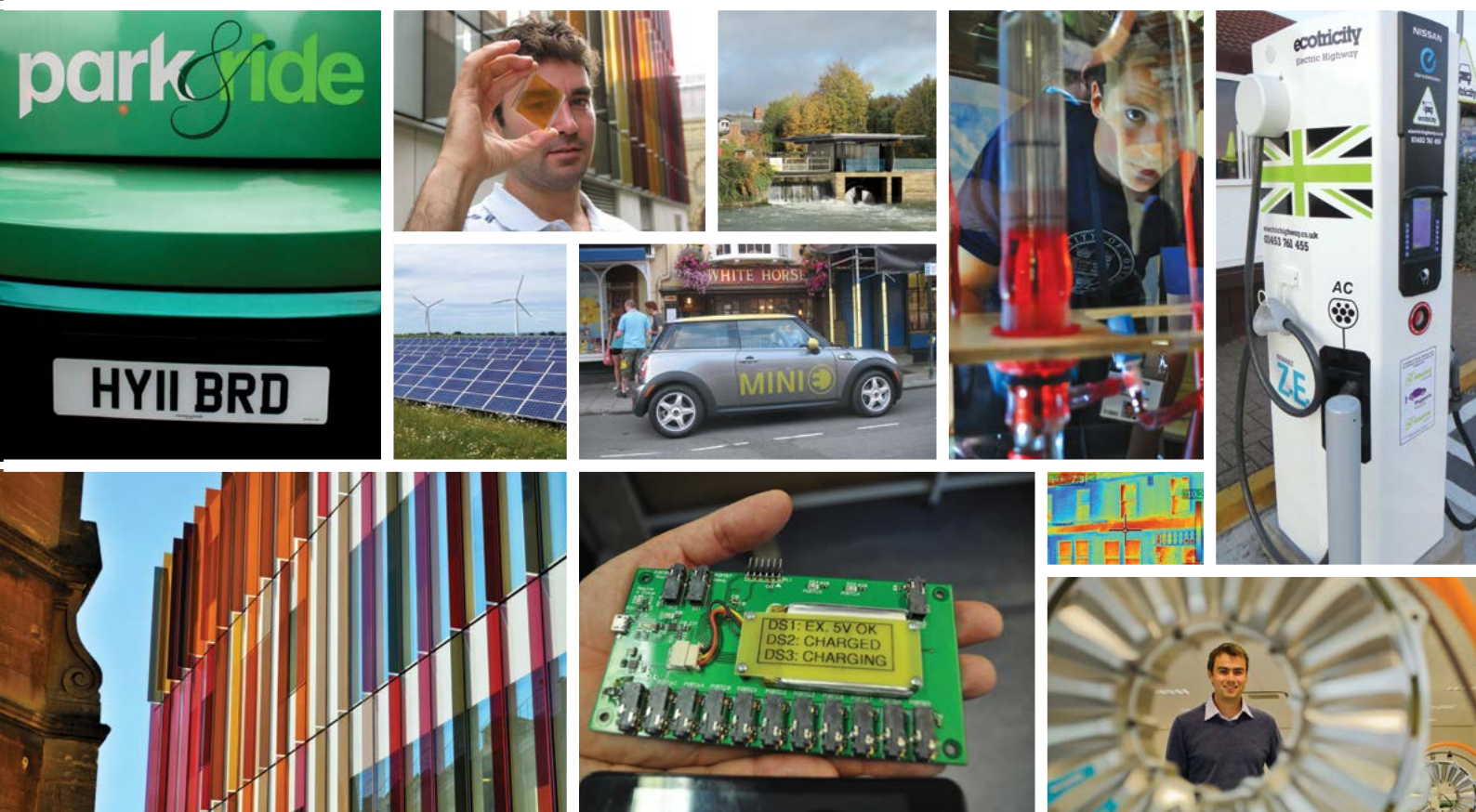


Oxfordshire's Low Carbon Economy



A report by the Environmental Change Institute and Low Carbon Oxford

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Supporting material

The full report by Vivid Economics is available as an on-line appendix, providing more detail on the economic analysis presented here. There is also a collection of case studies, highlighting some of the innovative and ground-breaking initiative and business ideas which already exist in Oxfordshire. Space in the report was too limited to publish them all, so the reader is encouraged to view the full set in electronic form.

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List of abbreviations

AC	Alternating current	IPCC	Inter-governmental Panel on Climate Change
AECB	Association for Environment-Conscious Building	ISfB	Innovation Support for Business
AERE	Atomic Energy Research Establishment	JET	Joint European Torus
BEPIT	Bicester Eco-Town Improvement Toolkit	KTN	Knowledge Transfer Network
CA	Comparative advantage	kWh	Kilowatt-hour(s)
CAG	Community Action Group	kWh/m² year	Kilowatt-hours per square metre and year
CC	County Council	LCA	Life-cycle analysis
CCS	Carbon capture and storage	LCH	Low Carbon Hub
CEGB	Central Electricity Generating Board	LCO	Low Carbon Oxford
CHP	Combined heat and power	LED	Light-emitting diode
Climate-KIC	Climate-Knowledge Innovation Community	LEP	Local Enterprise Partnership
CO₂	Carbon dioxide	LEZ	Low emission zone
DC	Direct current	LGF	Local Growth Fund
DC	District Council	LTP	Local Transport Plan
DECC	Department for Energy and Climate Change	MobOx	Oxford Transport Laboratory
DNO	District network operator	MW	Megawatt(s)
EAFRD	European Agricultural Fund for Rural Development	MWh	Megawatt-hour(s)
EBLL	Eco-Bicester Living Lab	NEF	National Energy Foundation
ECI	Environmental Change Institute	NOx	Nitrous oxides
ECO	Energy Company Obligation	OECD	Organisation for Economic Co-operation and Development
EFW	Energy from waste	OLEV	Office for Low Emission Vehicles
ERDF	European Regional Development Fund	OLH	Osney Lock Hydro
ESCAT	European Centre for Space Applications and Telecommunications	OTS	Oxford Transport Strategy
ESIF	European Structural and Investment Fund	P&R	Park and ride
EU	European Union	PHEV	Plug-in hybrid electric vehicle
EV	Electric vehicle	PV	Photovoltaic(s)
FIA	Fédération Internationale de l'Automobile	R&D	Research and development
FIT	Feed-in tariff	RAL	Rutherford Appleton Laboratory
FTE	Full-time equivalent	RD&D	Research, development and deployment
GD	Green Deal	RHI	Renewable heat incentive
GDP	Gross domestic product	SEP	Strategic Economic Plan
GPS	Global positioning system	SHMA	Strategic Housing Market Assessment
GSHP	Ground source heat pump	SME	Small and medium-sized enterprise
GVA	Gross value added	SSE	Scottish and Southern Energy
GW	Gigawatt(s)	tCO₂	Tonnes of carbon dioxide
GWh	Gigawatt-hour(s)	UKAEA	United Kingdom Atomic Energy Authority
ICT	Information and communications technology	VC	Venture capital
IEA	International Energy Agency	VED	Vehicle excise duty
		WHO	World Health Organisation
		WHP	Williams Hybrid Power
		WPD	Western Power Distribution

Foreword by Tim Stevenson

In January this year I was privileged to welcome some 200 leaders and entrepreneurs from business, local communities, education and the public sector to a conference entitled *OxFutures*: it proved an inspiring opportunity to consider the multiple possible benefits of the creation of a low carbon future for Oxfordshire.

Those attending the conference were struck by the breadth of ideas and enthusiasm generated: there was clear commitment from people and organisations to develop and take forward initiatives of impact and scale. And the context was compelling: reports by economic and scientific experts - national and international - argued that the economy could be decarbonised at a cost justified by the avoided risks of dangerous climate change, enhanced value to our energy security and increased economic activity.

However, despite existing local initiatives, it was clear that the economic case for action in the county had not been adequately made. Basic questions were difficult to answer. How many jobs could a low carbon economy create in Oxfordshire? What type of jobs would they be? How much investment would this need? And from where might this come? How would low carbon innovation fit with - and complement – Oxfordshire's strengths in research and technology and plans for growing our knowledge economy.

The purpose of this report, *Oxfordshire's Low Carbon Economy*, is to start to fill these gaps. It draws on the expertise of Low Carbon Oxford and its Pathfinder organisations together with the research experience of the Lower Carbon Futures team at the University of Oxford's Environmental Change Institute.

The report makes a powerful case and provides important food for thought for local decision makers – in business, the public sector, our universities and communities. For its argument is that substantial opportunities exist, of mutual benefit to us all. It therefore deserves careful reading as a route to both serious debate, and encouragement of the concerted, coordinated action that would be needed if that argument is accepted. It plots a course towards a collective opportunity to show national leadership in creating a low carbon future for Oxfordshire.

I commend the report to you.

