 1993 and 2010 an increase in rail, bus and cycle use could generate 130,000 jobs nationally, which would more than offset the 43,000 jobs lost in the motor industry through reduced car use. If this is true, then modal shift would have a significant impact on jobs and GVA in LCR since the job gains are most likely to be local whilst many the job losses are likely to occur outside LCR due to the location of the car industry.

Some of the cost effective and cost neutral measures are associated with the introduction of hybrid and electric vehicles. These changes are unlikely to have a significant impact on jobs in LCR since we are not aware of any major car, light vehicle or truck manufacturers in the region. There is a major bus manufacturer in Leeds, Optaire, which supplies hybrid and electric drive trains but the MAC data here does not include buses.

There may be some job creation potential in the supply of components for hybrid and electric vehicles (e.g. electric motors and batteries) but we are not aware of any suppliers in LCR, which could benefit from the opportunities. The establishment of an electric vehicle charging infrastructure in LCR will lead to some job creation. However, the potential is not likely to be very significant since the current suppliers of these systems are based outside LCR and hence the opportunities are mainly associated with local installation.

The introduction of biodiesel and bioethanol has already and will continue to create jobs but the main impact of this in the wider region will be in the Hull and Humber region where the large biofuel plants and refineries are located.

Table 14: League Table of the Most Carbon Effective Measures for the Transport Sector

	Central business case	KTCO2
1	Biofuels	210.45
2	Micro hybrid vehicles	144.73
3	Full hybrid vehicles	140.91
4	Plug-in hybrid vehicles	82.41
5	Electric	64.67
6	Demand management	48.09
7	Mild hybrid vehicles	47.36
8	Smarter choices	16.22
9	Bus priority and quality enhancements	12.87
10	Rail electrification	4.99
11	Cycling	3.35
12	Express bus/coach network	2.10
13	Park and ride schemes	1.45
14	New railway stations	0.87

Low Carbon Investment: Supply and Demand

The analysis has highlighted that within the Leeds City Region there is very considerable potential to reduce energy use and carbon footprints through cost effective and cost neutral investments on commercial terms. However, the fact that these opportunities exist on this scale is obviously not enough to ensure that they are actually exploited. Incentives – no matter how strong they are – have to be matched with appropriate capacities if progress is to be made. These relate both to the capacity to supply appropriate levels of investment, and to the capacity to stimulate and sustain demand for such investments.

Supply side factors: unlocking the supply of investment resources

The most obvious capacity that is needed is a capacity to raise, invest and secure returns on the very significant sums that are highlighted as being required within the report. We forecast that to exploit the cost effective opportunities alone, a total investment of £4.62 billion is needed. When spread over ten years, this equates to an investment of less than 1% of LCR GDP per year. Potentially, some of this level of investment could come from the Green Deal or the Green Investment Bank, but these investment opportunities are forecast to be profitable on commercial terms – particularly for investors with slightly longer time horizons than most UK investors (i.e. pension funds and other large institutional investors). The potential to attract very substantial levels of private sector investment should also therefore be explored.

The potential for investment depends in part on the mechanisms for cost recovery and the arrangements for benefit sharing that could be put in place. Public and private sector expertise on cost recovery has advanced rapidly in the UK in recent years, both through the development of the Green Deal and through experiments with different forms of Energy Service Company (ESCO). These mechanisms offer an opportunity to collect returns on investment either through energy companies on a pay as you save basis, or through longer term energy service contracts. Benefit sharing arrangements are also key as there needs to be a strong enough incentive for both the source and the recipient of the investment to participate. Such arrangements can easily be tailored to reflect the levels of risk and return associated with different low carbon options.

The potential for investment also depends in part on the development of innovative financing mechanisms, such as revolving or self-replenishing funds. Potentially, a much smaller level of initial investment could enable the exploitation of the most cost effective measures first, with the investment fund then replenishing itself before moving on to less cost effective measures. The detailed analysis of the capital and operational costs and benefit streams of the wide range of low carbon options that have been investigated in this report could be used to underpin the more detailed cash-flow analysis that is needed to investigate this issue further. Different cost recovery and benefit sharing arrangements could easily be explored in such an investigation.

The potential for investment also depends on capacities for identifying and managing risk. The energy and hence financial savings forecast in this report are based on detailed evaluations of different energy saving or low carbon measures in different contexts carried out for the CCC. The results of these evaluations are then interpreted conservatively to generate the data that has underpinned this research. The results have also been subjected to a sensitivity test to see how susceptible they are to changes in key factors such as energy prices or interest rates. To this extent this analysis represents the most detailed and robust assessment of the economics of decarbonising a city or city region that we know of. But there are still risks of course – and the actual potential of many of the cost effective low carbon measures identified will need to be evaluated before investment in particular measures can be recommended.

Demand side factors: unlocking demand for investment resources

As well as raising sufficient investment funds, there is also a need to consider the extent to which different actors in the domestic, commercial, industrial or transport sectors may want to access these funds and participate in any related schemes. A long list of issues could restrict their involvement (see BIS, 2009, 2010; DEFRA, 2010a and 2010b; Carbon Trust, 2010; Federation of Small Businesses, 2010).

Short-termism can be a key barrier to change. Even where there are demonstrable returns on investments in the medium to long term, some actors appear to overlook them because of more pressing priorities in the short term. High levels of risk aversity can also mean that some actors are sceptical about the presence or the relevance of purported opportunities in their particular context. Perceived risks can be higher where there is a lack of honest brokers who are sufficiently trusted and who have the expertise and experience needed to make a compelling case for investment, or a lack of learning networks through which information can flow and capacities can be built.

There can also be significant opportunity costs where the perceived risks of diverting scarce resources (including time and attention) from priority areas and channelling them towards what can be seen as peripheral issues can prevent the exploitation of apparent opportunities. Under these conditions, decision makers tend to over-estimate the costs and under-estimate the benefits. There are often also organisational barriers to investment, and these in turn often relate to split incentives where the costs of investment fall on one party (i.e. a landlord or a finance department) whilst the benefits accrue to another (i.e. a tenant or another department or subsidiary). On occasion there can also be regulatory barriers that prevent change – for example in the regulated utilities companies can be legally prevented from investing in various low carbon options.

Furthermore, there are commonly significant issues to do with embedded or locked-in forms of behaviour. Habits and routines emerge gradually over many years, and they can be incredibly resistant to change, particularly in large, complex organisations. Technological lock-in can also be a major factor as some decisions – such as investments in major infrastructure or capital projects – have long life times and the windows of opportunity within which changes can be made do not arise very regularly. And in smaller organisations the fixed costs (and the hassle costs) of searching for and accessing information on particular options can fall on one person who often lacks the time and the specialist expertise needed to take a good decision. Finally, instead of being available in the form of relatively `big wins', efficiency issues often present themselves as a large number of small and fragmented opportunities. This amplifies the significance of many of the other barriers to change mentioned above.

Unless all of these factors can be overcome, it is quite possible that opportunities to improve energy use and carbon footprints will be overlooked even if investment resources are made available. We need to think then not only about raising investment, but also about stimulating demand through an appropriate delivery vehicle that has the capacity to address all of the barriers to change presented above, whether in the domestic, commercial, industrial or transport sectors.

The potential to attract very substantial levels of private sector investment should be explored.

Conclusions and Recommendations

From a climate and carbon perspective, the analysis in this report suggests that the Leeds City Region has to exploit all of the cost effective measures and virtually all of the cost neutral measures identified above if it is to reduce its carbon emissions by 40% by 2022.

Decarbonising on this scale and at this rate should be possible. The technological and behavioural options are readily available, the energy and financial savings associated with these are clear (even based on conservative assessments), the investment criteria are commercially realistic, and the deployment rates have been judged by the independent Committee for Climate Change to be challenging but still realistic.

The economic returns on investment could be very significant indeed. Many of the measures would pay for themselves in a relatively short period of time, they would generate significant levels of employment and economic growth in the process, and if done well there may be a wider range of indirect benefits (not least from being a first mover in this field). The political and business case for very large investments in the low carbon economy is very strong indeed.

