The Economics of Low Carbon Cities

A Mini-Stern Review for Birmingham and the Wider Urban Area

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Contents

Tables, Figures and Appendices

The Economics of a Low Carbon Birmingham and Wider Urban Area

Today

10% of city-scale GVA leaves the local economy every year through payment of the energy bill.

10% of GVA leaks out of the economy

Tomorrow

Investing 1% of GVA p.a.

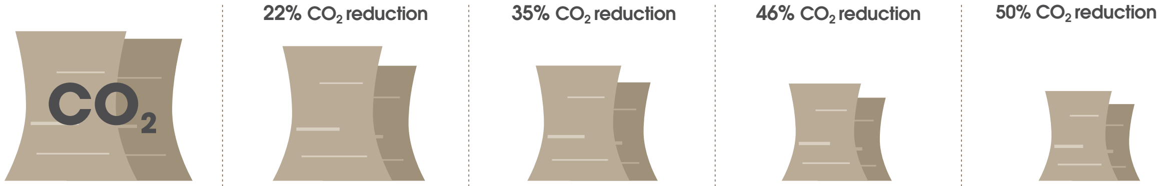
1% of GVA could be profitably invested, every year for ten years, to exploit commercially attractive energy efficiency and low carbon opportunities.

Leads to...

- **Energy**
  reductions in the energy bill equalling 2.3% of GVA
- **Financial viability**
  just under 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 GVA
- **Wider social benefits**
  reductions in fuel poverty, improvements in health

Potential to reduce CO_2 emissions

1990 | 2022 →



1990	22% CO_2 reduction	35% CO_2 reduction	46% CO_2 reduction	50% 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 Birmingham and the Wider Urban Area

Executive Summary

What is the most effective and efficient way to decarbonise Birmingham and the wider urban area as represented by the Greater Birmingham and Solihull and the Black Country Local Enterprise Partnerships? 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.

Birmingham and the wider urban area has a population of 3 million, an economy worth £50 billion a year and an energy bill of £5.1 billion a year.

The Context

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 Birmingham and the Wider Urban Area (BWUA), an area with a population of 3 million, an economy worth £50 billion a year and an energy bill of £5.1 billion a year. Whilst highlighting the very significant and commercially viable opportunities for the decarbonisation of Birmingham and the Wider Urban Area – 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 – BWUA could reduce its carbon emissions by 2022 by:

- 10.8% through cost effective investments that would pay for themselves (on commercial terms) over their lifetime. This would require an investment of £3.6 billion, generating annual savings of £954 million, paying back the investment in 3.8 years but generating annual savings for the lifetime of the measures.
- 14.9% through cost neutral investments that could be paid for at no net cost to the BWUA economy if the benefits from cost effective measures were captured and re-invested in further low carbon measures. This would require an investment of £6.1 billion, generating annual savings of £1.1 billion, paying back the investment in 5.3 years but generating annual savings for the lifetime of the measures.
- 16.1% with the exploitation of all of the realistic potential of the different measures. This would require an investment of £8.1 billion, generating annual savings of £1.3 billion, paying back the investment in 6.2 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 2012 energy bill for the BWUA is £5.15 billion per year, but we forecast that this will grow to £5.64 billion by 2022 – a £490 million increase in the BWUA annual energy bill.

- With investment in all of the cost effective measures, this £490 million increase in the annual energy bill could be cut by £954 million, (194% of the projected increase) saving £464 million.
- With investment in all of the cost neutral measures, it could be cut by £1.15 billion (235% of the projected increase) saving £660 million.
- With investment to exploit all of the realistic potential, it could be cut by £1.3 billion (265% of the projected increase) saving £810 million.

Birmingham and the Wider Urban Area could therefore insulate itself against projected energy price increases to a very large extent through investments in energy efficiency and low carbon options.

The 2012 BWUA energy bill is £5.15 billion per year, but we forecast that this will grow to £5.64 billion by 2022.

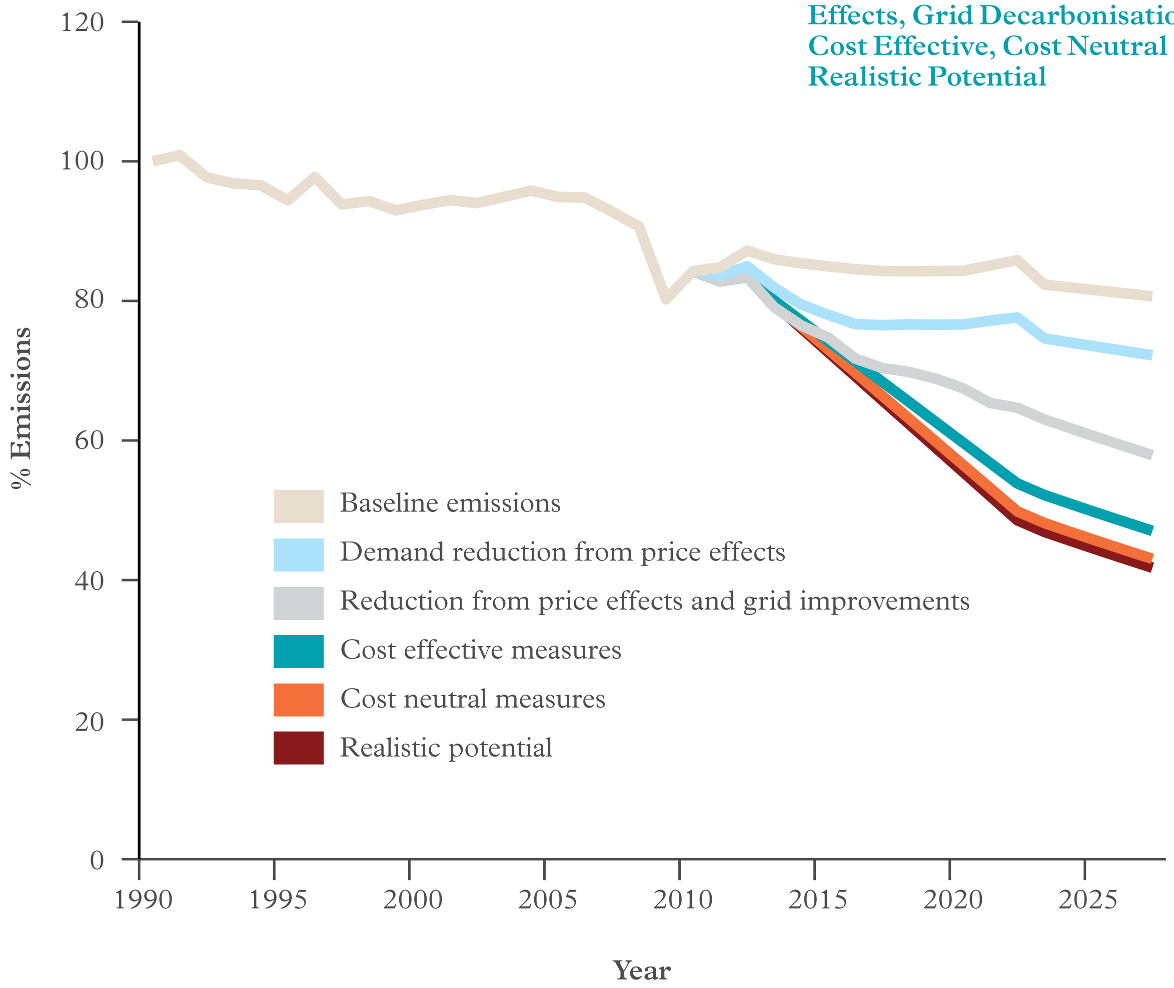
The Wider Context – Other Influences on BWUA Carbon Emissions

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 14% decrease in BWUA carbon emissions between 1990 and 2022.
- Higher energy price increases will impact on demand, and this will lead to a 8% drop in BWUA 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 22% drop in BWUA emissions between 1990 and 2022.
- The decarbonisation of the national electricity system will lead to a 13% drop in BWUA 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 35% drop in BWUA 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 46% drop in BWUA 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 50% drop in BWUA 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 51% drop in BWUA 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 1 below.