Tim Stevenson

Lord Lieutenant of Oxfordshire

Foreword by Cameron Hepburn

Imagine you are driving down an unfamiliar road. You see some kind of corner approaching. At some point, you are going to hit the brakes. Our emissions of greenhouse gases have taken us down that unfamiliar road, and the corner is virtually upon us. But humanity has been accelerating, rather than braking. Irrespective of the fashionable pessimism about multilateral negotiations on climate, at some point we will decide that it is time to slam on the brakes. Various countries, counties and cities have already reached that conclusion, and are already starting to apply the brakes, but most have not. When we do hit the brakes, great fortunes will be made (and lost) as we go around the bend.

Will some of those fortunes be made in Oxfordshire? It would seem possible, indeed likely, given the findings of this report. But the transition has barely begun, and many of the companies in Silicon Valley are eyeing up the prizes on offer – hundreds of billions of investment in new energy systems and the built environment, and trillions in the transport sector.

But what is Oxfordshire's future role? It does not necessarily follow from the fact that there are trillions at stake in the low-carbon transition that Oxford could or should be at the centre of it. Two prior questions need to be answered. First, is Oxfordshire likely to be able to “win” in the low-carbon domain? In other words, could we develop products and services for the rest of the world that can be scaled and replicated to make a real impact on the problem? Second, should Oxfordshire devote scarce resources to low-carbon innovation as opposed to other fields? This report set out to answer the first of these questions. It looks at past quantitative indicators of comparative advantage of Oxfordshire in various sectors, including low-carbon. It identifies where Oxfordshire's economy already has strengths, and then investigates the sectors of the regional economy which can contribute to economic growth and climate change mitigation at the same time.

The report does not address the second question – how does the opportunity here compare to those in medical sciences, biotech, or other fields. This is for others to do. But overall, the picture that emerges is that there is a huge opportunity here globally, and that Oxfordshire has the intellectual and skills base to capture specific subsets of those opportunities. Our probability of success is likely to be increased with better networking between the universities, corporates and financial capabilities. On this evidence, Oxfordshire seems well placed to become a leader among city-regions around the world which are tackling these difficult issues. There are challenges in pursuing any strategic path, and the low-carbon path is no exception. But while the challenges should not be under-estimated, nor should the size of the potential prize.

Cameron Hepburn

*Professor of Environmental Economics, University of Oxford
(Smith School/ Institute for New Economic Thinking, Oxford Martin School)*

Executive Summary

This report sets out to evaluate the economic case for investment in the low carbon economy in Oxfordshire.

The global opportunity for low carbon goods and services is likely to be very large in the coming decades. Annual global investment in low carbon will need to rise by about \$1 trillion, with a total investment in low carbon energy, buildings and transport of as much as \$20 trillion in the period 2010 to 2030. So the business opportunities are large and growing.

Oxfordshire is well positioned to become a low carbon economy leader. National data shows that our low carbon sectors already generate £1.15 billion/year in sales and employ 8,800 people: 7% of Oxfordshire's economy.

The shift to a low carbon economy requires broad innovation, which is consistent with Oxfordshire strengths as a knowledge economy and the growth plans of the Local Enterprise Partnership (LEP). Oxfordshire has strengths in several key economic sectors for a low carbon future – building technologies, alternative fuels and vehicles, and renewable energy technologies.

Oxfordshire's world class universities, R&D capabilities and start-up companies have some exciting opportunities, for example in renewable energy technologies, low carbon transport and smart energy and transport systems. Partnerships with larger companies are already bringing new technologies to deployment at scale.

Low-carbon innovation and investment can generate significant employment and economic output. Outcomes will depend on the scale of innovation success, but we estimate that an ambitious low carbon investment programme over the next 15 years might add £1.35 billion annually to the Oxfordshire economy by 2030, creating over 11,000 new jobs.

There are good reasons to believe that the fundamentals of our economy provide the basis on which to build. Oxfordshire has a key strategic position in south east England, with the combination of good access to London and a high quality natural and cultural environment that can attract investors, entrepreneurs and high skilled labour. The LEP and local government support business investment, with plans for growth and science parks attractive to innovative companies.

Oxfordshire has a growing and innovative low carbon service sector – in, for example, consultancy, finance, law and accountancy. Supportive and increasingly joined-up networks exist in business, research and local government. And Oxfordshire has nationally leading community groups and civil society initiatives in low carbon. Together these contribute to a low carbon ecosystem that can support research, innovative businesses and infrastructure providers in building a prosperous low carbon economy.

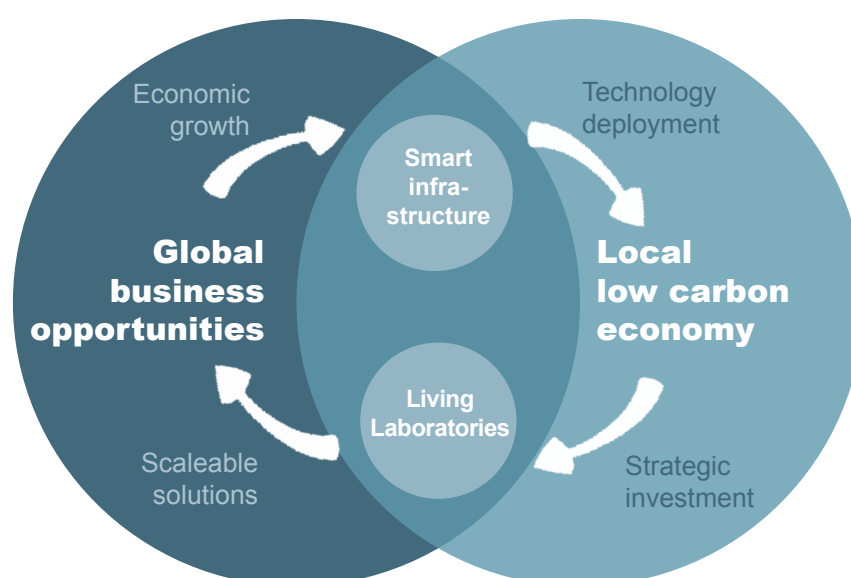
Just to meet our climate commitments, Oxfordshire will collectively need to invest at least £100 million/year to 2030, and perhaps treble that if we have aspirations for low carbon leadership. This may seem a large and off-putting number, but it is consistent with what is needed for important sectors of the local economy and the development of modern infrastructure. And it looks very small compared to the over £1 billion/year that Oxfordshire currently spends on carbon based energy sources, none of which are produced in the county. Low carbon research and innovation can turn those cash outflows into productive investment, economic activity and jobs within the County.

There is a wide range of investors whose interests intersect with this agenda. Research and development funding is available from the UK Research Councils, Innovate UK (formerly known as the Technology Strategy Board) and the EU's Horizon 2020 programme, amongst others. These bodies encourage (and sometimes require) collaborative projects between different organisations and sectors (especially between research and industry).

For start-up and early-stage businesses, Oxfordshire is well endowed with venture capitalists, angel investors and others. However, there are challenges in terms of the perceived benefits of investing in low-carbon ventures, and a wider problem (shared with the rest of the country) in attracting sufficient investors from London. These issues can be addressed to a degree through coordination of work and aggregation of the investment opportunity to increase scale.

The global business opportunities correlate with local areas needing infrastructure investment – transport, buildings and electricity. If Oxfordshire's new infrastructure is built to be smart and low carbon, it will support the innovative low carbon sectors, not only by providing effective infrastructure, but also as an early home market and testing ground for low carbon innovation. A coordinated programme of local 'living laboratories' could help create and spread the learning needed to achieve these objectives.

Figure 4.1: **The low carbon living laboratories as a driver of Oxfordshire's economy**



In the infrastructure sectors, investment is available from central government through competitively-awarded challenge funds. Infrastructure projects are also highly collaborative, so once again the coordination of effort (and funding) will be key, involving Network Rail, the Highways Agency, electricity Distribution Network Operators and others.

And last but not least, every homeowner, vehicle owner and business will be investing in their own assets, presenting many opportunities for deployment of cost effective energy efficiency. Barriers to energy efficiency exist (e.g. up-front costs, low awareness of potential, consumer mistrust, lack of skills and knowledge in building firms), so support activities are needed to stimulate demand and build the capacity to deliver.

The principal role of the LEP and local authorities in relation to all of these different types of investors is not to provide the bulk of the investment, but to catalyse and coordinate.

Effective land use planning will be important. This report does not seek to set out a planning blueprint for the County, but it identifies some important themes. The planning system needs to enable high quality space for innovative companies, with good access to university and R&D centre partners. But planning also needs to facilitate early investment in smart, green infrastructure for new developments, and to ensure that those developments are at the most appropriate scales and densities. Transport infrastructure and land-use planning need to be thought of in terms of making homes, workplaces, and leisure destinations accessible, not simply in terms of increasing capacity on roads and rail lines.