However, the transition depends on political and social capital as well as financial capital. The levels of ambition, investment and activity needed to exploit the available potential are very significant indeed. Enormous levels of investment are required, and major new initiatives are needed with widespread and sustained influence in the domestic, commercial and industrial sectors.

And of course we need to think about some major innovations, particularly in stimulating the supply of and the demand for major investment resources. We need to think about innovative financing mechanisms, based on new forms of cost recovery and benefit sharing and new ways of managing risk. And we need to develop new delivery mechanisms that can stimulate and sustain demand for investment in low carbon options by overcoming the many potential barriers to change.

Of course the list of low carbon measures included in the analysis here may not be complete. Identifying and evaluating other low carbon measures and including them in an analysis that allows their performance to be compared with the wider range of options is critically important if the LCR is to adopt a least cost pathway towards the low carbon economy/society.

And fundamentally, we should recognise that economics is not the only discipline that has something useful to say on the transition to a low carbon economy/society. A wider analysis should also consider the social and political acceptability of the different options, as well as issues relating to the social equity and broader sustainability of the different pathways towards a low carbon economy and society. We also need to think about `future proofing' investments to consider their compatibility with the more demanding targets for carbon reduction and with the different levels of climate change that are likely to come after 2022.

Acknowledgements

The project on which this report is based was commissioned and part-funded by the Leeds City Region through its Local Carbon Framework programme. Long term project funding was provided by the Centre for Low Carbon Futures. Additional funding was provided from the Centre for Climate Change Economics and Policy.

In addition to the inputs made by Melanie Taylor and the project steering committee, we would like to acknowledge the substantial contributions made by Ramzi Cherad, Roland Arnison, Helen Harwatt, Amanda Crossfield, John Barrett and Phil Webber in the preparation of this report. We also gratefully acknowledge the support provided by the UK Department for Energy and Climate Change and the UK Committee on Climate Change, and Katherine Robinson and Jon Price from the Centre for Low Carbon Futures.

References

AEA (2010) Local and Regional CO2 Emissions Estimates for 2005-2008, Statistical Release prepared for DECC.

Arup (2009) Leeds City Region Transport Strategy: Carbon Assessment, Ove Arup & Partners.

BIS (2009) Determining Cost Effective Action for Business to Reduce Carbon Emissions, Report by PwC, last accessed August 25th 2011 at http://randd.defra.gov.uk/Document.aspx?Document=EV0441_10072_FRP.pdf

BIS (2010) Low Carbon and Environmental Goods and Services: an industry analysis (update for 2008/9), UK Department of Business, Innovation and Skills, last accessed August 25th 2011 at http://www.bis.gov.uk/assets/biscore/corporate/docs/l/10-795-low-carbon-goods-analysis-update-2008-09.pdf.

Carbon Trust (2010) The Business of Energy Efficiency, last accessed August 25th 2011 at http://www.carbontrust.co.uk/Publications/pages/publicationdetail.aspx?id=CTA001&respos=0&q=business+of+energy+efficiency&o=Rank&od=asc&pn=0&ps=10

DECC (2010) Consultation Document on the Renewable Heat Incentive.

DEFRA (2010b) The Further Benefits of Business Resource Efficiency, Report for DEFRA by Oakdene Hollins, last accessed August 25th at http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=16943&FromSearch=Y&Publisher=1&SearchText=EV0441&SortString=ProjectCode&SortOrder=Asc&Paging=10

DEFRA (2010b)Reducing the Impact of Business Waste Through the Business Resource Efficiency and Waste Programme, Report for Defra by the National Audiy Office, last accessed August 25th 2011 at: http://www.nao.org.uk/publications/0910/business_waste.aspx

Ekosgen (2010) Employment in Sustainable Transport: A report for the Passenger Transport Executive Group, Campaign for Better Transport and Sustrans.

Federation of Small Businesses (2010) Making Sense of Going Green: Small Business and the Low Carbon Economy, last accessed August 25th 2011 at: http://www.fsb.org.uk/frontpage/assets/fsb0029_environment_report_web.pdf

United Nations World Urbanisation Prospects (UNWUP) (2009) The 2009 Revision Population Database. Available at: http://esa.un.org/unpd/wup/index.htm

United Nations HABITAT (UN HABITAT) (2011) State of the worlds cities 2010/2011: Bridging the urban divide.

United Nations HABITAT (UN HABITAT) (2011b) Cities and climate change: policy directions. Global report on human settlements.

Appendix A: Background Data

DECC (2010) projections of energy prices by year: Low price scenario

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
ELECTRICITY retail: domestic	p/kWh	9.33	9.49	10.02	9.76	10.33	10.69	11.02	11.40	11.88	12.20	12.58	12.72	13.20
ELECTRICITY – retail: commercial	p/kWh	7.63	7.66	7.99	8.17	8.56	8.90	9.26	9.62	10.15	10.57	10.98	11.34	11.83
ELECTRICITY – retail: industrial	p/kWh	7.00	7.03	7.33	7.50	7.85	8.17	8.49	8.83	9.32	9.70	10.08	10.40	10.86
ELECTRICITY – Variable element: domestic	p/kWh	5.07	5.01	5.19	5.18	5.26	5.25	5.28	5.31	5.34	5.39	5.42	5.50	5.61
ELECTRICITY – Variable element: commercial	p/kWh	4.62	4.56	4.72	4.71	4.78	4.76	4.79	4.81	4.83	4.88	4.90	4.97	5.07
ELECTRICITY – Variable element: industrial	p/kWh	4.33	4.28	4.43	4.42	4.48	4.47	4.50	4.52	4.54	4.58	4.61	4.67	4.76
GAS – retail: domestic	p/kWh	2.81	2.88	2.98	3.11	3.31	3.39	3.44	3.55	3.67	3.77	3.97	3.82	3.86
GAS – retail: commercial	p/kWh	1.89	1.90	1.93	1.96	2.01	2.07	2.14	2.24	2.36	2.52	2.70	2.72	2.74
GAS – retail: industrial	p/kWh	1.73	1.74	1.76	1.79	1.83	1.89	1.96	2.04	2.15	2.30	2.47	2.48	2.50
GAS – Variable element: domestic	p/kWh	1.27	1.28	1.29	1.30	1.31	1.32	1.33	1.34	1.35	1.36	1.36	1.37	1.38
GAS – Variable element: commercial	p/kWh	1.17	1.17	1.18	1.18	1.19	1.19	1.20	1.20	1.20	1.21	1.21	1.22	1.22
GAS – Variable element: industrial	p/kWh	1.17	1.17	1.18	1.18	1.19	1.19	1.20	1.20	1.20	1.21	1.21	1.22	1.22
COAL – retail: domestic	p/kWh	2.55	2.55	2.55	2.55	2.55	2.55	2.55	2.55	2.55	2.55	2.55	2.55	2.55
COAL – retail: commercial	p/kWh	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
COAL – retail: industrial	p/kWh	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
COAL – Variable element: domestic	p/kWh	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19
COAL – Variable element: commercial	p/kWh	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
COAL – Variable element: industrial	p/kWh	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
BURNING OIL – retail: domestic	p/litre	30.23	30.23	31.02	31.80	32.59	33.37	34.16	34.16	34.16	34.16	34.16	34.16	34.16
GAS OIL – retail: commercial	p/litre	34.64	34.64	35.45	36.25	37.05	37.85	38.65	38.65	38.65	38.65	38.65	38.65	38.65
GAS OIL – retail: industrial	p/litre	31.93	31.93	32.73	33.53	34.33	35.13	35.94	35.94	35.94	35.94	35.94	35.94	35.94
BURNING OIL – Variable element: domestic	p/litre	25.79	25.79	26.54	27.29	28.03	28.78	29.53	29.53	29.53	29.53	29.53	29.53	29.53
GAS OIL – Variable element: commercial	p/litre	22.80	22.80	23.60	24.40	25.20	26.01	26.81	26.81	26.81	26.81	26.81	26.81	26.81