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



Long Term Impacts in the Period to 2027

If the currently available options were exploited in the period before 2022, they would continue to impact on energy bills and carbon footprints through to 2027 and beyond. Between 2022 and 2027, we predict a continuation of current trends, where the impacts of growth are to some extent offset by the impacts of continuing increases in energy prices, further decreases in the carbon intensity of electricity supply and on-going improvements in energy efficiency. When combined with these trends, we predict that the full exploitation of all of the cost effective options included in this study would lead to carbon emissions from the Birmingham and Wider Urban Area to fall by 53% in the period between 1990 and 2027. We also predict that exploitation of all of the cost neutral options would lead to a 57% drop and of all of the realistic potential to a 58% in carbon emissions in 2027 based on 1990 levels. However, it is important to stress that these are the levels of decarbonisation that could be achieved through the wider deployment of the technologies and other options that exist now. New technologies, structural changes in the economy and deeper changes in behaviour would also lead to deeper levels of decarbonisation.

Executive Summary

Table 1: Cost, Benefits and Carbon Reduction by LEP and Local Authority from exploiting the cost-effective options

Local Authority	Energy bill 2012	Level of investment that could be secured*	Potential cut in energy bill*	Jobs created*	Carbon saved by 2022 (1990 baseline)*	Carbon saved by 2027 (1990 baseline)*
Birmingham	£1.62 billion	£1.09 billion	£294 million	505	-44.00%	-51.05%
Bromsgrove	£296 million	£139 million	£34 million	40	-31.24%	-36.83%
Cannock Chase	£136 million	£116 million	£32 million	46	-49.32%	-56.89%
East Staffordshire	£243 million	£151 million	£41 million	70	-47.32%	-54.61%
Lichfield	£238 million	£123 million	£34 million	50	-38.94%	-45.77%
Redditch	£122 million	£129 million	£32 million	46	-53.72%	-61.10%
Solihull	£464 million	£319 million	£73 million	99	-38.87%	-46.05%
Tamworth	£100 million	£94 million	£27 million	65	-52.48%	-59.78%
Wyre Forest	£165 million	£154 million	£38 million	88	-47.58%	-53.38%
Birmingham & Solihull LEP	**£3.38 billion**	**£2.34 billion**	**£604 million**	**1,009**	**-43.63%**	-50.59%
Dudley	£463 million	£319 million	£89 million	153	-48.06%	-54.77%
Sandwell	£527 million	£420 million	£111 million	223	-51.86%	-58.38%
Walsall	£413 million	£281 million	£77 million	136	-50.41%	-56.21%
Wolverhampton	£362 million	£251 million	£73 million	133	-52.20%	-59.26%
Black Country LEP	**£1.76 billion**	**£1.27 billion**	**£350 million**	**645**	**-50.64%**	-57.15%

*from exploiting cost effective options and taking into account other impacts

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 BWUA:

- 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 1,651 jobs and to growth in GVA of £100 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 3,085 jobs and to GVA growth of £128 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 4,736 jobs over the next ten years and to GVA growth of £251 million per year.

Low Carbon Investment: Supply and Demand

The analysis highlights that within BWUA 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 BWUA 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 50% 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 Birmingham and the Wider Urban Area? 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 Birmingham and the Wider Urban Area (BWUA) On this basis, we identify least cost pathways towards different levels of decarbonisation within BWUA, 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 BWUA – 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 BWUA 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 BWUA 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 (see page 9).

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.

However, we should stress that the data sets on which this analysis is based were developed to guide broad strategic decision making and as such they can only be seen to offer broad strategic insights. Further and more detailed analysis of the performance of all options is necessary to reduce levels of uncertainty before any specific decisions are taken based on this data.

Table 2: 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 BWUA
Operational costs of each measure	Rate of deployment in BWUA
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 3: 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^{0}C; 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 to 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. 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. 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 BWUA

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 BWUA, 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 data on public transport and demand management options drawn from the BWUA.

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. 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 BWUA, 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, 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 4: 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 BWUA economy.

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 BWUA, 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. 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.

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.

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 BWUA would have on employment and the wider BWUA 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 BWUA are made taking into account the strength of the supplier base and the level of competition from outside the BWUA in particular sectors, based on a recently completed study of the low carbon goods and services sector within the BWUA (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 BWUA 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.

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, BWUA could reduce its carbon emissions by 2022 by:

— 10.8% through cost effective investments that would pay for themselves (on commercial terms) over their lifetime. This would require an investment of £3.6 billion, generating annual savings of £954 million, paying back the investment in 3.8 years but generating annual savings for the lifetime of the measures.

— 14.9% through cost neutral investments that could be paid for at no net cost to BWUA economy if the benefits from cost effective measures were captured and re-invested in further low carbon measures. This would require an investment of £6.1 billion, generating annual savings of £1.1 million, paying back the investment in 5.3 years but generating annual savings for the lifetime of the measures.

— 16.1% with the exploitation of all of the realistic potential of the different measures. This would require an investment of £8.1 billion, generating annual savings of £1.3 billion, paying back the

Impacts on future energy bills

These figures are particularly significant in the context of projected energy price increases. We calculate that the 2012 BWUA energy bill is £5.15 billion per year, but we forecast that this will grow to £5.64 billion by 2022 – a £490 million increase in the BWUA annual energy bill.

— With investment in all of the cost effective measures, this £490 billion increase in the annual energy bill could be cut by £954 million, (194% of the projected increase) saving £464 million.

— With investment in all of the cost neutral measures, it could be cut by £1.15 billion (235% of the projected increase) saving £660 million.

— With investment to exploit all of the realistic potential, it could be cut by £1.3 billion (265% of the projected increase) saving £810 million.

BWUA 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

BWUA sector	Capital cost in 2012	Annual cost saving in 2022	Annual carbon saving in 2022	Payback	BWUA carbon cut in 2022 (above trend, 1990 base)
	£bn	£bn	$KTCO_2$	yrs	%
Cost effective measures					
Domestic	£0.45	£0.39	626.52	1.14	2.86%
Transport	£1.89	£0.23	326.74	8.27	1.49%
Commercial	£0.68	£0.21	809.99	3.27	3.69%
Industry	£0.56	£0.12	614.33	4.54	2.80%
Total	**£3.58**	**£0.95**	**2377**	**3.75**	**10.84%**
Cost neutral measures					
Domestic	£1.50	£0.51	1266.77	6.41	5.32%
Transport	£1.89	£0.23	606.32	8.50	2.54%
Commercial	£1.41	£0.29	1,024.27	4.83	4.67%
Industry	£1.17	£0.12	925.90	9.88	4.22%
Total	**£6.10**	**£1.15**	**3,258.45**	**5.31**	**14.86%**
Realistic technical potential					
Domestic	£1.50	£0.51	847.12	2.96	3.86%
Transport	£4.05	£0.38	738.36	10.38	3.35%
Commercial	£1.41	£0.29	1,024.27	4.83	4.67%
Industry	£1.17	£0.12	925.90	9.88	4.22%
Total	**£8.13**	**£1.30**	**3,535.66**	**6.19**	**16.10%**