Some risks and challenges of Oxfordshire's growth plans have already been identified, especially the need for adequate infrastructure investment to enable investment and growth. The nature of this investment could play a key role in assisting a globally competitive low carbon economy in Oxfordshire. However, if the investment is made in such a way that it locks Oxfordshire in to a high-carbon future, the risks to economic and social welfare are set to increase.

Quality of life is also important – not only to current residents, but also to prospective businesses looking to locate their activities. Investment in low carbon infrastructure is likely to make Oxfordshire a better place to live. “Co-benefits” include easier and more reliable journeys (from better communications and more efficient modes of transport), air quality (from reduced noxious emissions from fossil fuels), public health (from that better air quality, a more active population and better heated homes), poverty reduction (from the improvement of homes with high heating costs), and comfort (from better designed and operated buildings).

Delivering this will take coordinated and decisive action to secure investment in low carbon innovation and infrastructure. We conclude that developing Oxfordshire's low carbon economy needs a three-pronged approach:

1. Supporting innovation, building effective clusters of innovation that link research and development to early stage deployment in key potential low carbon growth sectors – alternative fuels and low carbon vehicles, building technologies, low carbon energy and supporting service sectors.
2. Enabling infrastructure, through public policy and planning, to provide the framework for business growth and living laboratories for new technologies and business models.
3. Coordinating the many potential source of investment in innovation, business development and infrastructure.

The City Deal, Strategic Economic Plan, European Structural Investment Fund, Oxfordshire Growth Deal, and the nascent ‘Smart City’ strategy, provide a framework for growth. The challenge is to use the opportunity of economic growth plans to set Oxfordshire on a low-carbon path, rather than locking the county in to a high-carbon future, which will be more expensive and difficult to remedy in decades to come.

The European Structural Investment Fund targets some modest resources on the low carbon sector and the OxFutures initiative sets some more ambitious goals. More will be needed to deliver an identified thriving and genuinely low-carbon economy for Oxfordshire, but a start is already being made.

1. Introduction

Oxfordshire is at a strategic crossroads. It has ambitious economic growth plans, seeking to build on its existing strengths in knowledge-intensive and high-tech sectors, and develop along a path of export-led growth. To be successful, these growth plans will require significant strategic investment from both private and public sectors. Making Oxfordshire attractive to businesses means creating a supportive environment for inward investment, and ensuring that the county's infrastructure is able to provide good quality housing, accessibility, amenities and quality of life for all of its residents.

Alongside the plans for economic growth Oxfordshire is also committed to a reduction of 50% in CO₂ emissions by 2030 compared to 2008, in line with national climate change policy targets. Tackling climate change represents an enormous global opportunity for low-carbon goods and services, which has been estimated to be worth roughly \$1 trillion per year. This report assesses how well Oxfordshire's economy is placed to take part in this global opportunity for export-led growth.

The UK as a whole has had some success in achieving GDP growth without causing proportional increases in CO₂ emissions. This 'de-coupling' of economic growth from the negative effects of energy use remains challenging, especially when the plans for economic growth and the targets for emissions reduction are ambitious, as they are in the case of Oxfordshire. This report also assesses how this de-coupling challenge might be realised for the city-region of Oxfordshire, whilst also achieving economic and social goals: how can Oxfordshire simultaneously develop global leadership in innovation, keep and grow existing businesses, attract new businesses, create jobs, build resilience, reduce carbon emissions and develop inclusive and thriving communities?

Background to the report and research approach

The report has been overseen by a high level Steering Group representing key stakeholders, including the city and county councils, the universities, businesses (Oxford Bus Company), NGOs and communities.

The research has been led by the Lower Carbon Futures team of the Environmental Change Institute, with specific expertise in low carbon technology, buildings and transport. In addition, the report draws on input from Low Carbon Oxford on the low carbon and knowledge economy sectors in Oxfordshire, and on consultancy support from Vivid Economics, who provided data and analysis on specific economic sectors. The full economic analysis is available on-line.

The research approach includes a high level economic assessment of Oxfordshire's economy and the low carbon global opportunities and risks, coupled with a 'bottom-up' assessment of Oxfordshire's specific opportunities for research and development, business and infrastructure. A list of workshop participants is given on page 80.

Global context: Climate change, global opportunity and risks

Climate change is a threat to prosperity. But it also presents a global business opportunity, and an opportunity to build prosperous and resilient communities. In a recently published report, the World Bank has highlighted the wide-ranging benefits of climate-smart development investments, including increased jobs and GDP, as well as the costs of inaction.¹

A number of studies have highlighted the need for urgency. The 2006 Stern Review set out a comprehensive case for investing in carbon mitigation now to avoid significant damage to economic growth in the future.² Its conclusions are supported by the Inter-governmental Panel on Climate Change (IPCC), which published its fifth assessment report on Climate Change Mitigation in March 2014,³ highlighting the need for large-scale changes in energy systems and arguing that delays in mitigation efforts will increase both long-term mitigation costs and/ or the risk of global temperature rises above two degrees. It has been suggested that we have a window of opportunity to reap economic, social and environmental rewards from targeted low carbon investment.⁴

Local economic context

Oxfordshire has a knowledge-based economy and is one of Europe's leading centres of enterprise and innovation, with the third highest concentration of research and development workers in the country after Cambridgeshire and Hertfordshire. It is home to two leading universities (the University of Oxford and Oxford Brookes University), as well as a group of large science and other research facilities. Its highly skilled labour force has a higher proportion of graduates than any other English county (47% in 2012 compared to a UK average of 34%).

Oxfordshire's economy grew consistently over the period 1997 to 2011, and its Gross Value Added (GVA) per person is well above the national average and slightly above Cambridgeshire. The number of unemployed in Oxfordshire has been consistently below national and regional averages. New enterprises in Oxfordshire have a higher survival rate than the average across the South East region and across England. Oxfordshire is ranked 7th in the country in terms of gross disposable household income.⁵

Oxfordshire's economic strategy is informed by many different organisations and networks, but a key organisation is the Local Enterprise Partnership (LEP).⁶ The government's vision for setting up the new LEPs in 2010 was:

Local Enterprise Partnerships will provide the clear vision and strategic leadership to drive sustainable private sector-led growth and job creation in their area. We particularly encourage partnerships working in respect to transport, housing and planning as part of an integrated approach to growth and infrastructure delivery. This will be a major step forward in fostering a strong environment for business growth.

1 Akbar, S.; Kleiman, G.; Menon, S.; Segafredo, L. (2014), "Main report. Vol. 1 of *Climate-smart development: adding up the benefits of actions that help build prosperity, end poverty and combat climate change*". Washington, DC : World Bank Group. <http://documents.worldbank.org/curated/en/2014/06/19703432/climate-smart-development-adding-up-benefits-actions-help-build-prosperity-end-poverty-combat-climate-change-vol-1-2-main-report>

2 Stern, N. (2006), "Stern Review: The Economics of Climate Change", http://webarchive.nationalarchives.gov.uk/20130129110402/http://www.hm-treasury.gov.uk/stern_review_report.htm

3 IPCC (2014), "Climate Change 2014: Mitigation of Climate Change", Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. <http://www.ipcc.ch/report/ar5/wg3/>

4 UCL Green Economy Policy Commission (2014), "Greening the Recovery", http://www.ucl.ac.uk/public-policy/Policy_Commissions/GEPC/GEP-Report

5 Vivid Economics (2014), "Low Carbon Oxfordshire – report prepared for ECI and LCO"

6 LEPs took over many of the functions of Regional Development Agencies (RDAs) in England after RDAs were abolished in 2010.

The Oxfordshire LEP covers the area of the City and County Councils (which includes the four District Council areas of Cherwell, South Oxfordshire, Vale of White Horse and West Oxfordshire). The Oxfordshire LEP aims to work with businesses, academia and the public sector to drive economic development across the county. The LEP can bid for government funds intended to boost growth through innovation. The integration of low-carbon innovation into these funding plans will be vital to build a functioning low carbon ecosystem. Oxfordshire LEP also has the potential to provide leadership in this area, setting and promoting a visionary and ambitious agenda for 2030 which sees low carbon investment as central to the county's future well-being and prosperity.

The LEP's Strategic Economic Plan (SEP) forms the basis of a bid for Local Growth Fund investment from central government. It sets out in detail how Oxfordshire's unique wider asset base, including its global brand and "quality of place" as well as its research strengths, give it a head start and clear advantages over other areas in leading sustainable, innovation-driven growth and thereby contributing to the UK's growth. The SEP also highlights Oxfordshire's strengths in terms of its skills levels, cultural economy, natural beauty and strategic geographic location and ease of access.⁷

The SEP identifies an investment need to 2030 of £6.32 billion in order to provide over £6.6 billion of additional gross value added (GVA) and 85,000 jobs. This investment would deliver upto 100,000 new homes, transform broadband connectivity, improve highways, develop public transport services, and make a significant investment in skills across the local economy. To lever in the necessary private sector investment, the SEP sets out a case for making a public sector investment of just under £680 million (9.7% of the total investment required).