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
GAS OIL – Variable element: industrial	p/litre	19.08	19.08	19.88	20.68	21.49	22.29	23.09	23.09	23.09	23.09	23.09	23.09	23.09
ROAD TRANSPORT – retail: petrol	p/litre	100.6	103.0	106.8	109.4	111.4	112.6	113.6	113.6	113.5	113.5	113.5	113.5	113.4
ROAD TRANSPORT – retail: DERV	p/litre	103.7	106.1	110.0	112.7	114.9	116.2	117.3	117.2	117.2	117.2	117.1	117.1	117.1
ROAD TRANSPORT – Variable element: petrol	p/litre	27.37	27.39	28.22	29.05	29.88	30.72	31.55	31.56	31.57	31.58	31.60	31.61	31.62
ROAD TRANSPORT – Variable element: DERV	p/litre	28.71	28.71	29.64	30.57	31.50	32.43	33.37	33.37	33.37	33.37	33.37	33.37	33.37
AVIATION – retail: Aviation fuel	p/litre	23.96	23.96	24.98	26.00	27.03	28.05	29.07	29.07	29.07	29.07	29.07	29.07	29.07
AVIATION – Variable element: Aviation fuel	p/litre	23.26	23.26	24.28	25.30	26.33	27.35	28.37	28.37	28.37	28.37	28.37	28.37	28.37

Note: Retail = taxes included; Variable element = without taxes

DECC (2010) projections of energy prices by year: Central price scenario

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
ELECTRICITY – retail: domestic	p/kWh	11.63	11.99	12.54	12.35	12.92	13.31	13.64	14.02	14.48	14.76	15.10	15.31	15.77
ELECTRICITY – retail: commercial	p/kWh	10.01	10.25	10.61	10.87	11.24	11.62	11.97	12.35	12.85	13.24	13.60	14.03	14.50
ELECTRICITY – retail: industrial	p/kWh	9.19	9.41	9.73	9.97	10.32	10.66	10.99	11.33	11.79	12.15	12.48	12.87	13.30
ELECTRICITY – Variable element: domestic	p/kWh	7.37	7.56	7.82	7.93	8.04	8.14	8.23	8.33	8.40	8.53	8.62	8.74	8.83
ELECTRICITY – Variable element: commercial	p/kWh	6.80	6.97	7.20	7.30	7.39	7.49	7.57	7.65	7.71	7.83	7.91	8.02	8.10
ELECTRICITY – Variable element: industrial	p/kWh	6.36	6.52	6.74	6.83	6.92	7.01	7.08	7.16	7.22	7.33	7.41	7.51	7.59
GAS – retail: domestic	p/kWh	3.75	3.89	4.01	4.16	4.38	4.48	4.55	4.68	4.81	4.93	5.14	5.02	5.08
GAS – retail: commercial	p/kWh	2.90	2.99	3.04	3.09	3.17	3.25	3.34	3.46	3.59	3.76	3.97	4.01	4.05
GAS – retail: industrial	p/kWh	2.64	2.73	2.77	2.82	2.89	2.96	3.05	3.15	3.28	3.43	3.62	3.66	3.70

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
GAS – Variable element: domestic	p/kWh	2.16	2.24	2.27	2.31	2.34	2.37	2.40	2.44	2.47	2.50	2.53	2.57	2.60
GAS – Variable element: commercial	p/kWh	2.06	2.14	2.17	2.19	2.22	2.25	2.27	2.30	2.33	2.35	2.38	2.41	2.44
GAS – Variable element: industrial	p/kWh	2.06	2.14	2.17	2.19	2.22	2.25	2.27	2.30	2.33	2.35	2.38	2.41	2.44
COAL – retail: domestic	p/kWh	3.12	3.07	3.01	2.95	2.89	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84
COAL – retail: commercial	p/kWh	1.46	1.40	1.35	1.29	1.24	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18
COAL – retail: industrial	p/kWh	1.24	1.19	1.13	1.08	1.02	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
COAL – Variable element: domestic	p/kWh	2.73	2.68	2.62	2.57	2.51	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46
COAL – Variable element: commercial	p/kWh	1.22	1.16	1.11	1.05	1.00	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
COAL – Variable element: industrial	p/kWh	1.12	1.06	1.01	0.96	0.90	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
BURNING OIL – retail: domestic	p/litre	38.08	38.48	38.87	39.26	39.65	40.05	40.44	40.83	41.23	41.62	42.01	42.40	42.80
GAS OIL – retail: commercial	p/litre	42.67	43.07	43.47	43.87	44.27	44.67	45.07	45.47	45.87	46.28	46.68	47.08	47.48
GAS OIL – retail: industrial	p/litre	39.95	40.35	40.75	41.15	41.55	41.95	42.35	42.76	43.16	43.56	43.96	44.36	44.76
BURNING OIL – Variable element: domestic	p/litre	33.27	33.64	34.02	34.39	34.77	35.14	35.51	35.89	36.26	36.64	37.01	37.38	37.76
GAS OIL – Variable element: commercial	p/litre	30.82	31.22	31.62	32.02	32.42	32.82	33.22	33.63	34.03	34.43	34.83	35.23	35.63
GAS OIL – Variable element: industrial	p/litre	27.10	27.50	27.90	28.30	28.70	29.11	29.51	29.91	30.31	30.71	31.11	31.51	31.91
ROAD TRANSPORT – retail: petrol	p/litre	110.2	113.1	116.5	118.5	120.1	120.8	121.3	121.8	122.2	122.7	123.1	123.6	124.1
ROAD TRANSPORT – retail: DERV	p/litre	114.7	117.7	121.1	123.2	124.8	125.6	126.1	126.6	127.1	127.6	128.2	128.7	129.2
ROAD TRANSPORT – Variable element: petrol	p/litre	35.58	36.01	36.43	36.85	37.27	37.70	38.12	38.54	38.96	39.39	39.81	40.23	40.65
ROAD TRANSPORT – Variable element: DERV	p/litre	38.02	38.49	38.96	39.42	39.89	40.35	40.82	41.28	41.75	42.22	42.68	43.15	43.61
AVIATION – retail: Aviation fuel	p/litre	34.18	34.69	35.20	35.71	36.23	36.74	37.25	37.76	38.27	38.78	39.29	39.80	40.31
AVIATION – Variable element: Aviation fuel	p/litre	33.48	33.99	34.50	35.01	35.53	36.04	36.55	37.06	37.57	38.08	38.59	39.10	39.61