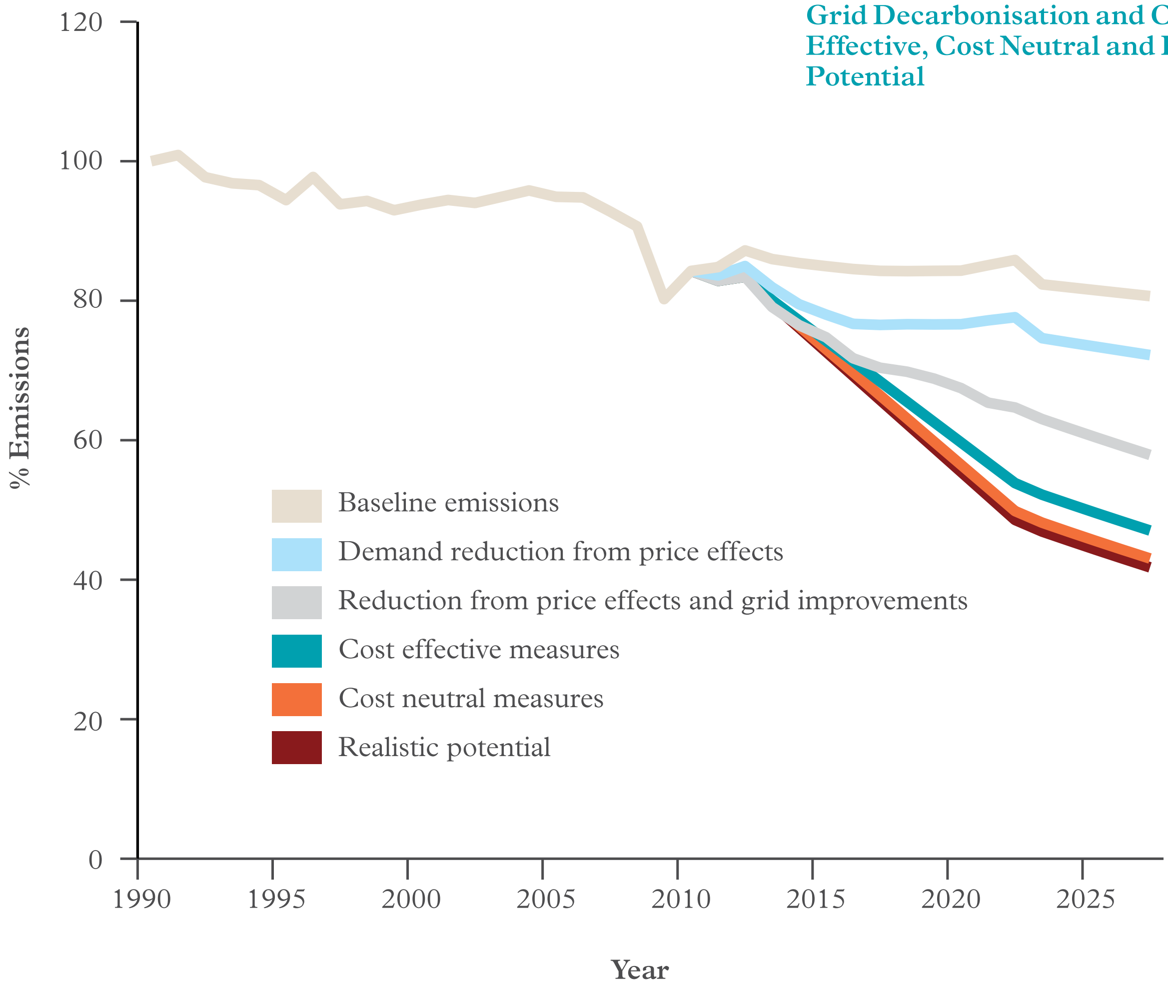
The wider context – other influences on BWUA carbon emissions

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 14% decrease in BWUA carbon emissions between 1990 and 2022.
- Higher energy price increases will impact on demand, and this will lead to a 8% drop in BWUA 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 22% drop in BWUA emissions between 1990 and 2022.
- The decarbonisation of the national electricity system will lead to a 13% drop in BWUA 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 35% drop in BWUA emissions between 1990 and 2022.

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



Long Term Impacts in the Period to 2027

If the currently available options were exploited in the period before 2022, they would continue to impact on energy bills and carbon footprints through to 2027 and beyond. Between 2022 and 2027, we predict a continuation of current trends, where the impacts of growth are to some extent offset by the impacts of continuing increases in energy prices, further decreases in the carbon intensity of electricity supply and on-going improvements in energy efficiency. When combined with these trends, we predict that the full exploitation of all of the cost effective options included in this study would lead to carbon emissions from the Birmingham and Wider Urban Area to fall by 53% in the period between 1990 and 2027. We also predict that exploitation of all of the cost neutral options would lead to a 57% drop and of all of the realistic potential to a 58% in carbon emissions in 2027 based on 1990 levels. However, it is important to stress that these are the levels of decarbonisation that could be achieved through the wider deployment of the technologies and other options that exist now. New technologies, structural changes in the economy and deeper changes in behaviour would also lead to deeper levels of decarbonisation.

— The total effect of all of the above plus the exploitation of all of the cost effective low carbon options will be a 46% drop in BWUA 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 50% drop in BWUA 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 51% drop in BWUA carbon emissions between 1990 and 2022.

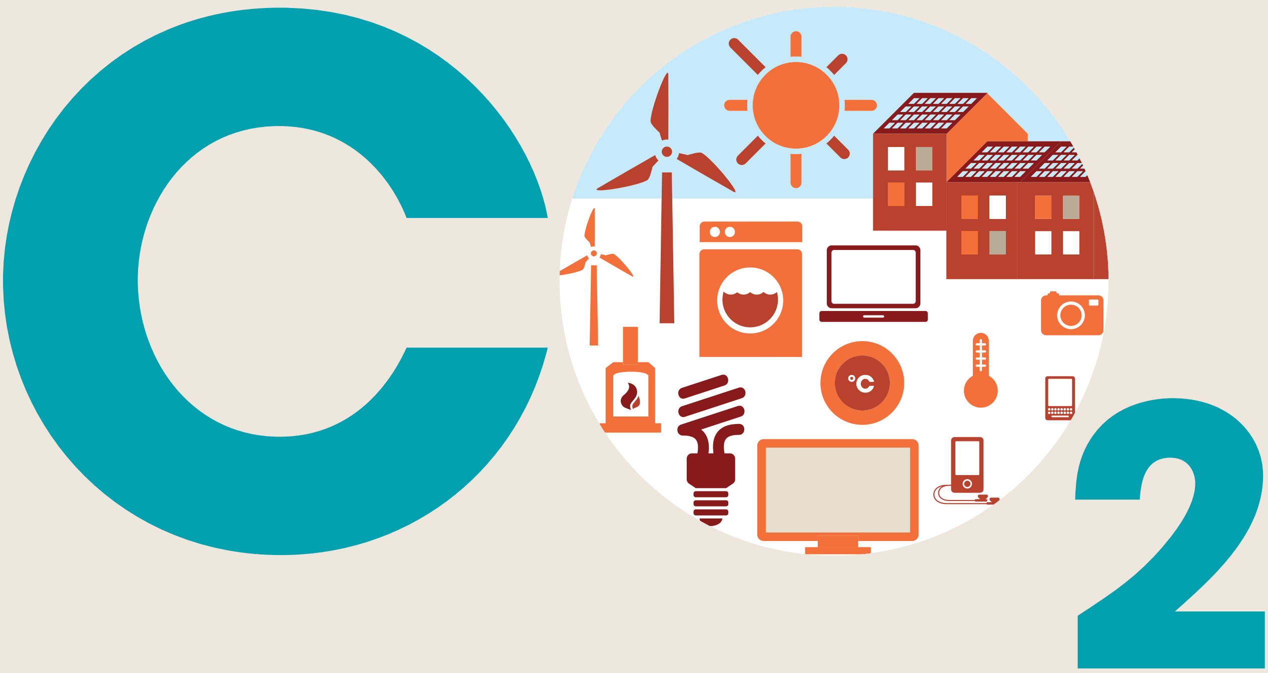
Wider impacts on employment and economic growth

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 4,737 additional jobs/annum and additional GVA of £251 million/ annum in BWUA over the 10 year period (or £2.51 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.