The SEP also identifies three 'priority localities' – Science Vale Oxford (Harwell – Milton Park – Didcot), Oxford and Bicester, which together make-up Oxfordshire's 'knowledge spine' (figure 1.1, overleaf).

The SEP has four thematic objectives:

- innovative enterprise, underpinned by the county's unrivalled R&D capacity
- innovative people, based on a highly skilled and flexible workforce and accelerating jobs growth
- innovative place, designed to deliver the quality and quantity of housing to meet growing demand whilst sustaining and capitalising on our exceptional quality of life, natural environment and rural and urban communities
- innovative connectivity, to deliver freedom of movement, infrastructure and facilities sustainably and universally across the county.

In particular, the City Deal sets out plans for investment in a network of innovation and incubation centres, building on the intellectual assets of Oxfordshire's universities and Big Science facilities (including the Harwell Innovation Hub, the UKAEA Culham Advanced Manufacturing Hub, the Oxford BioEscalator and the Begbroke Innovation Accelerator); as well as investment in innovation business support, new housing, new transport schemes (the Enterprise Zone, the Northern Gateway and the first phase of the Science Transit scheme), and investment in 500 new apprenticeships.

⁷ Oxfordshire LEP (2014), "Strategic Economic Plan – Driving economic growth through innovation", http://www.oxfordshirelep.org.uk/cms/sites/lep/files/folders/Strategic%20Economic%20Plan/Oxford_Strategic_Economic_Plan.pdf

Figure 1.1 **Oxfordshire knowledge spine**



Map provided with kind permission of Oxfordshire County Council

To deliver on this strategy, the European Structural and Investment Fund (ESIF) and the Local Growth Fund (LGF) channel European and UK government funds respectively. Low carbon innovation and R&D emerged as a thematic offer and strategic growth priority for Oxfordshire during the development of the City Deal, the SEP and ESIF.

Similarly, SQW's 2013 report on Oxfordshire's "Innovation Engine"⁸ supports the Strategic Economic Plan's assessment of Oxfordshire's strengths and highlights the importance of Oxfordshire's high tech sectors in terms of growth and employment, but also strengthening links between academia and business, building supply chains, developing local labour markets and contributing to Oxfordshire's reputation as a high tech location.

8 SQW (2013), "The Oxfordshire Innovation Engine: Realising the Growth Potential"

Oxfordshire CO₂ emissions

Oxfordshire's annual CO₂ emissions per head were 8tCO₂ in 2011, a little higher than the average for England, 7tCO₂ per head. Whilst Oxfordshire's carbon emissions have been declining overall, it performs slightly worse than the English average both in terms of overall emissions and in terms of the rate of emissions decline.⁹

Oxfordshire's highest emitting sector is transport, which accounts for almost 40% of all CO₂ emissions. Local road transport contributes to total emissions proportionally more in Oxfordshire than in the rest of the country, reflecting the presence of a busy motorway (M40) and trunk road (A34). It accounted for 17% of total CO₂ emissions in Oxfordshire, compared to only 12% in England. Industrial and commercial emissions accounted for 35% of total emissions in Oxfordshire (compared to 41% for England). The proportion of total emissions from housing is about the same in Oxfordshire as it is in England (29% compared to 27%).

Structure of the report and scope

This report starts by describing the state of Oxfordshire's economy and low carbon sectors and strengths, its wider ecosystem, drivers and barriers (Chapter 2). It then draws on economic analysis to identify clusters and sectors that present significant growth opportunities; and to make the case for decarbonising Oxfordshire's infrastructure (Chapter 3). Chapter 4 sets out cross-cutting issues for innovation and enterprise in achieving low-carbon growth. Chapters 5-8 provide detail on the scale and nature of the opportunity for low-carbon growth to 2030: chapter 5 introduces three scenarios, which have been developed to stimulate debate about the scale of the task ahead. This is followed by three sector-specific chapters on infrastructure: transport (chapter 6), housing (chapter 7) and energy systems (chapter 8). Finally, chapter 9 lists a number of specific opportunities and suggested next steps for taking forward the report's findings. Case studies throughout the report (and a more complete set on-line) show that there are already numerous initiatives in place taking forward this agenda, from which future activities can learn and take inspiration.

⁹ See on-line appendix for more detail of Oxfordshire's current emissions compared with the country as a whole.

2. Oxfordshire's knowledge economy

This chapter looks in more detail at the current state of Oxfordshire's knowledge economy, highlighting those sectors where Oxfordshire has comparative advantage (ie where Oxfordshire's economy is strongest compared with England as a whole).

Comparative advantage

Comparative advantage (CA) in this report is based on employment numbers: for any given sector, the proportion of the workforce in Oxfordshire is compared with the proportion at a national level. If the proportions are the same, the CA value is 1, indicating that Oxfordshire is no different from the national average for that sector of the economy; a value below 1 indicates a sector where Oxfordshire employs relatively few people compared with national figures; and a CA value of more than 1 indicates a sector where Oxfordshire employs relatively more than the national average.

$$CA_i = \frac{\text{Number of employees in sector } i \text{ in Oxfordshire}}{\text{Total number of employees in Oxfordshire}} \div \frac{\text{Number of employees in sector } i \text{ in England}}{\text{Total number of employees in England}}$$

This analysis of comparative advantage is done for the entire Oxfordshire economy and for the sub-set of economic activity which is classified as 'low carbon'.

Oxfordshire's economic profile

High technology activities make a significant contribution to the overall economic activity in the county. The growth in high-tech activities has been accompanied by a considerable growth in professional, knowledge-based services such as financial, legal and business and management. In 2010, 55% of Oxfordshire's employees worked in knowledge intensive sectors.¹⁰ High tech activities in 2011 made up 6.2% of Oxfordshire's total employment; compared to 5.1% for England as a whole.¹¹

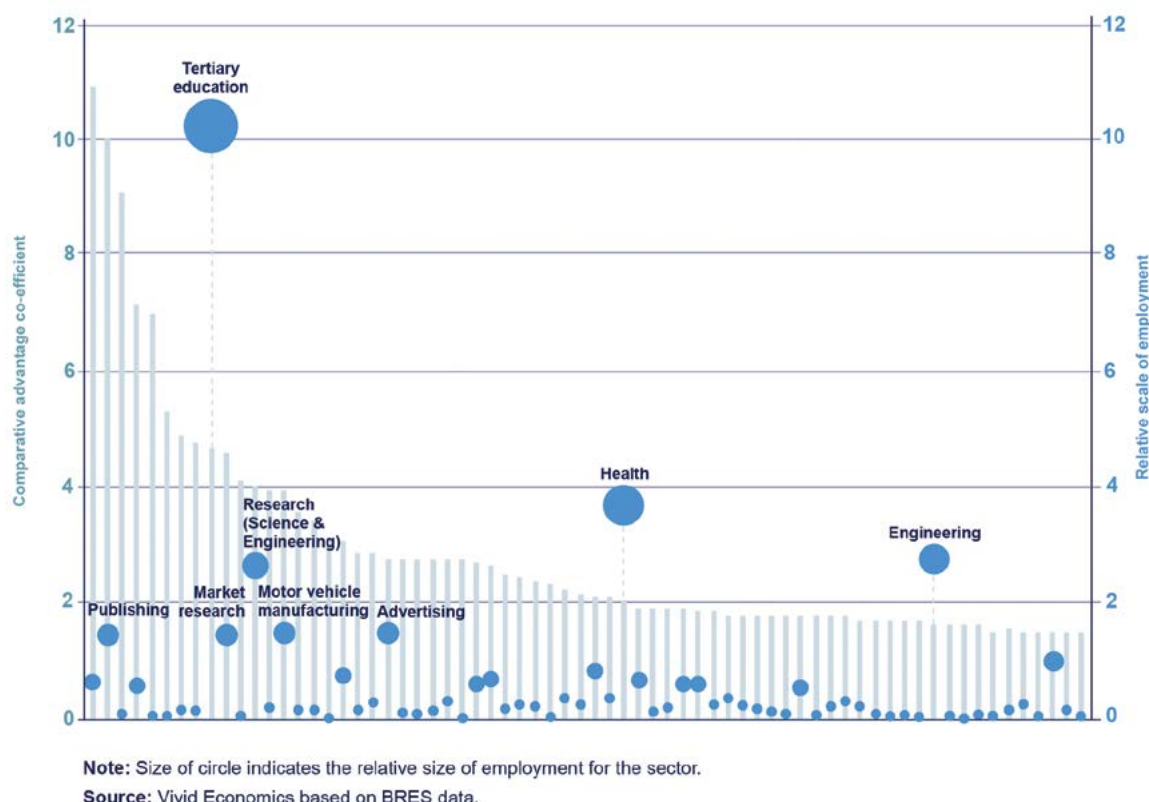
Oxfordshire's economy enjoys a high degree of specialisation in creative, knowledge-intensive and high-tech sectors. Of these, the six most important sectors employ 35,000 workers, accounting for 11% of total employees in 2011 (see Figure 2.2). These sectors are:

- manufacturing of computers and peripheral components
- book publishing
- manufacturing of chemical products
- tertiary education
- research and development in natural science and engineering
- manufacturing of motor vehicles.