Note: Retail = taxes included; Variable element = without taxes

DECC (2010) projections of energy prices by year: High price scenario

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
ELECTRICITY – retail: domestic	p/kWh	12.73	13.17	13.90	13.89	14.59	15.08	15.45	16.00	16.34	16.55	16.94	17.46	17.98
ELECTRICITY – retail: commercial	p/kWh	11.16	11.48	12.02	12.46	12.98	13.45	13.86	14.40	14.78	15.08	15.51	16.26	16.79
ELECTRICITY – retail: industrial	p/kWh	10.24	10.53	11.03	11.44	11.91	12.34	12.72	13.21	13.56	13.84	14.23	14.92	15.41
ELECTRICITY – Variable element: domestic	p/kWh	8.45	8.72	9.17	9.46	9.75	9.99	10.19	10.56	10.58	10.72	10.97	11.39	11.48
ELECTRICITY – Variable element: commercial	p/kWh	7.81	8.06	8.47	8.75	9.01	9.23	9.42	9.75	9.77	9.89	10.13	10.52	10.60
ELECTRICITY – Variable element: industrial	p/kWh	7.30	7.53	7.92	8.18	8.42	8.63	8.80	9.12	9.14	9.25	9.47	9.84	9.92
GAS – retail: domestic	p/kWh	4.17	4.33	4.52	4.74	5.04	5.21	5.34	5.54	5.74	5.92	6.20	6.05	6.08
GAS – retail: commercial	p/kWh	3.35	3.46	3.59	3.72	3.87	4.02	4.19	4.38	4.59	4.83	5.10	5.12	5.13
GAS – retail: industrial	p/kWh	3.05	3.16	3.27	3.39	3.53	3.67	3.82	3.99	4.18	4.41	4.66	4.67	4.68
GAS – Variable element: domestic	p/kWh	2.56	2.66	2.76	2.86	2.97	3.07	3.17	3.27	3.37	3.47	3.57	3.57	3.58
GAS – Variable element: commercial	p/kWh	2.46	2.56	2.65	2.75	2.84	2.94	3.04	3.13	3.23	3.32	3.42	3.42	3.42
GAS – Variable element: industrial	p/kWh	2.46	2.56	2.65	2.75	2.84	2.94	3.04	3.13	3.23	3.32	3.42	3.42	3.42
COAL – retail: domestic	p/kWh	3.22	3.18	3.14	3.11	3.07	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03
COAL – retail: commercial	p/kWh	1.55	1.51	1.48	1.44	1.40	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37
COAL – retail: industrial	p/kWh	1.33	1.30	1.26	1.22	1.19	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
COAL – Variable element: domestic	p/kWh	2.83	2.79	2.75	2.72	2.68	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64
COAL – Variable element: commercial	p/kWh	1.31	1.27	1.24	1.20	1.16	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13
COAL – Variable element: industrial	p/kWh	1.21	1.17	1.14	1.10	1.06	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
BURNING OIL – retail: domestic	p/litre	43.58	44.76	46.33	47.90	49.08	50.65	51.83	53.40	54.97	56.15	57.72	57.72	57.72
GAS OIL – retail: commercial	p/litre	48.28	49.48	51.09	52.69	53.90	55.50	56.70	58.31	59.91	61.11	62.72	62.72	62.72
GAS OIL – retail: industrial	p/litre	45.56	46.77	48.37	49.97	51.18	52.78	53.99	55.59	57.19	58.40	60.00	60.00	60.00
BURNING OIL – Variable element: domestic	p/litre	38.51	39.63	41.12	42.62	43.74	45.24	46.36	47.86	49.35	50.47	51.97	51.97	51.97
GAS OIL – Variable element: commercial	p/litre	36.43	37.64	39.24	40.84	42.05	43.65	44.86	46.46	48.06	49.27	50.87	50.87	50.87
GAS OIL – Variable element: industrial	p/litre	32.72	33.92	35.52	37.13	38.33	39.93	41.14	42.74	44.35	45.55	47.15	47.15	47.15

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
ROAD TRANSPORT – retail: petrol	p/litre	116.8	121.0	125.6	128.9	131.8	133.8	135.5	137.2	139.0	140.7	142.4	142.4	142.4
ROAD TRANSPORT – retail: DERV	p/litre	122.2	126.7	131.5	135.1	138.1	140.4	142.3	144.3	146.3	148.2	150.2	150.2	150.1
ROAD TRANSPORT – Variable element: petrol	p/litre	41.18	42.69	44.19	45.70	47.20	48.71	50.21	51.72	53.22	54.73	56.23	56.24	56.25
ROAD TRANSPORT – Variable element: DERV	p/litre	44.37	46.07	47.76	49.46	51.15	52.84	54.54	56.23	57.92	59.62	61.31	61.31	61.31
AVIATION – retail: Aviation fuel	p/litre	44.52	39.29	41.34	42.87	44.91	46.96	48.49	50.54	52.07	54.11	56.16	57.69	59.74
AVIATION – Variable element: Aviation fuel	p/litre	43.82	38.59	40.63	42.17	44.21	46.25	47.79	49.83	51.36	53.41	55.45	56.99	59.03

Note: Retail = taxes included; Variable element = without taxes

DECC (2010) projections of energy prices by year: High price scenario

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
ELECTRICITY – retail: domestic	p/kWh	14.18	14.88	15.91	16.16	17.12	17.77	18.37	18.66	18.51	18.60	18.72	19.02	19.64
ELECTRICITY – retail: commercial	p/kWh	12.66	13.26	14.10	14.82	15.60	16.25	16.88	17.15	17.03	17.21	17.35	17.87	18.51
ELECTRICITY – retail: industrial	p/kWh	11.62	12.16	12.94	13.60	14.31	14.91	15.49	15.74	15.63	15.80	15.92	16.40	16.99
ELECTRICITY – Variable element: domestic	p/kWh	9.81	10.37	11.13	11.72	12.31	12.77	13.28	13.42	12.99	13.08	13.11	13.24	13.40
ELECTRICITY – Variable element: commercial	p/kWh	9.09	9.62	10.32	10.87	11.42	11.85	12.33	12.45	12.04	12.12	12.14	12.26	12.41
ELECTRICITY – Variable element: industrial	p/kWh	8.49	8.98	9.64	10.15	10.67	11.07	11.51	11.63	11.25	11.33	11.35	11.46	11.60
GAS – retail: domestic	p/kWh	4.69	4.97	5.27	5.60	6.01	6.29	6.54	6.64	6.73	6.82	6.99	6.83	6.87
GAS – retail: commercial	p/kWh	3.91	4.14	4.39	4.64	4.91	5.19	5.48	5.55	5.66	5.79	5.95	5.96	5.98
GAS – retail: industrial	p/kWh	3.56	3.78	4.00	4.24	4.48	4.73	5.00	5.07	5.16	5.28	5.43	5.44	5.45
GAS – Variable element: domestic	p/kWh	3.06	3.27	3.48	3.69	3.90	4.11	4.32	4.32	4.33	4.34	4.34	4.35	4.36

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
GAS – Variable element: commercial	p/kWh	2.96	3.17	3.37	3.57	3.78	3.98	4.19	4.19	4.19	4.19	4.19	4.19	4.20
GAS – Variable element: industrial	p/kWh	2.96	3.17	3.37	3.57	3.78	3.98	4.19	4.19	4.19	4.19	4.19	4.19	4.20
COAL – retail: domestic	p/kWh	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31
COAL – retail: commercial	p/kWh	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64
COAL – retail: industrial	p/kWh	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42
COAL – Variable element: domestic	p/kWh	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92
COAL – Variable element: commercial	p/kWh	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
COAL – Variable element: industrial	p/kWh	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
BURNING OIL – retail: domestic	p/litre	51.04	54.18	57.33	60.08	63.22	66.36	69.50	69.50	69.50	69.50	69.50	69.50	69.50
GAS OIL – retail: commercial	p/litre	55.90	59.11	62.32	65.13	68.33	71.54	74.75	74.75	74.75	74.75	74.75	74.75	74.75
GAS OIL – retail: industrial	p/litre	53.18	56.39	59.60	62.41	65.62	68.82	72.03	72.03	72.03	72.03	72.03	72.03	72.03
BURNING OIL – Variable element: domestic	p/litre	45.61	48.60	51.60	54.21	57.21	60.20	63.19	63.19	63.19	63.19	63.19	63.19	63.19
GAS OIL – Variable element: commercial	p/litre	44.05	47.26	50.47	53.28	56.49	59.70	62.90	62.90	62.90	62.90	62.90	62.90	62.90
GAS OIL – Variable element: industrial	p/litre	40.34	43.54	46.75	49.56	52.77	55.98	59.19	59.19	59.19	59.19	59.19	59.19	59.19
ROAD TRANSPORT – retail: petrol	p/litre	126.1	132.3	138.9	144.3	149.2	153.2	157.0	157.0	156.9	156.9	156.9	156.9	156.9
ROAD TRANSPORT – retail: DERV	p/litre	132.8	139.6	146.7	152.6	158.0	162.6	166.9	166.9	166.8	166.8	166.8	166.7	166.7
ROAD TRANSPORT – Variable element: petrol	p/litre	49.07	52.31	55.55	58.78	62.02	65.26	68.50	68.51	68.52	68.53	68.55	68.56	68.57
ROAD TRANSPORT – Variable element: DERV	p/litre	53.33	56.99	60.65	64.31	67.97	71.63	75.28	75.28	75.28	75.28	75.28	75.28	75.28
AVIATION – retail: Aviation fuel	p/litre	44.52	46.96	51.05	55.14	59.22	62.80	66.89	70.98	75.07	75.07	75.07	75.07	75.07
AVIATION – Variable element: Aviation fuel	p/litre	43.82	46.25	50.34	54.43	58.52	62.10	66.19	70.28	74.36	74.36	74.36	74.36	74.36