Sector Focus

The Domestic Sector



Main Findings
The Domestic Sector

Cost effective opportunities

- There are £450 million worth of cost-effective, energy efficient and low carbon investment opportunities available in the domestic sector in BWUA.
- Exploiting these would generate annual savings of £395 million a year.
- At commercial rates, these investments would pay for themselves in under two years, whilst generating annual savings for the lifetime of the measures.
- If exploited, these investments would reduce BWUA carbon emissions by 2.9% by 2022, compared to 1990.

Cost neutral opportunities

- There are £1.5 billion of cost-neutral, energy efficient and low carbon investment opportunities available in the domestic sector in BWUA.
- Exploiting these would generate annual savings of £508 million a year.
- At commercial rates, these investments would pay for themselves in three years, whilst generating annual savings for the lifetime of the measures.
- These investments would reduce BWUA carbon emissions by 3.9% by 2022, compared to 1990.

Table 6: League Table of the Most Cost Effective Measures for the Domestic Sector

	Central business case	$£/TCO_2$
1	Mini wind turbines (5kW) with FiT	-499.01
2	Reduce heating for washing machines	-317.98
3	Electronic products	-293.33
4	Information and Communication Technology products	-292.92
5	Integrated digital TVs	-276.03
6	Reduced standby consumption	-275.94
7	Reduce household heating by 1°C	-238.58
8	A++ rated cold appliances	-219.81
9	A-rated ovens	-214.85
10	Efficient lighting	-194.87
11	Turn unnecessary lighting off	-171.16
12	A-rated condensing boiler	-158.05
13	Insulate primary pipework	-149.60
14	Induction hobs	-146.43
15	Uninsulated cylinder to high performance	-136.95
16	Glazing – old double to new double	-132.05
17	Glazing – single to new	-129.56
18	Insulated doors	-127.03
19	A+ rated wet appliances	-93.82
20	Loft insulation 0–270mm	-86.38
21	Improve airtightness	-80.46
22	Pre76 cavity wall insulation	-80.20

FiT = Feed-in Tariff. 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 BWUA. 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 and Table 8.

23	DIY floor insulation (susp. timber floors)	-77.04
24	Loft insulation 25–270mm	-75.80
25	Ground Source Heat Pumps with RHI	-67.48
26	Loft insulation 50–270mm	-65.61
27	76-83 cavity wall insulation	-63.11
28	Loft insulation 75–270mm	-59.25
29	Post ‘83 cavity wall insulation	-37.14
30	Biomass boilers with RHI	-34.85
31	Installed floor insulation (susp. timber frames)	-32.31
32	Air Source Heat Pump with RHI	-31.17
33	Loft insulation 100–270mm	-15.12
34	Glazing (to Best Practice)	-12.64

35	Solid wall insulation	1.69
36	Loft insulation 125–270mm	4.49
37	Room thermostat to control heating	48.02
38	Loft insulation 150–270mm	51.98
39	Paper type solid wall insulation	68.91
40	Modestly insulated cyl to high performance	74.19
41	Thermostatic radiator valves	124.17
42	Photovoltaic generation with FIT	161.84
43	Solar water heating with RHI	314.13
44	Micro wind turbines (1kW) with FIT	630.07
45	Hot water cylinder ‘stat	653.68

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

	Central business case	KTCO$_2$
1	Reduce household heating by 1°C	179.12
2	Solid wall insulation	169.63
3	Pre76 cavity wall insulation	61.19
4	Electronic products	55.79
5	Ground Source Heat Pumps with RHI	54.90
6	Air Source Heat Pump with RHI	49.19
7	Information and Communication Technology products	36.59
8	Efficient lighting	35.13
9	Solar water heating with RHI	28.65
10	Glazing – single to new	15.33
11	DIY floor insulation (susp. timber floors)	13.09
12	A+ rated wet appliances	11.22
13	Loft insulation 100–270mm	11.19
14	Loft insulation 0–270mm	10.49
15	Loft insulation 75–270mm	9.86
16	Uninsulated cylinder to high performance	9.81
17	Mini wind turbines (5kW) with FIT	9.43
18	Photovoltaic generation with FIT	9.06
19	Improve airtightness	8.80
20	Glazing (to Best Practice)	8.29
21	Reduce heating for washing machines	7.64
22	Glazing – old double to new double	7.35

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

The analysis shows that bigger domestic wind turbines (with FiT) are the most cost effective measure, but the aggregated carbon saving potential from this measure is relatively small across the BWUA. Renewable heat measures are estimated to have a large potential for carbon saving, with both ground source and air source heat pumps considered to be cost-effective over their lifetime.

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 BWUA 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 savings in the domestic sector relate to reducing household heating levels by 1 degree and insulating solid walls. Investments in solid wall insulation are not cost effective but as part of a package of measures could be considered cost neutral over their lifetime.

Cost effective

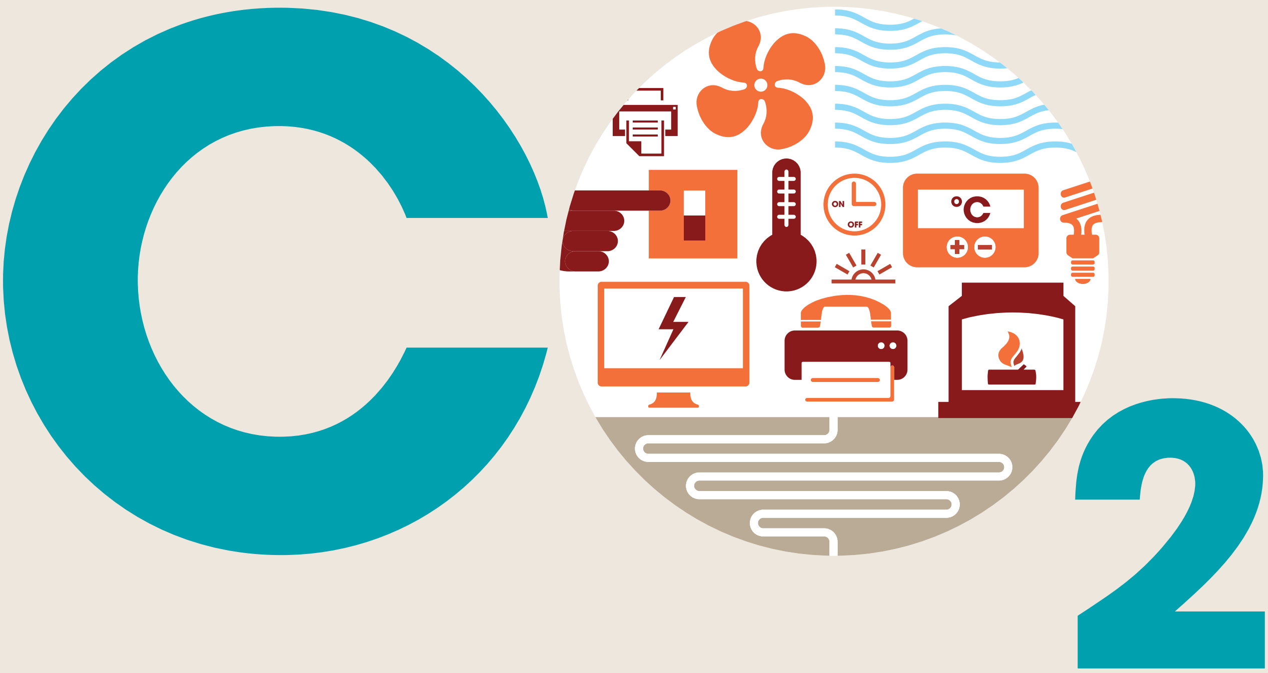
Cost neutral

23	Biomass boilers with RHI	7.13
24	Reduced standby consumption	6.86
25	Loft insulation 50–270mm	5.85
26	Modestly insulated cyl to high performance	5.67
27	76-83 cavity wall insulation	3.85
28	Room thermostat to control heating	3.54
29	Post '83 cavity wall insulation	2.11
30	Turn unnecessary lighting off	1.97
31	Thermostatic radiator valves	1.86
32	Loft insulation 25–270mm	1.48
33	Insulate primary pipework	1.46
34	Paper type solid wall insulation	1.11
35	Micro wind turbines (1kW) with FIT	0.79
36	Integrated digital TVs	0.74
37	A++ rated cold appliances	0.68
38	Hot water cylinder 'stat	0.27
39	A-rated ovens	0.00
40	A-rated condensing boiler	0.00
41	Induction hobs	0.00
42	Insulated doors	0.00
43	Installed floor insulation (susp. Timber Frames)	0.00
44	Loft insulation 125–270mm	0.00
45	Loft insulation 150–270mm	0.00

In total, 2,202 jobs are estimated to be created by the investment in cost-effective and cost-neutral measures in the domestic sector, the indirect effects of which add £104 million in GVA to the economy each year.