¹⁰ Oxfordshire County Council. (2012). *Oxfordshire Economic Assessment: Part Two - Update of evidence*.

¹¹ *Ibid*.

Figure 2.2 **Top knowledge-intensive economic sectors in Oxfordshire**
based on comparative advantage and numbers employed



At the same time, Oxfordshire has a few notable economic and innovation weaknesses compared to other similar counties. Despite being in the top three counties for knowledge-intensive activities, these sectors grew by only 1% between 2008 and 2010, compared to 23% in Cambridgeshire. Also, Oxfordshire has produced relatively few businesses that have scaled up to become large businesses, suggesting that it performs better in the early stages of the innovation chain than the later stages. Oxfordshire is also less attractive to inward investment than other comparable counties; only 3% of South East jobs from Foreign Direct Investment were located in the county between 1999 and 2010 as compared to 16% in Surrey and 15% in Buckinghamshire.

Economic clusters

Oxfordshire already has several mature and world-class economic clusters, especially in high-tech and knowledge-intensive sectors, such as space and satellite applications, life sciences, and advanced engineering. For example, Invest in Oxfordshire reports that Harwell Oxford Science and Innovation Campus is the home of international space collaborations including the Satellite Applications Catapult, the European Space Agency's new European Centre for Space Applications and Telecommunications (ESCAT) facility, RAL Space, and the UK Space Agency. Additionally, Oxfordshire is at the heart of Motorsport Valley with four Formula 1 teams based in the county; supported by 4,000 high performance engineering companies in the area.

The benefits of clusters are in increased efficiency and productivity, as well as in providing critical mass and new opportunities through collaborative working. Economic benefits of clusters can also spill over into other economic sectors, as has happened with the development of space applications and intellectual property for use in environmental and agricultural management.

Sectors with potential for growth in a low-carbon future

Defining 'Low carbon'

Goods and services which have the potential to reduce CO₂ emissions can justifiably be termed 'low carbon'. CO₂ emissions from energy use can be thought of as a product of three things, which we illustrate here with examples from transport: firstly, there is the energy service demand (e.g. how many people or goods need to travel how far?); secondly, we need to take account of the efficiency of the technology chosen (emissions per kilometre travelled with a given vehicle or transport mode); and finally, there is the interaction of technology with people (e.g. driving behaviour).

It therefore makes more sense to think of 'low carbon' as the outcome of people and technologies in a system, rather than as a characteristic of the technologies themselves. Systemic effects can have a strong influence, such as the interaction of housing density with the viability of certain transport modes (mass transit systems, cycling and walking). Some examples of energy supply technologies and demand management options are shown below (not exhaustive lists).

Supply side technologies¹²

Biomass
Geothermal
Hydro
Photovoltaics
Solar thermal
Marine (wave and tidal)
Wind
Alternative Fuel Vehicles
Alternative Fuels
Carbon Capture & Storage
Nuclear Power

Demand management strategies

Education and training
Energy management & system controls
Information systems
Marketing and promotional campaigns
Building design
Land-use planning

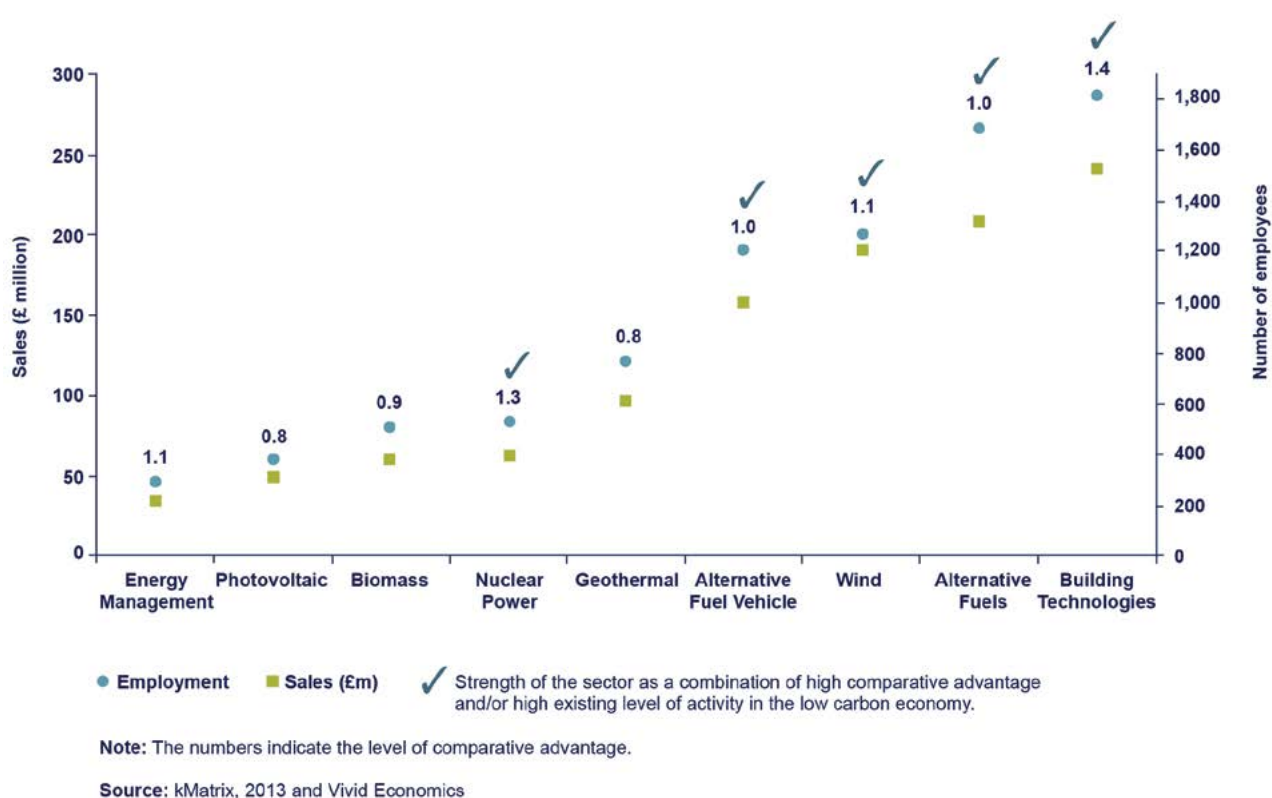
Within this wider knowledge economy, Oxfordshire has significant and growing low carbon sectors. Low carbon sectors generated £1.15 billion worth of sales in Oxfordshire in 2013 and employed 8,800 workers, generating 7% of GVA in 2011. Between 2011 and 2013, sales and employment increased by 10% and 5%, respectively.

National statistics suggest that Oxfordshire currently has comparative advantage compared to the rest of the UK (in terms of sales and employment) in building technologies, nuclear power and wind (mainly systems and equipment manufacture and supply) and significant activity in sectors which are likely to grow in response to demand for low carbon goods and services, including building technologies, alternative fuels, wind and alternative fuel vehicles¹³ (see Figure 2.3). Together these four sectors employed 4,000 people in Oxfordshire in 2013 (nearly 2% of the county's workforce).

¹² Adapted from government definition. See BIS (2013) "Low Carbon Environmental Goods and Services (LCEGS) – Report for 2011/2012", July 2013, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/224068/bis-13-p143-low-carbon-and-environmental-goods-and-services-report-2011-12.pdf

¹³ As defined by BIS, this sub sector includes Low Carbon Fuel and technology activities that relate to (predominantly) automotive transport. It is divided into Alternative Fuels (main stream) and Other Fuels and Vehicles, and including Research, Design, Development and Prototyping activities.

Figure 2.3 **Low carbon goods and services in Oxfordshire**
– comparative advantage and scale (sales and employment)



All of these sectors have the potential to grow further, as both the technologies and the markets for technology deployment evolve. While there can be no certainty in predicting the size of future markets, the policy signals are clear enough: growth in these sectors would be consistent with meeting the UK's (and Oxfordshire's) climate change targets.