Note: Retail = taxes included; Variable element = without taxes

DECC (2011) projections of carbon emissions factors by year

Carbon emissions factor (kgCO2/kWh)

Year	Electricity	Gas	Oil	Solid fuel	Space heating	Water heating	Petrol	Diesel
Source	DECC	DECC	DECC	CCC	Derived	Derived	DECC	DECC
Units	kgCO2/kWh	kgCO2/kWh	kgCO2/kWh	kgCO2/kWh	kgCO2/kWh	kgCO2/kWh	kgCO2/litre	kgCO2/litre
2012	0.48	0.185	0.245	0.329	0.202	0.219	2.238	2.525
2013	0.46	0.185	0.245	0.329	0.202	0.219	2.226	2.511
2014	0.46	0.185	0.245	0.329	0.202	0.220	2.223	2.508
2015	0.46	0.185	0.245	0.329	0.202	0.220	2.199	2.481
2016	0.43	0.185	0.245	0.329	0.202	0.220	2.176	2.454
2017	0.41	0.185	0.245	0.329	0.202	0.221	2.152	2.428
2018	0.41	0.185	0.245	0.329	0.202	0.221	2.128	2.401
2019	0.39	0.185	0.245	0.329	0.203	0.222	2.104	2.374
2020	0.37	0.185	0.245	0.329	0.203	0.222	2.081	2.347
2021	0.33	0.185	0.245	0.329	0.203	0.223	2.081	2.347
2022	0.31	0.185	0.245	0.329	0.203	0.223	2.081	2.347

Sources: DECC = Dept. of Energy and Climate Change, CCC = Committee on Climate Change

Appendix B:
Baseline Data Analysis

Baseline Scenario for Leeds City Region

In order to support the analysis of the different climate change mitigation measures for the Leeds City Region, baseline scenarios from 1990-2022 were constructed. These baseline scenarios provide an indication of the emissions level, energy use and financial cost to consumers associated with a continuation of historical trends in energy use at the local level and existing policies at the national level. The baselines are based on the published emissions and energy use data for each energy-using sector in the Local Authorities (LAs) from 2005-2008. These published 2005-2008 energy use and emissions figures are not altered in the baseline scenario. Each backcast from 2005 to 1990, and each projection from 2008-2022 was then calculated individually for each sector in each local authority. This approach was limited by the data available at local authority level and in the absence of any LA specific data a secondary method was applied – projecting the local authority data using regional or national datasets.

Backcasts to 1990

Backcasts to 1990 were made for each local authority using local (when available) or national emissions and energy use data. Where data were unavailable at the local level, national datasets were used. As a result, many of the local authorities follow the same historical trend as the nationally published data for a particular sector.

Projections to 2022

The projections to 2022 were made by analysing the relationship between the energy use and explanatory variables for different sectors, such as number of consumers and any historical data on the energy use per consumer. This varied by sector, energy type and data available. Specific local data projections were used if available, such as household number projections by local authority published by the Department for Communities and Local Government (DCLG), or road traffic forecasts from the Department for Transport (DfT). The emissions and costs associated with this energy use were calculated accordingly based on the emissions and costs associated the fuel type, conversion factors published by the Department of Environment and Rural Affairs (Defra) and forecast prices provided by the Department for Energy and Climate Change (DECC).

Projected Scenarios

Three projected scenarios for 2008-2022 were calculated for the local authorities within the Leeds City Region. They are all based on the method described in the section above, but vary as follows:

1. Future trends assuming no change to the electricity grid or demand reduction due to price increases.
2. Future trends incorporating projected shifts in demand due to price rises (assuming medium term price elasticities for different fuel types)
3. Future trends incorporating projected improvements to the electricity grid and changes to demand due to price effects.

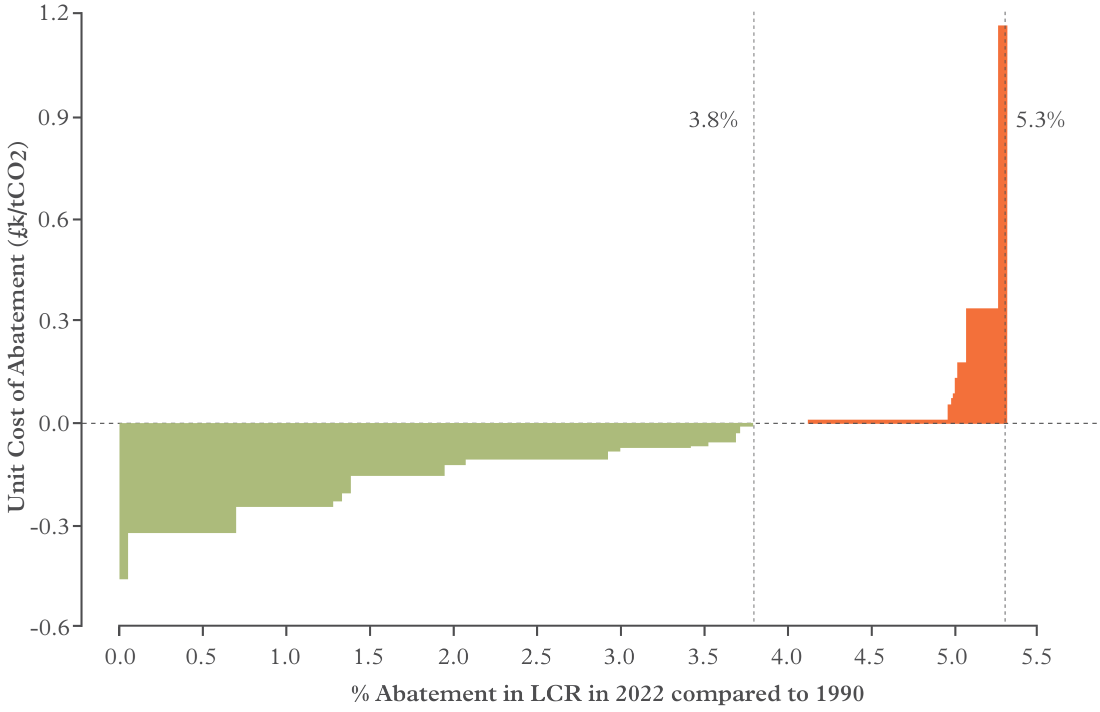
These three scenarios demonstrate the independent contribution of each of the three variables of the baseline – the underlying background trends in energy use and emissions; the improvements to the national grid and the price effects.

Appendix C: Employment and Wider Economic Effects

1. To evaluate job and wealth creating potential, we use the lists of measures included in the wider analysis for domestic and commercial buildings, transport and renewable heat and on the broader categories of measures selected for industry.
2. Calculations on costs, benefits and up-take are based on the central business case scenario – 8% interest rates, and DECC 'high' energy price forecasts.
3. For each measure, total capital expenditure data over the 10 year period to 2022 is generated in the wider analysis for the domestic, commercial and industrial sectors and for the renewable heat technologies. We translate this into an average annual expenditure over the period. Clearly, the actual spend profile will vary from year-to-year but there is no data on which to base a realistic analysis by year.
4. In the transport sector, the economic benefits are based on assessing the impacts of modal change from cars to public transport and cycling using vehicle kilometres figures used in the wider analysis and on data in an Arup report for LCR (Arup, 2009). This has been translated into jobs using ratios derived from a report by Ekosgen on employment in sustainable transport (Ekosgen, 2010).
5. The number of direct annual jobs for the domestic, commercial and industrial sectors has been calculated using average job/turnover ratios - based on ABI and ABS data from the Office of National Statistics - for various measures e.g. installation, wholesale/retail, manufacturing and consultancy/technical services depending on the sector and measure.
6. The annual GVA has been calculated using average GVA/employee data for the relevant job categories based on ABI and ABS data from the Office of National Statistics.
7. Assumptions are made about the proportions of the jobs and GVA that will be retained within the Leeds City Region (LCR) taking account of the strengths of the local supplier base and competition from outside LCR. For most of the installation work, this is assumed to be 80% since there is a strong base of installers for energy efficiency and renewable energy measures – however, some leakage of the work to companies outside LCR is likely. The proportion has been reduced to 70% for PV generation and 60% for biomass district heating based on competition from outside LCR. In the industrial sector, a range of proportions have been used depending on local manufacturing strengths.
8. Finally, composite multipliers have been used to calculate indirect jobs based on supply chain and income (or induced) effects. The multipliers are based on the third edition of the Additionality Guide: a standard approach to assessing the additional impact of interventions produced by English Partnerships. Three levels of regional composite multipliers are suggested:
   - Low – limited local supply linkages and induced or income effects: 1.3;
   - Medium – average linkages – the majority of interventions will be in this category: 1.5;
   - High - strong local supply linkages and induced or income effects: 1.7.