Sector Focus

The Commercial Sector



The Commercial Sector

Cost effective opportunities

- There are £675 million of cost-effective, energy efficient and low carbon investment opportunities available in the commercial sector within the BWUA area.
- Exploiting these would generate annual savings of £206 million a year.
- These investments would pay for themselves in 3.3 years, whilst generating annual savings for the lifetime of the measures.
- If exploited, these investments would reduce BWUA carbon emissions by 3.7% by 2022, compared to 1990.

Cost neutral opportunities

- There are £1.4 billion of cost-effective, energy efficient and low carbon investment opportunities available in the commercial sector within the BWUA area.
- Exploiting these would generate annual savings of £292 million a year.
- Collectively, these investments would pay for themselves in 4.83 years, whilst generating annual savings for the lifetime of the measures.
- Collectively, these investments would reduce BWUA area carbon emissions by 4.7% by 2022, compared to 1990.

Table 8: League Table of the Most Cost Effective Measures for the Commercial Sector

	Central business case	£/TCO_2
1	Vending Machines Energy management	-233.67
2	Photocopiers – Energy Management	-233.67
3	Computers – Energy Management	-233.67
4	Monitors – Energy Management	-233.67
5	Printers – Energy Management	-233.67
6	Office Equipment – Most energy efficient monitor pc only	-209.41
7	Lights – Turn off Lights for an extra hour	-194.08
8	Lights – Sunrise-Sunset Timers	-193.90
9	Lights – Basic Timer	-193.78
10	Heating – More efficient air conditioning	-193.73
11	Office Equipment – Most energy efficient Monitor	-192.18
12	Lights – Light Detectors	-188.92
13	Stairwell Timer	-180.65
14	Heating – Programmable Thermostats High	-159.50
15	Heating – Optimising Start Times	-158.88
16	Heating – Reducing Room Temperature	-158.32
17	Most energy efficient fridge	-156.83
18	Heating – Thermostatic Radiator Valves Fully Installed	-140.77
19	Compressed air	-136.45
20	Most energy efficient freezer	-108.99

FiT = Feed-in Tariff. 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.

21	Presence Detector	-104.92
22	Most energy efficient fridge-freezer	-67.84
23	Heating – most energy efficient boiler	-60.22
24	Most energy efficient flat roof insulation	-59.58
25	Air Source Heat Pump with RHI	-22.62
26	Biomass boilers with RHI	-19.33
27	Most energy efficient cavity wall insulation	-10.54
28	Most energy efficient pitched roof insulation	-10.27
29	Most energy efficient external wall insulation	10.48
30	Lights – Metal Halide Floods	19.92
31	Lights – IRC Tungsten-Halogen – Spots	23.05
32	Ground Source Heat Pump with RHI	56.95
33	Lights- Most energy efficient Replacement 26mm	154.45
34	Solar water heating with RHI	173.30
35	Motor – 4 Pole Motor – EFF1 replace 4 Pole	192.51
36	Lights – High frequency ballast	194.73
37	Lights- Most energy efficient Replacement Tungsten	521.57
38	Variable Speed Drives	687.98
39	Most energy efficient double glazing	691.05
40	Most energy efficient double glazing (replace double)	2918.71

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

Central business case		$KTCO_2$
1	Heating – most energy efficient boiler	139.21
2	Heating –Programmable Thermostats High	131.44
3	Biomass boilers with RHI	114.04
4	Air Source Heat Pump with RHI	94.65
5	Ground Source Heat Pump with RHI	93.83
6	Heating – Reducing Room Temperature	80.38
7	Most energy efficient double glazing	47.21
8	Heating – Optimising Start Times	45.14
9	Lights – Basic Timer	32.14
10	Heating – More efficient air conditioning	28.55
11	Heating – Thermostatic Radiator Valves Fully Installed	24.93
12	Lights- Most energy efficient Replacement 26mm	20.80
13	Lights – Turn off Lights for an extra hour	17.48
14	Monitors – Energy Management	15.00
15	Most energy efficient external wall insulation	14.71
16	Most energy efficient flat roof insulation	14.51
17	Lights – High frequency ballast	13.87
18	Solar water heating with RHI	12.60

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

The analysis shows that the most cost effective measures for the commercial sector all involve replacing office equipment with more energy efficient alternatives. However, at the BWUA 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 more efficient boilers, thermostats and renewable heat measures such as biomass boilers, and air source heat pumps (all taking into account the effect of RHIs).Thereafter, the biggest carbon savings from cost effective measures come from reducing room temperatures, optimising start times for heating, and lighting systems and adopting more energy efficient air conditioning.

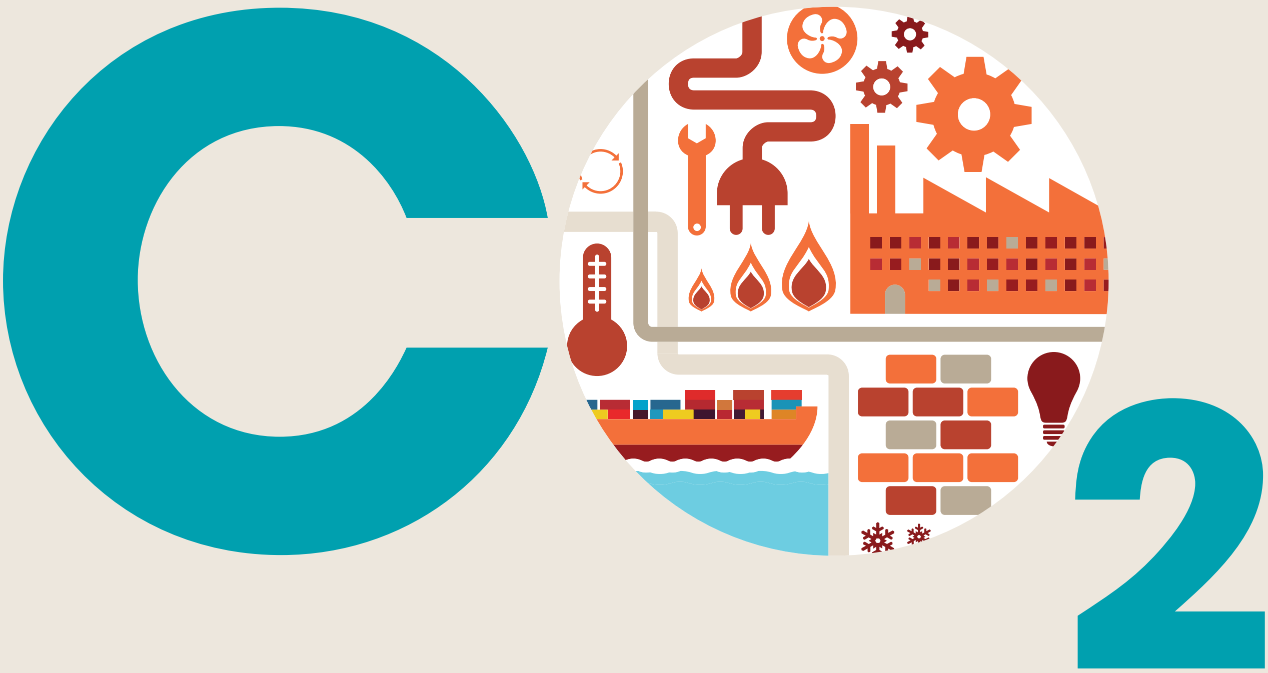
In total, 1,704 jobs are estimated to be created by the investment in cost-effective and cost-neutral measures in the commercial sector, the indirect effects of which add £75 million GVA to the economy each year.