Three strong sectors with high growth and employment potential in a low carbon scenario emerge out of the analysis based on high number of current employees, comparative advantage and high growth:

- alternative fuel vehicles
- wind and photovoltaic energy, especially systems and equipment
- building technologies

In addition to these specifically low-carbon sectors, Oxfordshire's economy is also strong in engineering-related research and development, which underpins technological innovations of all kinds, including ones with strong low-carbon potential.

Research strengths

Innovations with potential global impact are emerging from Oxfordshire's universities and research centres. New technologies under development within Oxford's two universities, spinouts and local SMEs include:

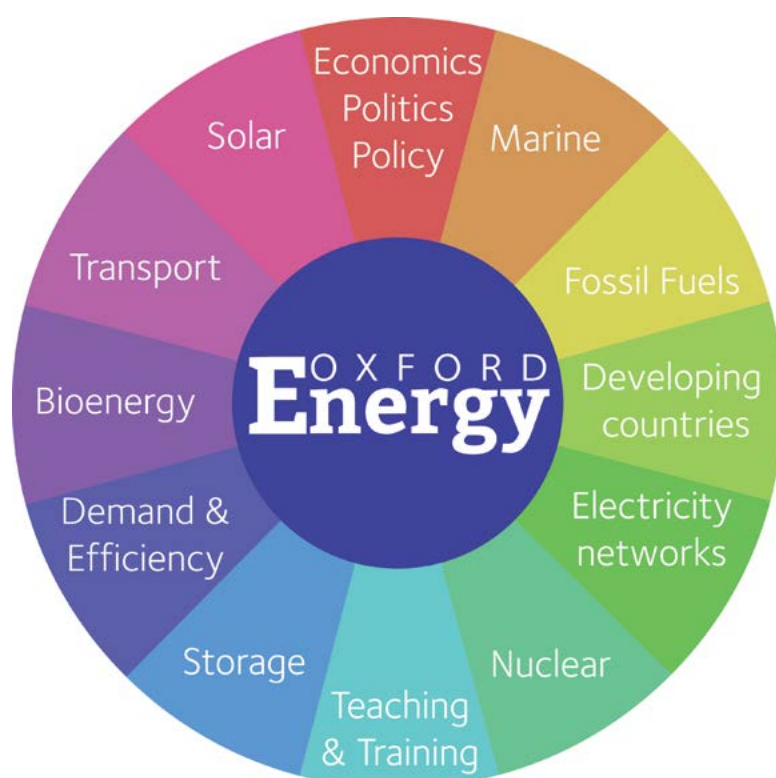
- advanced materials for low cost solar cells
- alternative fuels manufactured from waste carbon dioxide
- smart immersion heaters

- Biomass Stirling engines for off grid electricity generation
- improved performance fuel cells using enzymes
- low cost energy management applications
- exhaust energy systems for large vehicles and fleets
- advanced vehicle control systems and automotive engine management electronics.

Oxford's two universities, the University of Oxford and Oxford Brookes, are examples of organisations that are critical to the development of the global low carbon business opportunity through innovation, but that also have the potential to lead locally in investment in infrastructure and the local low carbon economy, as they decarbonise their buildings and operations.

In particular, **Oxford University** has over 180 senior researchers (and over 500 researchers in total) whose research is wholly or partly related to energy (see Figure 2.4). Supported by the university's technology transfer company, Isis Innovation, this research has spun-out a number of energy related companies as well as intellectual property that is being exploited commercially under numerous license agreements. Responsible for over 25% of commercial and industrial CO₂ emissions in Oxford,¹⁴ Oxford University also has an important role in reducing emissions on its own estate, and in encouraging staff and students to conserve energy and carbon and make low carbon investments at work and at home.

Figure 2.4 The University of Oxford's energy research activities



Source: Oxford Energy Network, <http://www.energy.ox.ac.uk/>

¹⁴ Figures for 2010. See LCO, "Building momentum", <http://www.oxford.gov.uk/Library/Documents/Environmental%20Development/Low%20Carbon%20Oxford%20Building%20Momentum%20Report.pdf>

Oxford University's multiple roles in the low carbon agenda create an opportunity for leadership within the wider Oxfordshire ecosystem. This diversity, while bringing its own challenges, can – and is – stimulating engagement across the full spectrum of local partners: from high-tech enterprise (e.g. YASA Motors and Drayson Racing Technologies) to communities seeking to reduce their energy consumption (e.g. the recent collaboration between Pilio Ltd and the Diocese of Oxford).

Similarly, Oxford Brookes has low carbon research strengths and is well placed to play a leading role in Oxfordshire's low carbon ecosystem. The Low Carbon Building (LCB) Research Group of the Oxford Institute for Sustainable Development at the School of Architecture has an international reputation in the fields of carbon counting and carbon reduction from buildings; building performance evaluation; advanced low-carbon refurbishment, climate change adaptation and low carbon communities.

Oxford Brookes' existing activities put it in a strong position not only to reduce its own carbon emissions (with its ambitious targets of reducing its carbon emissions by 50% by 2020), but to act as a leading player in Oxfordshire's wider low carbon ecosystem, by influencing its staff and students, engaging with communities and SMEs through its activities and research, and collaborating across sectors. An example is Oxford Brookes' collaboration with Oxford Bus Company and Williams to provide low carbon transport technology.

Oxfordshire's stakeholders and networks

Key to the transition to a low-carbon economy is an inclusive, multi-agency approach that extends beyond the technological and business communities to include local government, essential service providers, and civil society (table 2.1).

Table 2.1 **Stakeholders for a low-carbon economy in Oxfordshire** (not an exhaustive list)

Sector	Stakeholders
Public sector	County, City and District Councils
Research/ higher education	University of Oxford, Oxford Brookes University, colleges, UK Atomic Energy Authority (UKAEA), Rutherford Appleton Laboratory (RAL), Centre for Sustainable Healthcare
Large businesses	Mini plant Oxford, Unipart
Specialist firms	ICE Energy, Oxford PV, Williams, Navetas
Transport	Network Rail, train operators, Stagecoach, GoAhead/ Oxford Bus Company
Housing/construction	Local authorities, registered housing providers, GreenSquare, A2Dominion, Grosvenor, Buildbase, construction firms
Energy	Energy suppliers, District Network Operators
Consultancy and professional services	Ricardo AEA, Poyry, ERM, Anthesis (Best Foot Forward), Blake Morgan, Grant Thornton
Finance	Oxford Capital, Oxford Technology, corporates and individuals
Civil society/ community groups	Low Carbon Hub, Oxford Civic Society, Oxfordshire Rural Community Council, Community Action Groups (a coordinated network of 50+ community groups)

A number of network organisations provide support for low carbon innovation and investment by influencing strategies and funding decisions and by facilitating investment, spin-outs, collaboration, networking, and sharing of best practice (table 2.2). In addition, a wide range of individuals, businesses, geographical communities and communities of interest act as connectors and enablers on the low carbon agenda.

Table 2.2 **Multi-sector networks in Oxfordshire** (not an exhaustive list)

Business networks	Science Parks, Oxford Innovation Society, Innovation Support for Business Programme, Oxford Investment Opportunity Network, Invest, Low Carbon Oxford, Oxford Energy Network, Oxford Early Investments, Venturefest, Invest in Oxfordshire, Federation of Small Businesses, Oxfordshire Construction Training Group
Research networks	Oxford Energy Network, Oxford Networks for the Environment, Environmental Sustainability-Knowledge Transfer Network
Cross-cutting strategic networks	Local Enterprise Partnership, Oxfordshire's Spatial Planning and Infrastructure Partnership, Oxford Strategic Partnership and Oxfordshire Partnership
Civil society networks	Low Carbon Hub, Community Action Group (CAG) network

What has been missing to date is a coordinating function across these networks, as well as outreach to other constituencies, such as public health, environment, education and skills, agriculture, tourism. Together with the Low Carbon Hub and supported by European funding, Oxford City and Oxfordshire County councils launched the OxFutures vision in 2014, which aims to raise £400 million into clean energy projects in Oxfordshire by 2020.¹⁵ As part of this, Oxford City Council recently announced the creation of a £2.3 million loan facility to enable the construction of local renewable energy projects.¹⁶ OxFutures and the LEP's Innovation Support for Business Programme could signal the beginnings of a wider, joined-up support structure that could mobilise a coordinated, cross-sectoral effort to attract investment to Oxfordshire specifically in pursuit of low carbon goals.

¹⁵ <http://oxfutures.org/>

¹⁶ http://www.oxford.gov.uk/PageRender/decN/newsarticle.htm?newsarticle_itemid=54630

3. The economic case for low carbon innovation and investment

This chapter sets out in more detail the economic case for low carbon innovation and investment; and argues that low-carbon activity could add significantly to Oxfordshire's economic growth in coming years. It starts by setting out the economic rationale for low carbon investment generally; describes the global business opportunity for Oxfordshire; and sets out economic arguments for decarbonising Oxfordshire's infrastructure. It then analyses the potential economic impact of low carbon investment on Oxfordshire's economy. It identifies opportunities and challenges based on fairly high level economic and industrial data.