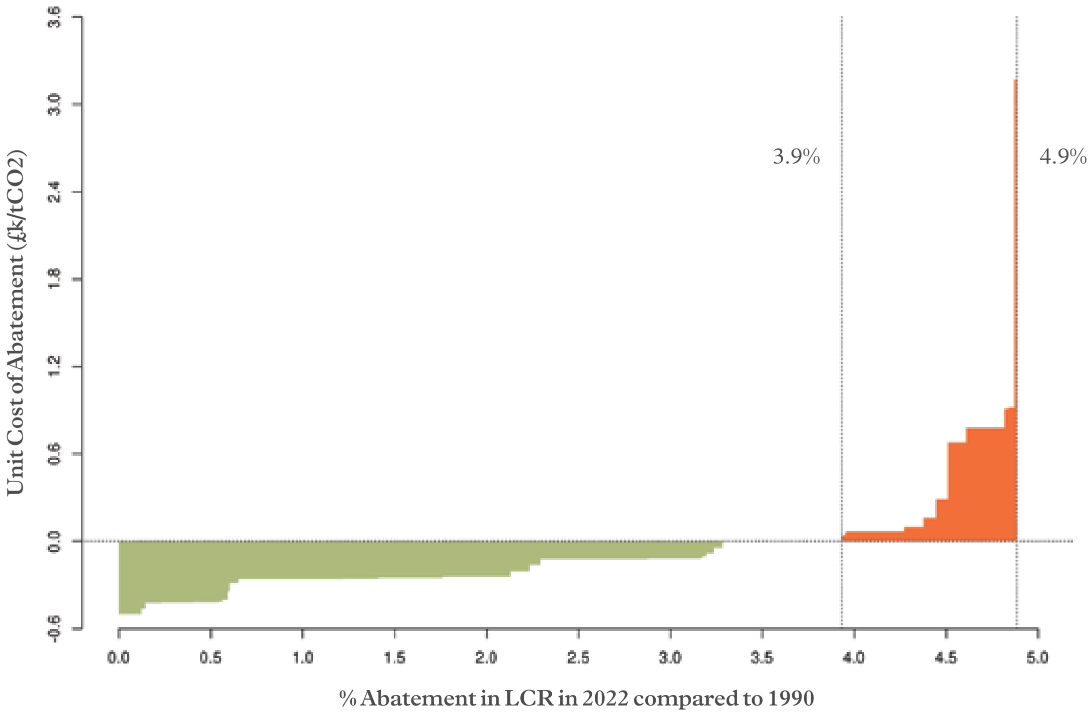
Appendix D:

Domestic Sector : Marginal Abatement Cost (MAC) Curve



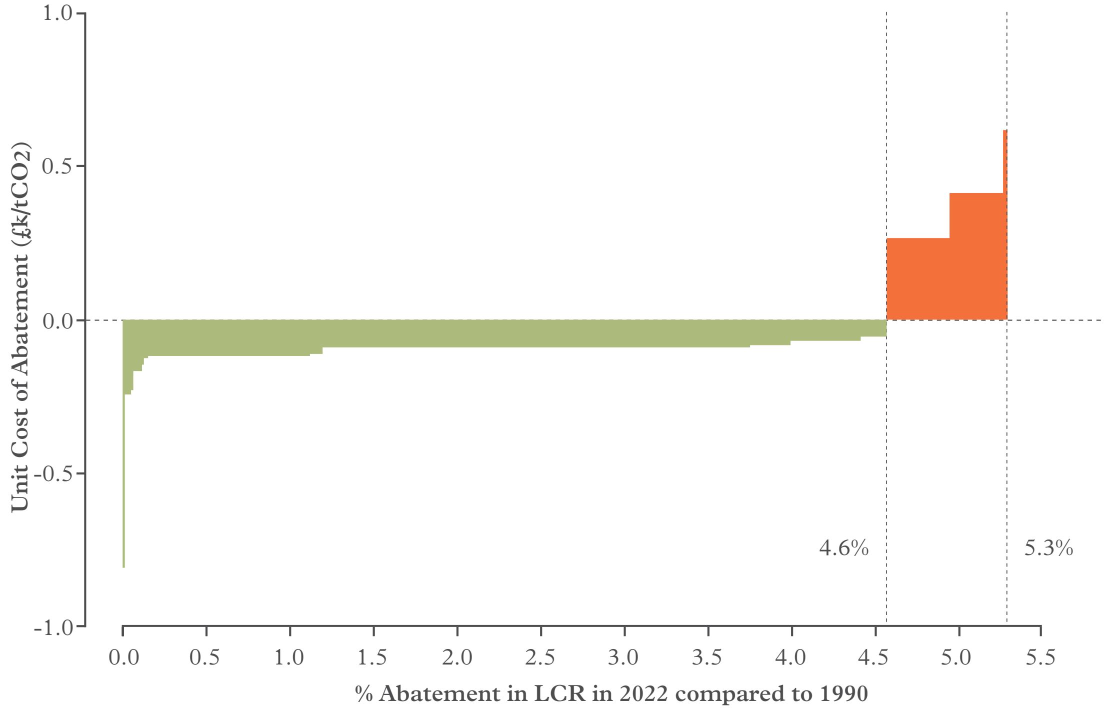
Appendix E:

Commercial Sector: Marginal Abatement Cost (MAC) Curve



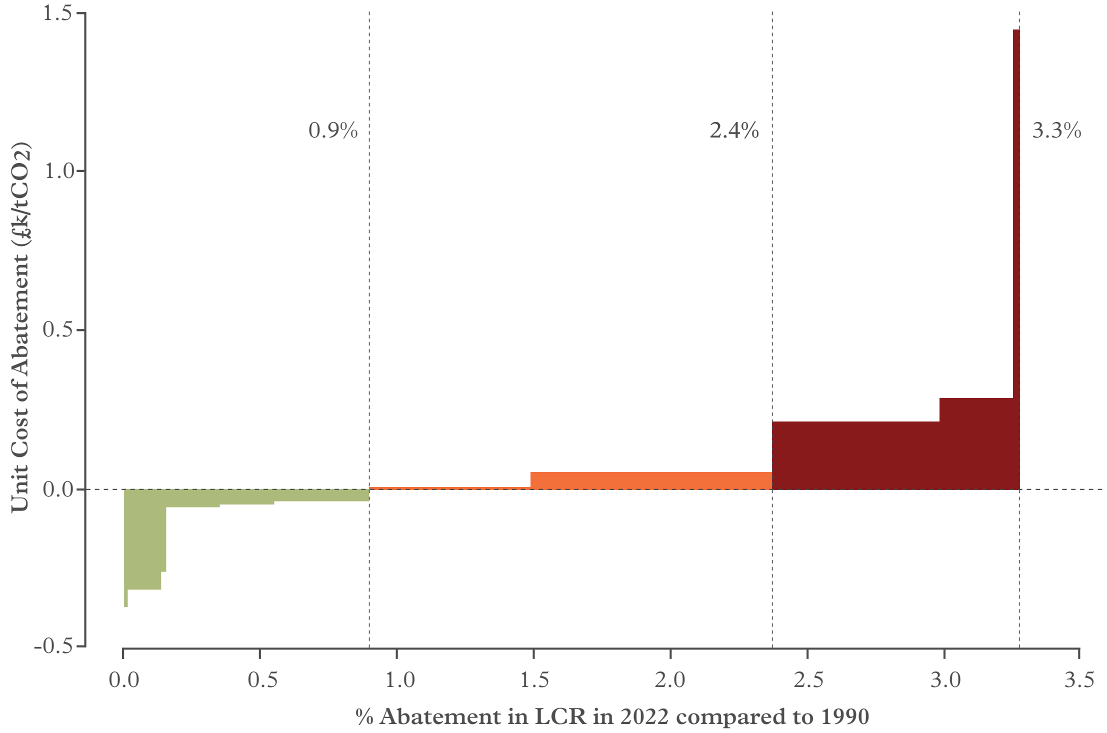
Appendix F:

Industrial Sector : Marginal Abatement Cost (MAC) Curve



Appendix G:

Transport Sector: Marginal Abatement Cost (MAC) Curve



Appendix H: Overall List of the Most Cost Effective Measures

Cost effective
Cost neutral
Realistic technical potential

Central business case			£/TCO2
1	Industry	Burners	-805.96
2	Commercial	Office equipment fax machine switch off	-500.11
3	Commercial	Photocopiers – energy management	-500.11
4	Commercial	Monitors – energy management	-500.11
5	Commercial	Computers – energy management	-500.11
6	Commercial	Printers – energy management	-500.11
7	Commercial	Vending machines energy management	-500.11
8	Commercial	Office equipment – most energy efficient monitor PC only	-462.94
9	Domestic	Mini wind turbines (5kW) with FiT	-457.39
10	Commercial	Office equipment – most energy efficient monitor	-436.54
11	Commercial	Lights – turn off lights for an extra hour	-422.63
12	Commercial	Lights – sunrise-sunset timers	-422.35
13	Commercial	Lights – basic timer	-422.16
14	Commercial	Heating – more efficient air conditioning	-420.26
15	Commercial	Lights – light detectors	-414.59
16	Commercial	Stairwell timer	-401.69
17	Transport	Park and ride	-370.03
18	Transport	Express bus/coach network	-370.03
19	Commercial	Compressed air	-343.71
20	Domestic	Biomass boilers with RHI	-324.77
21	Transport	Bus priority and quality enhancements	-316.54
22	Transport	Smarter choices	-315.17
23	Commercial	Presence detector	-283.64
24	Transport	Cycling	-261.97
25	Commercial	Heating – programmable thermostats high	-257.85
26	Commercial	Heating – optimising start times	-255.15
27	Commercial	Heating – reducing room temperature	-251.48
28	Domestic	Electronic products	-244.68
29	Domestic	Information and communication technology products	-244.28
30	Industry	Refrigeration and air-conditioning	-243.94
31	Commercial	Biomass boilers	-243.03

32	Industry	Compressed air	-229.77
33	Domestic	Integrated digital TVs	-228.08
34	Domestic	Reduced standby consumption	-228.04
35	Commercial	Most energy efficient fridge-freezer	-221.49
36	Domestic	Reduce heating for washing machines	-208.79
37	Commercial	Heating – thermostatic radio valves fully installed	-205.74
38	Industry	Lighting	-195.92
39	Domestic	A++ rated cold appliances	-180.33
40	Domestic	A rated ovens	-175.41
41	Industry	Fabrication and machining	-166.62
42	Commercial	Most energy efficient flat roof insulation	-161.18
43	Domestic	Biomass district heating with RHI	-155.23
44	Domestic	Efficient lighting	-152.82
45	Industry	Design	-147.74
46	Domestic	A-rated condensing boiler	-145.33
47	Domestic	Insulate primary pipework	-132.31
48	Industry	Building energy management	-129.87
49	Domestic	Glazing – old double to new double	-122.87
50	Domestic	Uninsulated cylinder to high performance	-121.96
51	Commercial	Heating – most energy efficient boiler	-120.99
52	Industry	Operation and maintenance	-120.46
53	Domestic	Glazing – single to new	-120.39
54	Industry	Heat recovery	-120.23
55	Industry	Drying and separation	-119.03
56	Industry	Low temperature heating	-118.92
57	Industry	New food and drink plant	-118.90
58	Domestic	Insulated doors	-117.88
59	Commercial	Biomass district heating	-115.64
60	Industry	Space heating	-111.22
61	Domestic	Reduce household heating by 1^0C	-110.55
62	Domestic	Induction hobs	-109.79
63	Commercial	Lights – metal halide floods	-108.45

Cost effective
Cost neutral
Realistic technical potential

64	Commercial	Lights – IRC tungsten-halogen – spots	-103.65
65	Industry	High temperature heating	-93.80
66	Industry	Renewable heat	-91.03
67	Industry	Controls	-86.10
68	Commercial	Most energy efficient pitched roof insulation	-80.47
69	Domestic	Loft insulation 0 - 270mm	-79.42
70	Domestic	Pre '76 cavity wall insulation	-73.25
71	Industry	Process improvement	-71.72
72	Domestic	Improve airtightness	-71.34
73	Domestic	Diy floor insulation (susp. Timber floors)	-70.10
74	Domestic	Loft insulation 25 - 270mm	-68.85
75	Domestic	Loft insulation 50 - 270mm	-58.66
76	Domestic	76-83 Cavity wall insulation	-56.15
77	Domestic	A+ rated wet appliances	-54.24
78	Transport	Demand management	-53.45
79	Domestic	Loft insulation 75 - 270mm	-52.29
80	Industry	Energy management	-51.50
81	Transport	Mild hybrid	-49.44
82	Transport	Plug-in hybrid	-43.73
83	Commercial	Mostenergy efficientcavity wall insulation	-41.78
84	Domestic	Post '83 cavity wall insulation	-30.19
85	Domestic	Turn unnecessary lighting off	-28.26
86	Domestic	Installed floor insulation (susp. timber frames)	-25.38
87	Domestic	Loft insulation 100 - 270mm	-8.18
88	Domestic	Glazing (to best practice)	-3.54
89	Commercial	Air source heat pump	-1.99
90	Domestic	Ground source heat pump with RHI	2.44
91	Transport	Full hybrid	4.91
92	Domestic	Solid wall insulation	8.62
93	Domestic	Loft insulation 125 - 270mm	11.42
94	Commercial	Most energy efficient freezer	39.44
95	Transport	Biofuels	53.11

96	Domestic	Loft insulation 150 - 270mm	58.91
97	Domestic	Room thermostat to control heating	59.10
98	Commercial	Most energy efficient fridge	61.40
99	Commercial	Ground source heat pump	68.11
100	Domestic	Paper type solid wall insulation	75.82
101	Domestic	Modestly insulated cylinder to high performance	89.77
102	Commercial	Lights– most energy efficient replacement 26mm	98.16
103	Domestic	Thermostatic radiator valves	135.25
104	Commercial	Motor – 4 Pole motor – EFF1 replace 4 Pole	156.60
105	Commercial	Lights – HF ballast	160.00
106	Domestic	Photovoltaic generation with FiT	180.21
107	Transport	Micro hybrid	214.47
108	Industry	Ventilation	267.37
109	Industry	Others	271.90
110	Commercial	Most energy efficient external wall insulation	288.06
111	Transport	Electric	290.71
112	Industry	Information technology	339.14
113	Domestic	Air source heat pump with RHI	340.39
114	Industry	Motors and drives	411.12
115	Industry	Insulation	618.82
116	Domestic	Micro wind turbines (1kW) with FiT	639.41
117	Domestic	Hot water cylinder 'stat	670.95
118	Commercial	Solar thermal	679.15
119	Commercial	Most energy efficient double glazing	779.40
120	Commercial	Lights – most energy efficient replacement tungsten	911.53
121	Commercial	Variable speed drives	917.51
122	Domestic	Solar water heating with RHI	1173.14
123	Transport	New railway stations	1429.09
124	Transport	Rail electrification	1448.29
125	Commercial	Most energy efficient double glazing (replace double)	3170.37