Cost effective
Cost neutral

19	Most energy efficient cavity wall insulation	10.55	Cost effective
20	Most energy efficient pitched roof insulation	9.63	Cost effective
21	Presence Detector	9.36	Cost effective
22	Computers – Energy Management	6.40	Cost effective
23	Variable Speed Drives	5.96	Cost neutral
24	Stairwell Timer	5.94	Cost effective
25	Lights- Most energy efficient Replacement Tungsten	4.93	Cost neutral
26	Office Equipment – Most energy efficient monitor PC only	4.56	Cost effective
27	Lights – IRC Tungsten-Halogen – Spots	4.06	Cost neutral
28	Most energy efficient freezer	3.89	Cost effective
29	Lights – Sunrise-Sunset Timers	3.41	Cost effective
30	Lights – Light Detectors	3.39	Cost effective
31	Most energy efficient double glazing (replace double)	2.98	Cost neutral
32	Compressed air	2.38	Cost effective
33	Printers – Energy Management	1.67	Cost effective
34	Lights – Metal Halide Floods	1.64	Cost neutral
35	Most energy efficient fridge	1.27	Cost effective
36	Photocopiers – Energy Management	0.93	Cost effective
37	Vending Machines Energy management	0.35	Cost effective
38	Motor – 4 Pole Motor – EFF1 replace 4 Pole	0.30	Cost neutral
39	Most energy efficient fridge-freezer	0.12	Cost effective
40	Office Equipment – Most energy efficient monitor	0.06	Cost effective

Sector Focus

The Industrial Sector



Cost effective opportunities

- There are £564 million of cost effective, energy efficient and low carbon investment opportunities available in industry in the BWUA area.
- Exploiting these would generate annual savings of £124 million a year.
- At commercial rates, these investments would pay for themselves in 4.5 years, whilst generating annual savings for the lifetime of the measures.
- If exploited, these investments would reduce BWUA area carbon emissions by 2.8% by 2022, compared to 1990.

Cost neutral opportunities

- There are £1.17 billion of cost neutral, energy efficient and low carbon investment opportunities available in industry in the BWUA area.
- Exploiting these would generate annual savings of £118 million a year.
- Collectively, these investments would pay for themselves in 9.9 years, whilst generating annual savings for the lifetime of the measures.
- Collectively, these investments would reduce BWUA area carbon emissions by 4.2% 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 10: League Table of the Most Cost Effective Measures for the Industrial Sector*

	Central business case	£/TCO_2
1	Burners	-715.26
2	Refrigeration & Aircon	-239.22
3	Lighting	-196.90
4	Compressed air	-188.82
5	Design	-149.03
6	Fabrication & Machining	-146.73
7	Low Temperature Heating	-125.79
8	Building Energy Management	-120.38
9	New Food & Drink Plant	-118.90
10	Operation & Maintenance	-118.23
11	Drying & Separation	-118.03
12	Space Heating	-107.10
13	High Temperature Heating	-91.09
14	Controls	-78.69
15	Heat Recovery	-73.49
16	Process Improvement	-49.82
17	Energy Management	-43.88
18	Renewable Heat	-24.73
19	Others	254.59
20	Ventilation	366.31
21	Motors & Drives	391.63
22	Insulation	546.64
23	Information Technology	625.53

Cost effective
Cost neutral
Realistic technical potential

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

	Central business case	$KTCO_2$
1	Renewable Heat	205.99
2	Others	92.98
3	High Temperature Heating	87.21
4	Process Improvement	85.39
5	Drying & Separation	78.32
6	Motors & Drives	66.08
7	Controls	58.06
8	Heat Recovery	50.75
9	Operation & Maintenance	44.46
10	Energy Management	38.39
11	Low Temperature Heating	36.26
12	Space Heating	21.36
13	Fabrication & Machining	13.13
14	Ventilation	10.29
15	Refrigeration & Aircon	9.97
16	Building Energy Management	8.59
17	Insulation	4.74
18	Compressed air	4.65
19	Design	4.04
20	New Food & Drink Plant	1.81
21	Lighting	1.65
22	Burners	1.05
23	Information Technology	0.72

* *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 BWUA 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.

920 jobs are estimated to be created by the investment in cost-effective and cost neutral measures in the commercial sector, the indirect effects of which add a further £66 million GVA to the economy each year.

Sector Focus

The Transport Sector

Main Findings
The Transport Sector

Cost effective opportunities

- There are £1.9 billion of cost effective, energy efficient and low carbon investment opportunities available in the transport sector in the BWUA.
- Exploiting these would generate annual savings of £228 million a year.
- These investments would pay for themselves in 8.3 years, whilst generating annual savings for the lifetime of the measures.
- These investments would reduce BWUA carbon emissions by 1.5% by 2022, compared to 1990.

Cost neutral opportunities

- There are £2.0 billion of cost neutral, energy efficient and low carbon investment opportunities available in the transport sector in the BWUA.
- Exploiting these would generate annual savings of £230 million a year.
- Collectively, these investments would pay for themselves in 8.8 years, whilst generating annual savings for the lifetime of the measures.
- Collectively, these investments would reduce BWUA carbon emissions by 2.1% 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 Birmingham and the Wider Urban Area. 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 certain types of hybrid vehicle type can be cost-effective as well as also offering large carbon savings. All of the public transport and demand management options analysed in the BWUA context were not cost effective when assessed only on carbon terms – they could of course be cost effective in other terms, i.e. at reducing congestion. They were also estimated to have the potential to save much less carbon than improving the carbon performance of the private vehicle stock. Overall the introduction of bioethanol and biodiesel to the transport fuel supply was considered to offer the largest carbon saving for the BWUA, and this option is also predicted to be close to being cost-effective.

Cost effective	(teal)
Cost neutral	(orange)
Realistic technical potential	(dark red)

Table 12: League Table of the Most Cost Effective Measures for the Transport Sector

Central business case		£/TCO_2
1	Plug-in Hybrid	-90.79
2	Mild Hybrid	-64.12
3	Full Hybrid	-18.55
4	Biofuels	53.11
5	New railway Stations	101.34
6	Cycling	107.41
7	Express Bus/Coach Network	179.43
8	Micro Hybrid	272.84
9	Electric	347.48
10	Park and Ride (Rail)	434.64
11	Rail Electrification	569.38
12	Park and Ride (Bus)	978.80
13	Smarter Choices	1029.99
14	Bus Priority and Quality Enhancements	9620.89
15	Park and Ride (Bus + Dedicated service)	13257.83

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

Central business case		$KTCO_2$
1	Biofuels	189.57
2	Full Hybrid	155.64
3	Micro Hybrid	146.77
4	Plug-in Hybrid	105.65
5	Electric	74.70
6	Mild Hybrid	65.45
7	Smarter Choices	7.75
8	Cycling	3.67
9	Park and Ride (Rail)	0.74
10	Rail Electrification	0.69
11	New railway Stations	0.59
12	Bus Priority and Quality Enhancements	0.23
13	Park and Ride (Bus)	0.17
14	Express Bus/Coach Network	0.16
15	Park and Ride (Bus + Dedicated service)	0.03

Low Carbon Investment: Supply and Demand

The analysis has highlighted that within Birmingham and the Wider Urban Area 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 the GDP of BWUA 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. 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 BWUA area could reduce its carbon footprint by 50% at no net cost, by exploiting all of the cost effective and cost neutral measures outlined in this report 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 BWUA 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.