There are two key arguments for low carbon investment in Oxfordshire, (1) the global business opportunity and (2) the need to improve and decarbonise Oxfordshire's infrastructure to help deliver this opportunity and meet emissions targets, reduce energy costs and protect against the risk of future resource shocks. We have estimated that opportunities in transport, housing and energy could generate over 11,000 additional jobs and £1.35 billion value added for the Oxfordshire economy by 2030.

Global business opportunity for Oxfordshire in low carbon goods and services

The Inter-governmental Panel on Climate Change (IPCC) has estimated that increases in low carbon investment of \$1 trillion annually will be needed to meet globally agreed goals (Figure 3.1¹⁷, overleaf).

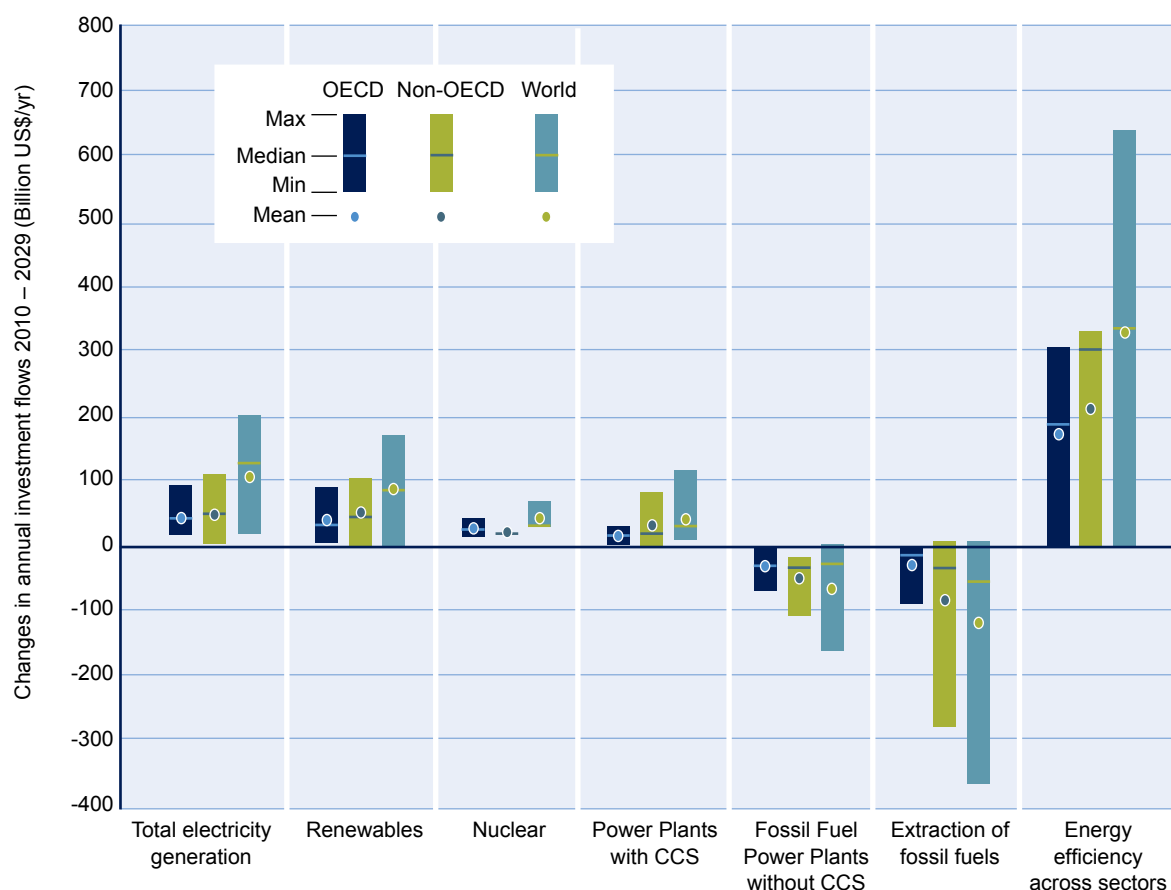
Similarly, the International Energy Agency (IEA) indicates that the global capacities for many low carbon technologies will need to increase by one or more orders of magnitude by 2030 in order to limit global temperature rise to 2 degrees Celsius.¹⁸ To give an indication of the scale of growth needed, the IEA's 'technology perspective' scenario includes the following increases in technology up-take:

- electric vehicles (EV) and plug-in hybrid EV (PHEV) are assumed to reach global yearly sales of 40 million by 2030 (in 2012 only 80,000 electric vehicles were sold)
- capacity of wind energy increases globally from 158 GW in 2012 to 1,400 GW in 2030
- photovoltaic capacity is projected to increase globally from 22 GW to about 700 GW over the same period.

17 IPCC (2014), "Summary for Policymakers", In: Climate Change 2014, Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. http://report.mitigation2014.org/spm/ipcc_wg3_ar5_summary-for-policymakers_approved.pdf

18 International Energy Agency (2012) *Energy Technology Perspectives 2012* <http://www.iea.org/etp/>

Figure 3.1 Change in annual global investment flows 2010 – 2029



Source: IPCC 2014¹⁹

Higher world demand for low carbon goods – in particular efficient energy systems, new technology for renewable energy and higher demand for alternative fuel vehicles – can promote innovation and growth in Oxfordshire.

Economic rationale for low carbon investment

The long-term rationale for low carbon investment is that without it, we face unacceptable risks to economic and social welfare from significant environmental damage.²⁰

In the short to medium term, the global low carbon economy creates growth opportunities from low carbon innovation and investment, in turn creating the potential for local job creation and prosperity. In addition, low carbon investment in infrastructure helps protect against the economic risks of future resource shocks and energy system costs. The UK Energy Research Centre has estimated that investment in technology supported by lifestyle changes (in particular in transport and buildings practices) could result in energy system cost reductions of close to £90 billion annually by 2050, which would suggest (based on population) about £900 million annually in Oxfordshire.²¹

19 Inter-governmental Panel on Climate Change 2014 Climate Change 2014: mitigation of climate change, IPCC fifth assessment report: IPCC, Geneva. <http://www.ipcc.ch/report/ar5/wg3/>

20 E.g. UCL Green Economy Policy Commission (2014), "Greening the Recovery", http://www.ucl.ac.uk/public-policy/Policy_Commissions/GEPC/GEPCreport

21 Eyre, N., Anable, J., Brand, C., Layberry, R. and Strachan, N. (2010) The way we live from now on: lifestyle and energy consumption. Chapter 9 in, Skea, J., Ekins, P. and M. Winskel (eds.) Energy 2050: Making the Transition to a Secure Low Carbon Energy System. Earthscan. 408 pp. ISBN: 9781849710848.

Local drivers of demand

While export markets operate on a global scale, there are also local issues which support the case for aligning strategic economic investments with the low-carbon growth agenda. Local climate policy is an over-arching driver: The County Council, four District Councils and Oxford City Council have all agreed a 50% CO₂ emissions reduction target by 2030, compared to 2008.²²

Costs of energy and energy-related levies

An increasingly important benefit of low carbon investment relates to the costs of energy in the Oxfordshire economy. These now amount to more than £1 billion annually. The vast majority of the energy used in the county is currently derived from fossil fuels, none of which are produced in Oxfordshire, so most of these energy revenues flow out of the county. In contrast, investment in low carbon energy, whether in energy saving or renewable energy, is predominantly in capital within the county. Most of the installations and a proportion of the equipment will be made in the local economy, so these economic benefits are largely retained within Oxfordshire. Moreover, the more successful Oxfordshire becomes in developing the supply chains for these technologies, the bigger this effect becomes. The energy produced from low carbon technologies may be more or less expensive than fossil fuel alternatives, depending on the technology (energy saving is usually cheaper than fossil fuel energy, renewables somewhat more expensive). But the benefits to the local economy will always be larger than buying fuel produced elsewhere.

Some of the key drivers of regulation and incentives lie with EU and UK policymakers, and therefore are essentially 'given' for Oxfordshire decision-makers. A detailed examination of relevant policies is beyond the scope of this report. However there is a growing number of incentive schemes, driven by national Government policy, for example:

- incentives to promote investment in renewable energy including Feed-in-tariffs and the Renewable Heat Incentive
- the Renewables Obligation and 'Contracts for Difference' for larger low carbon power generation schemes
- incentives for energy efficiency in housing through the Energy Company Obligation (ECO)
- incentives for low carbon vehicle technology deployment, e.g. plug-in vehicle grants and tax breaks such as differential vehicle excise duty (VED) and fuel tax.

These are funded from general taxation or by energy and transport users. The costs fall relatively evenly across the UK, but the benefits only accrue to those who make use of the incentives.