Appendix I: Overall List of the Most Carbon Effective Measures

Cost effective
Cost neutral
Realistic technical potential

Central business case			KTCO2
1	Industry	Renewable heat	516.84
2	Transport	Biofuels	210.45
3	Domestic	Reduce household heating by 1^{0}C	201.15
4	Domestic	Solid wall insulation	198.03
5	Commercial	Air source heat pump	154.79
6	Domestic	Biomass boilers with RHI	153.76
7	Transport	Micro hybrid	144.73
8	Transport	Full hybrid	140.91
9	Commercial	Heating – most energy efficient boiler	139.46
10	Commercial	Heating – programmable thermostats high	135.57
11	Domestic	Pre '76 cavity wall insulation	101.64
12	Industry	Process improvement	101.55
13	Industry	Drying and separation	101.18
14	Industry	High temperature heating	93.24
15	Commercial	Biomass boilers	88.08
16	Domestic	Electronic products	84.59
17	Commercial	Heating – reducing room temperature	82.47
18	Transport	Plug-in hybrid	82.41
19	Domestic	Biomass district heating with RHI	79.66
20	Industry	Others	79.44
21	Domestic	Ground source heat pump with RHI	77.05
22	Commercial	Ground source heat pump	75.24
23	Industry	Motors and drives	74.73
24	Commercial	Biomass district heating	69.11
25	Transport	Electric	64.67
26	Industry	Controls	57.39
27	Domestic	Information and communication technology products	55.49
28	Domestic	Efficient lighting	51.90
29	Commercial	Most energy efficient double glazing	49.64
30	Transport	Mild hybrid	48.09

31	Transport	Demand management	47.36
32	Commercial	Heating – optimising start times	46.46
33	Domestic	Air source heat pump with RHI	45.87
34	Industry	Heat recovery	45.26
35	Industry	Low temperature heating	42.33
36	Industry	Operation and maintenance	40.23
37	Commercial	Lights – basic timer	37.65
38	Industry	Energy management	35.54
39	Commercial	Heating – more efficient air conditioning	33.51
40	Commercial	Heating – thermostatic radio valves fully installed	24.88
41	Commercial	Lights – most energy efficient replacement 26mm	24.37
42	Commercial	Solar thermal	23.63
43	Commercial	Lights – turn off lights for an extra hour	20.48
44	Domestic	Loft insulation 0 - 270mm	18.38
45	Industry	Space heating	17.72
46	Commercial	Monitors – energy management	17.49
47	Domestic	A+ rated wet appliances	16.98
48	Commercial	Lights – HF ballast	16.25
49	Transport	Smarter choices	16.22
50	Commercial	Most energy efficient external wall insulation	15.37
51	Domestic	Diy floor insulation (susp. timber floors)	14.71
52	Commercial	Most energy efficient flat roof insulation	13.86
53	Transport	Bus priority and quality enhancements	12.87
54	Domestic	Mini wind turbines (5kW) with FiT	12.69
55	Domestic	Glazing – single to new	12.37
56	Domestic	Reduce heating for washing machines	12.32
57	Domestic	Photovoltaic generation with FiT	12.20
58	Industry	Fabrication and machining	11.26
59	Industry	Ventilation	11.22
60	Domestic	Uninsulated cylinder to high performance	11.14
61	Domestic	Loft insulation 100 - 270mm	11.10
62	Commercial	Presence detector	10.96

Cost effective
Cost neutral
Realistic technical potential

63	Commercial	Most energy efficient cavity wall insulation	10.81
64	Domestic	Solar water heating with RHI	10.68
65	Domestic	Reduced standby consumption	10.40
66	Commercial	Most energy efficient pitched roof insulation	10.09
67	Domestic	Improve airtightness	9.77
68	Domestic	Glazing (to best practice)	9.31
69	Domestic	Loft insulation 75 - 270mm	9.01
70	Industry	Refrigeration and air-comditioning	8.91
71	Domestic	Glazing – old double to new double	8.21
72	Commercial	Computers – energy management	7.46
73	Commercial	Variable speed drives	6.98
74	Commercial	Stairwell timer	6.96
75	Domestic	76-83 cavity wall insulation	6.70
76	Domestic	Modestly insulated cylinder to high performance	6.45
77	Industry	Building energy management	6.28
78	Commercial	Lights– most energy efficient replacement tungsten	5.77
79	Commercial	Office equipment – most energy efficient monitor pc only	5.31
80	Transport	Rail electrification	4.99
81	Industry	Insulation	4.96
82	Domestic	Loft insulation 50 - 270mm	4.89
83	Commercial	Lights – IRC tungsten-halogen – spots	4.76
84	Commercial	Most energy efficient freezer	4.56
85	Industry	Compressed air	4.55
86	Commercial	Lights – sunrise-sunset timers	4.00
87	Domestic	Room thermostat to control heating	3.98
88	Commercial	Lights – light detectors	3.97
89	Domestic	Post '83 cavity wall insulation	3.71
90	Transport	Cycling	3.35
91	Domestic	Turn unnecessary lighting off	3.17
92	Industry	Design	3.06
93	Commercial	Most energy efficient double glazing (replace double)	3.03
94	Commercial	Compressed air	2.79

Cost effective
Cost neutral
Realistic technical potential

95	Transport	Express bus/coach network	2.10
96	Domestic	Thermostatic radiator valves	2.09
97	Commercial	Printers – energy management	1.95
98	Commercial	Lights – metal halide floods	1.92
99	Industry	New food and drink plant	1.90
100	Domestic	Insulate primary pipework	1.64
101	Industry	Lighting	1.52
102	Commercial	Most energy efficient fridge	1.49
103	Transport	Park and ride	1.45
104	Industry	Burners	1.27
105	Domestic	Paper type solid wall insulation	1.24
106	Domestic	Integrated digital TVs	1.12
107	Commercial	Photocopiers – energy management	1.08
108	Domestic	Micro wind turbines (1kW) with FiT	1.07
109	Domestic	A++ rated cold appliances	1.03
110	Domestic	Loft insulation 25 - 270mm	0.97
111	Transport	New railway stations	0.87
112	Commercial	Office equipment fax machine switch off	0.57
113	Commercial	Vending machines energy management	0.41
114	Industry	Information technology	0.40
115	Commercial	Motor – 4 Pole motor – EFF1 replace 4 Pole	0.35
116	Domestic	Hot water cylinder 'stat	0.31
117	Commercial	Most energy efficient fridge-freezer	0.14
118	Commercial	Office equipment – most energy efficient monitor	0.07
119	Domestic	A rated ovens	0.00
120	Domestic	A rated condensing boiler	0.00
121	Domestic	Insulated doors	0.00
122	Domestic	Induction hobs	0.00
123	Domestic	Installed floor insulation (susp. timber frames)	0.00
124	Domestic	Loft insulation 125 - 270mm	0.00
125	Domestic	Loft insulation 150 - 270mm	0.00

About us

The Centre for Low Carbon Futures is a collaborative membership organisation that focuses on sustainability for competitive advantage. Founded by the Universities of Hull, Leeds, Sheffield and York, the Centre brings together multidisciplinary and evidence-based research to both inform policy making and to demonstrate low carbon innovations.

Our research themes are Smart Infrastructure, Energy Systems and the Circular Economy. Our activities are focused on the needs of business in both the demonstration of innovation and the associated skills development.

Registered in the UK at Companies House 29th September 2009 Company No: 7033134.

CLCF is grateful for funding and support from Accenture, the Beijing Institute of Technology, the Energy Intensive Users Group, the Foreign and Commonwealth Office, the Regional Development Agency, the Trades Union Congress, the UK Department of Energy and Climate Change, the University of Hull, the University of Leeds, the University of Sheffield and the University of York.

The Centre for Low Carbon Futures partnership

University of Hull · The University of York · The University of Sheffield · University of Leeds

Correspondence

For further information on this study, or to discuss wider applications, please contact:

Prof Andy Gouldson
School of Earth and Environment,
University of Leeds, Leeds,
LS2 9JT, UK.
email: a.gouldson@see.leeds.ac.uk
Tel: +44 (0)113 343 6417

Jon Price, Director
Centre for Low Carbon Futures
email: jon.price@lowcarbonfutures.org
www.lowcarbonfutures.org

Centre for Low Carbon Futures 2050