References

AEA (2010) Local and Regional CO_2 Emissions Estimates for 2005-2008, Statistical Release prepared for DECC.

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

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.

Appendices

Appendix A: Baseline Data Analysis

Baseline Scenario for Birmingham and the Wider Urban Area

In order to support the analysis of the different climate change mitigation measures for BWUA, 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 BWUA. 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 B: Overall List of the Most Cost Effective Measures

Cost effective
Cost neutral
Realistic technical potential

Central business case — £/TCO_2

1	Industry	Burners	-715.258
2	Domestic	Mini wind turbines (5kW) with FIT	-499.01
3	Domestic	Reduce heating for washing machines	-317.98
4	Domestic	Electronic products	-293.33
5	Domestic	Information and Communication Technology products	-292.92
6	Domestic	Integrated digital TVs	-276.03
7	Domestic	Reduced standby consumption	-275.94
8	Industry	Refrigeration & Aircon	-239.223
9	Domestic	Reduce household heating by 1°C	-238.58
10	Commercial	Vending Machines Energy management	-233.67
11	Commercial	Photocopiers – Energy Management	-233.67
12	Commercial	Computers – Energy Management	-233.67
13	Commercial	Monitors – Energy Management	-233.67
14	Commercial	Printers – Energy Management	-233.67
15	Domestic	A++ rated cold appliances	-219.81
16	Domestic	A-rated ovens	-214.85
17	Commercial	Office Equipment – Most energy efficient monitor pc only	-209.41
18	Industry	Lighting	-196.905
19	Domestic	Efficient lighting	-194.87
20	Commercial	Lights – Turn off Lights for an extra hour	-194.08
21	Commercial	Lights – Sunrise-Sunset Timers	-193.90
22	Commercial	Lights – Basic Timer	-193.78
23	Commercial	Heating – More efficient air conditioning	-193.73
24	Commercial	Office Equipment – Most energy efficient Monitor	-192.18
25	Commercial	Lights – Light Detectors	-188.92
26	Industry	Compressed air	-188.821
27	Commercial	Stairwell Timer	-180.65
28	Domestic	Turn unnecessary lighting off	-171.16
29	Commercial	Heating – Programmable Thermostats High	-159.50
30	Commercial	Heating – Optimising Start Times	-158.88
31	Commercial	Heating – Reducing Room Temperature	-158.32

32	Domestic	A-rated condensing boiler	-158.05
33	Commercial	Most energy efficient fridge	-156.83
34	Domestic	Insulate primary pipework	-149.60
35	Industry	Design	-149.028
36	Industry	Fabrication & Machining	-146.729
37	Domestic	Induction hobs	-146.43
38	Commercial	Heating – Thermostatic Radiator Valves Fully Installed	-140.77
39	Domestic	Uninsulated cylinder to high performance	-136.95
40	Commercial	Compressed air	-136.45
41	Domestic	Glazing – old double to new double	-132.05
42	Domestic	Glazing – single to new	-129.56
43	Domestic	Insulated doors	-127.03
44	Industry	Low Temperature Heating	-125.786
45	Industry	Building Energy Management	-120.382
46	Industry	New Food & Drink Plant	-118.903
47	Industry	Operation & Maintenance	-118.227
48	Industry	Drying & Separation	-118.03
49	Commercial	Most energy efficient freezer	-108.99
50	Industry	Space Heating	-107.098
51	Commercial	Presence Detector	-104.92
52	Domestic	A+ rated wet appliances	-93.82
53	Industry	High Temperature Heating	-91.0915
54	Transport	Plug-in Hybrid	-90.7942
55	Domestic	Loft insulation 0–270mm	-86.38
56	Domestic	Improve airtightness	-80.46
57	Domestic	Pre76 cavity wall insulation	-80.20
58	Industry	Controls	-78.6944
59	Domestic	DIY floor insulation (susp. timber floors)	-77.04
60	Domestic	Loft insulation 25–270mm	-75.80
61	Industry	Heat Recovery	-73.4879
62	Commercial	Most energy efficient fridge-freezer	-67.84
63	Domestic	Ground Source Heat Pumps with RHI	-67.48

Cost effective
Cost neutral
Realistic technical potential

64	Domestic	Loft insulation 50–270mm	-65.61
65	Transport	Mild Hybrid	-64.1169
66	Domestic	76-83 cavity wall insulation	-63.11
67	Commercial	Heating – most energy efficient boiler	-60.22
68	Commercial	Most energy efficient flat roof insulation	-59.58
69	Domestic	Loft insulation 75–270mm	-59.25
70	Industry	Process Improvement	-49.817
71	Industry	Energy Management	-43.8832
72	Domestic	Post '83 cavity wall insulation	-37.14
73	Domestic	Biomass boilers with RHI	-34.85
74	Domestic	Installed floor insulation (susp.Timber Frames)	-32.31
75	Domestic	Air Source Heat Pump with RHI	-31.17
76	Commercial	Air Source Heat Pump with RHI	-22.62
77	Commercial	Biomass boilers with RHI	-19.33
78	Transport	Full Hybrid	-18.5523
79	Domestic	Loft insulation 100–270mm	-15.12
80	Domestic	Glazing (to Best Practice)	-12.64
81	Commercial	Most energy efficient cavity wall insulation	-10.54
82	Commercial	Most energy efficient pitched roof insulation	-10.27
83	Domestic	Solid wall insulation	1.69
84	Domestic	Loft insulation 125–270mm	4.49
85	Commercial	Most energy efficient external wall insulation	10.48
86	Commercial	Lights – Metal Halide Floods	19.92
87	Commercial	Lights – IRC Tungsten-Halogen – Spots	23.05
88	Industry	Renewable Heat	24.7286
89	Domestic	Room thermostat to control heating	48.02
90	Domestic	Loft insulation 150–270mm	51.98
91	Transport	Biofuels	53.11
92	Commercial	Ground Source Heat Pump with RHI	56.95
93	Domestic	Paper type solid wall insulation	68.91
94	Domestic	Modestly insulated cyl to high performance	74.19
95	Transport	New railway Stations	101.342

96	Transport	Cycling	107.4073
97	Domestic	Thermostatic radiator valves	124.17
98	Commercial	Lights- Most energy efficient Replacement 26mm	154.45
99	Domestic	Photovoltaic generation with FIT	161.84
100	Commercial	Solar water heating with RHI	173.30
101	Transport	Express Bus/Coach Network	179.4277
102	Commercial	Motor – 4 Pole Motor – EFF1 replace 4 Pole	192.51
103	Commercial	Lights – High frequency ballast	194.73
104	Industry	Others	254.5861
105	Transport	Micro Hybrid	272.8425
106	Domestic	Solar water heating with RHI	314.13
107	Transport	Electric	347.479
108	Industry	Ventilation	366.3107
109	Industry	Motors & Drives	391.6276
110	Transport	Park and Ride (Rail)	434.644
111	Commercial	Lights – Most energy efficient Replacement Tungsten	521.57
112	Industry	Insulation	546.637
113	Transport	Rail Electrification	569.3817
114	Industry	Information Technology	625.5327
115	Domestic	Micro wind turbines (1kW) with FIT	630.07
116	Domestic	Hot water cylinder ‘stat	653.68
117	Commercial	Variable Speed Drives	687.98
118	Commercial	Most energy efficient double glazing	691.05
119	Transport	Park and Ride (Bus)	978.8004
120	Transport	Smarter Choices	1029.986
121	Commercial	Most energy efficient double glazing (replace double)	2918.71
122	Transport	Bus Priority and Quality Enhancements	9620.888
123	Transport	Park and Ride (Bus + Dedicated service)	13257.83

Appendix C:
Overall List of the Most Carbon Effective Measures

Cost effective
Cost neutral
Realistic technical potential

Central business case			$KTCO_2$
1	Industry	Renewable Heat	205.99
2	Transport	Biofuels	189.57
3	Domestic	Reduce household heating by 1°C	179.12
4	Domestic	Solid wall insulation	169.63
5	Transport	Full Hybrid	155.64
6	Transport	Micro Hybrid	146.77
7	Commercial	Heating – most energy efficient boiler	139.21
8	Commercial	Heating – Programmable Thermostats High	131.44
9	Commercial	Biomass boilers with RHI	114.04
10	Transport	Plug-in Hybrid	105.65
11	Commercial	Air Source Heat Pump with RHI	94.65
12	Commercial	Ground Source Heat Pump with RHI	93.83
13	Industry	Others	92.98
14	Industry	High Temperature Heating	87.21
15	Industry	Process Improvement	85.39
16	Commercial	Heating – Reducing Room Temperature	80.38
17	Industry	Drying & Separation	78.32
18	Transport	Electric	74.70
19	Industry	Motors & Drives	66.08
20	Transport	Transport	65.45
21	Domestic	Pre76 cavity wall insulation	61.19
22	Industry	Controls	58.06
23	Domestic	Electronic products	55.79
24	Domestic	Ground Source Heat Pumps with RHI	54.90
25	Industry	Heat Recovery	50.75
26	Domestic	Air Source Heat Pump with RHI	49.19
27	Commercial	Most energy efficient double glazing	47.21
28	Commercial	Heating – Optimising Start Times	45.14
29	Industry	Operation & Maintenance	44.46
30	Industry	Energy Management	38.39

31	Domestic	Information and Communication Technology products	36.59
32	Industry	Low Temperature Heating	36.26
33	Domestic	Efficient lighting	35.13
34	Commercial	Lights – Basic Timer	32.14
35	Domestic	Solar water heating with RHI	28.65
36	Commercial	Heating – More efficient air conditioning	28.55
37	Commercial	Heating – Thermostatic Radiator Valves Fully Installed	24.93
38	Industry	Space Heating	21.36
39	Commercial	Lights- Most energy efficient Replacement 26mm	20.80
40	Commercial	Lights – Turn off Lights for an extra hour	17.48
41	Domestic	Glazing – single to new	15.33
42	Commercial	Monitors – Energy Management	15.00
43	Commercial	Most energy efficient external wall insulation	14.71
44	Commercial	Most energy efficient flat roof insulation	14.51
45	Commercial	Lights – High frequency ballast	13.87
46	Industry	Fabrication & Machining	13.13
47	Domestic	DIY floor insulation (susp. timber floors)	13.09
48	Commercial	Solar water heating with RHI	12.60
49	Domestic	A+ rated wet appliances	11.22
50	Domestic	Loft insulation 100–270mm	11.19
51	Commercial	Most energy efficient cavity wall insulation	10.55
52	Domestic	Loft insulation 0–270mm	10.49
53	Industry	Ventilation	10.29
54	Industry	Refrigeration & Aircon	9.97
55	Domestic	Loft insulation 75–270mm	9.86
56	Domestic	Uninsulated cylinder to high performance	9.81
57	Commercial	Most energy efficient pitched roof insulation	9.63
58	Domestic	Mini wind turbines (5kW) with FIT	9.43
59	Commercial	Presence Detector	9.36
60	Domestic	Photovoltaic generation with FIT	9.06
61	Domestic	Improve airtightness	8.80
62	Industry	Building Energy Management	8.59

Cost effective
Cost neutral
Realistic technical potential

63	Domestic	Glazing (to Best Practice)	8.29
64	Transport	Smarter Choices	7.75
65	Domestic	Reduce heating for washing machines	7.64
66	Domestic	Glazing – old double to new double	7.35
67	Domestic	Biomass boilers with RHI	7.13
68	Domestic	Reduced standby consumption	6.86
69	Commercial	Computers – Energy Management	6.40
70	Commercial	Variable Speed Drives	5.96
71	Commercial	Stairwell Timer	5.94
72	Domestic	Loft insulation 50–270mm	5.85
73	Domestic	Modestly insulated cyl to high performance	5.67
74	Commercial	Lights- Most energy efficient Replacement Tungsten	4.93
75	Industry	Insulation	4.74
76	Industry	Compressed air	4.65
77	Commercial	Office Equipment – Most energy efficient monitor pc only	4.56
78	Commercial	Lights – IRC Tungsten-Halogen – Spots	4.06
79	Industry	Design	4.04
80	Commercial	Most energy efficient freezer	3.89
81	Domestic	76–83 cavity wall insulation	3.85
82	Commercial	Cycling	3.67
83	Commercial	Room thermostat to control heating	3.54
84	Commercial	Lights – Sunrise-Sunset Timers	3.41
85	Commercial	Lights – Light Detectors	3.39
86	Commercial	Most energy efficient double glazing (replace double)	2.98
87	Commercial	Compressed air	2.38
88	Domestic	Post '83 cavity wall insulation	2.11
89	Domestic	Turn unnecessary lighting off	1.97
90	Domestic	Thermostatic radiator valves	1.86
91	Industry	New Food & Drink Plant	1.81
92	Commercial	Printers – Energy Management	1.67
93	Industry	Lighting	1.65
94	Commercial	Lights – Metal Halide Floods	1.64

Cost effective
Cost neutral
Realistic technical potential

95	Domestic	Loft insulation 25–270mm	1.48
96	Domestic	Insulate primary pipework	1.46
97	Commercial	Most energy efficient fridge	1.27
98	Domestic	Paper type solid wall insulation	1.11
99	Industry	Burners	1.05
100	Commercial	Photocopiers – Energy Management	0.93
101	Domestic	Micro wind turbines (1kW) with FIT	0.79
102	Transport	Park and Ride (Rail)	0.74
103	Domestic	Integrated digital TVs	0.74
104	Industry	Information Technology	0.72
105	Transport	Rail Electrification	0.69
106	Domestic	A++ rated cold appliances	0.68
107	Transport	New railway Stations	0.59
108	Commercial	Vending Machines Energy management	0.35
109	Commercial	Motor – 4 Pole Motor – EFF1 replace 4 Pole	0.30
110	Domestic	Hot water cylinder 'stat	0.27
111	Transport	Bus Priority and Quality Enhancements	0.23
112	Transport	Park and Ride (Bus)	0.17
113	Transport	Express Bus/Coach Network	0.16
114	Commercial	Most energy efficient fridge-freezer	0.12
115	Commercial	Office Equipment – Most energy efficient Monitor	0.06
116	Transport	Park and Ride (Bus + Dedicated service)	0.03
117	Domestic	A-rated ovens	0.00
118	Domestic	A-rated condensing boiler	0.00
119	Domestic	Induction hobs	0.00
120	Domestic	Insulated doors	0.00
121	Domestic	Installed floor insulation (susp.Timber Frames)	0.00
122	Domestic	Loft insulation 125–270mm	0.00
123	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. Formed by the University of Birmingham, University of Hull, University of Leeds, University of Sheffield and University of York, we work across the EU, Asia and Latin America. The Centre brings together engineers, natural scientists and social scientists to deliver high-impact research on our 2013/14 themes of Energy Systems, Green Growth and Smart Infrastructure. We provide evidence to inform policy formation, encourage technological innovation and build capacity to improve resource efficiency and promote sustainable leadership in the food-energy-water nexus.

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