²² Oxfordshire Partnership 2030 Strategy, "Oxfordshire 2030", <http://www.oxfordshirepartnership.org.uk/wps/wcm/connect/occ/OxfordshirePartnership/Oxfordshire+2030/>

Similarly, there are nationally funded programmes for infrastructure projects, such as

- the Local Sustainable Transport Fund
- Big Lottery funding for walking and cycling schemes
- the Low Carbon Network Fund for smart grid innovation.

Again, the costs fall widely across the country, but the benefits are focused in a specific area.

In all these cases the aim (from an Oxfordshire economy perspective) should be to maximise the fraction of these benefits that come to the county. There are many ways that local policy decisions can assist in achieving this, for example:

- local planning frameworks, strategies and decisions that prioritise low carbon transport, buildings and energy
- local electric vehicle (EV) infrastructure promotion
- low carbon procurement policies
- policies to support low carbon R&D and enterprise, inward investment and exports;
- congestion charging, with revenue streams hypothecated for sustainable transport schemes
- low carbon priorities in local transport plans.

Growth plans as an opportunity to meet multiple objectives

Oxfordshire's ambitious growth plans recognise population growth and increased pressure on existing infrastructure, and require investment in significant new housing and transport innovation and infrastructure. A failure to provide good enough new infrastructure could make Oxfordshire a less attractive location for firms looking to take part in the county's economic growth plans. The need for infrastructure investment represents a 'once in a generation' opportunity to do so as part of a local low-carbon strategy. Missing that opportunity may lead to new infrastructure being 'locked in' to a high carbon path, with little or no security in the face of future rises in fossil energy prices. Seizing it would allow multiple policy objectives to be met: achieving economic growth; reducing carbon emissions; improving health through greater access to healthy modes of transport and energy-efficient homes; quality of life and place (in particular air pollution, congestion and accessibility).

Barriers to change

Barriers to innovation and growth generally

The 2013 SQW 'Innovation Engine' report identified a number of constraints to realising innovation and growth in Oxfordshire:

- research infrastructure
- soft infrastructure
- access to risk capital
- improving access to scientific and technical expertise
- information on the high tech community
- networks
- physical infrastructure
- strategy and leadership.

Many of these have been identified as focus areas in preparing for and delivering the City Deal and SEP – for example, the Innovation Support for Business (ISfB) programme is intended to join up the disparate networks, develop the soft infrastructure and create a leadership and governance structure for innovation. Improved broadband access for SMEs in the city and county is also a priority in the SEP. Deep challenges remain, including housing availability and affordability, economic inclusion (particularly in areas of multiple deprivation and also rural communities), and demographic shifts.

Barriers to low carbon innovation and growth

The Centre for Cities²³ has pointed out that many low carbon investments “will not produce tangible results within traditional political cycles”. The key to overcoming that is to provide long-term leadership and vision.

Oxfordshire also has a number of specific barriers to low carbon innovation and investment to overcome. These are explored in Chapters 6-8 across the different sectors, with the key barriers summarised in Table 3.1, overleaf.

Opportunity for Oxfordshire

There are two key arguments for low carbon investment in Oxfordshire, (1) the global business opportunity and (2) the need to improve and decarbonise Oxfordshire’s infrastructure. Both arguments support the idea of developing markets for technology deployment, using technologies and business sectors where Oxfordshire has strengths, and which can also contribute to low-carbon outcomes. Although small compared with the potential of global markets, a city-region the size of Oxfordshire provides a large enough market to provide a valuable test-bed for deployment. Infrastructure and technology could both be improved in a mutually reinforcing series of programmes to install, monitor and evaluate performance of technologies in real-life settings. This model of a ‘living laboratory’ has been pursued successfully in many parts of the world.²⁴ Strong candidates for technology sectors to include in a living laboratory in Oxfordshire include alternative fuel vehicles and building technologies.

²³ Centre for Cities (2013), “Delivering change: How cities go low carbon while supporting economic growth”

²⁴ See, for example, Bergvall-Kareborn, B., Stahlbrost, A. (2009) ‘Living Lab: an open and citizen-centric approach for innovation’, *International Journal of Innovation and Regional Development* 1(4), 356-370.

Table 3.1 **Barriers to low carbon innovation and investment**

Transport	Innovation and enterprise	Housing	Energy
• road and rail congestion • poor accessibility in key enterprise corridors • the challenge of market breakthrough of low carbon technology • fragmented transport governance • the need for collaboration between stakeholders • the need for shift in public attitudes.	• access to risk capital / early stage investment • attracting and retaining innovators and entrepreneurs • low venture capital (VC) appetite to invest in low carbon due to its perceived high risk / uncertainty of return • the entrepreneurial culture in Oxfordshire and the drain to Silicon Valley and elsewhere • the supporting 'expert services' around low carbon innovation such as legal, financial, policy etc.	• a weak policy framework and financial incentive framework (eg Green Deal and Energy Company Obligation) • design-performance gap • lack of knowledge and skills for low-energy buildings; • uncertainty over house-building targets • fragmented property ownership • fragmented construction industry • planning conditions which constrain, rather than encourage, technology up-take • lack of business models to coordinate the supply chain • low consumer trust in SME construction firms.	• limited local capacity due to the lack of energy duties and activities in local institutions • limited local engagement of key energy institutions, e.g. District Network Operators, Department of Energy and Climate Change, electricity generators • relatively poor resource for some renewables, e.g. marine technologies • no plausible local sites for some low carbon energy supply technologies, e.g. nuclear and carbon capture and storage (CCS) • difficulties in securing planning consent.

Alternative fuel vehicles

The motor vehicle cluster in Oxfordshire and other high tech sectors are well placed to lead innovation in alternative fuel vehicles, which include electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs). Oxfordshire has a large automotive and motor sport cluster as well as a large ICT sector. It also has a strong presence in related science and engineering research, including for example electric motor and materials technology. Electric vehicle technology is at an early stage of adoption and will require a great deal of investment in research, development and deployment (RD&D). Oxfordshire with its strong high tech clusters can benefit from the growth potential offered by this sector. The presence of a large motor vehicle manufacturer can help create demand for investment in automotive R&D and innovation. This leadership and growth opportunity would be further supported by Oxfordshire taking a lead in demonstrating electric vehicles, which requires infrastructure planning to include investment in charging stations.

Building technologies

Building technologies (e.g. for heating and insulation) is a sector that can play an important role in Oxfordshire's low carbon economy strategy. Oxfordshire has a clear comparative advantage in the building insulation sector with 1,000 workers out of a total 36,000 in the UK based in Oxfordshire in 2013. The UK Government's 2016 zero carbon homes policy reinforces an opportunity for Oxfordshire to focus on fostering skills used to build low carbon houses. Oxfordshire could take a leading role in supporting new business models and construction processes by sponsoring demonstration projects, industry networks, training and specialised clusters in the building technology sector. Proposals to build potentially up to 100,000 new homes by 2030 offer a platform to create demand at scale for this cluster. Oxfordshire is also home to the first 'eco town' project in the UK at Bicester, with advanced plans for 5,000 homes, a school, community centre and a business centre for small and medium enterprises and with a focus on low environmental impact construction and provision of environmental goods and services. Investments and innovations in this sector also have the potential to be economically inclusive, creating jobs for those who tend to be excluded from knowledge and high tech sectors.

These opportunities, alongside opportunities for low carbon electricity innovation and investment, are explored further in Chapters 6-8.

OxFutures: revolving fund for local technology deployment

The Low Carbon Hub is working with Resonance, Oxford City Council and Oxfordshire County Council to develop a revolving loan fund for major renewable energy and energy reduction projects across the city and county. The focus is on practical local projects, working with business partners, the public sector and communities to increase the scale of activity on the ground in Oxfordshire.

Initially funded by a grant from the EU's Intelligent Energy Europe programme, OxFutures aims to leverage investment of £20 million into local energy projects by 2016. The first phase of the fund will target investment for renewable installations on the public estate and underwrite start-up funding for community energy schemes.

The OxFutures programme features local renewable energy schemes ('power up' projects) and energy efficiency initiatives ("power down" projects):

- **Power Up:** the Low Carbon Hub has £12.5 million worth of renewable energy projects in development, including eight community microhydro schemes along the Thames, solar PV projects on community buildings, a cohort of solar schools, and a total of 3.5MW of solar PV with local businesses across Oxfordshire.
- **Power Down:** the target is 19,600MWh energy savings by 2016 (equivalent to the total energy consumption of roughly 800 homes). One of the key aims of this project is to tackle fuel poverty locally. Oxford City Council and the Low Carbon Hub are currently running a pilot scheme in Barton to improve the energy efficiency of local homes.

OxFutures is also set to deliver renewable projects on the public estate. The first phase is the Low Carbon Hub's solar energy scheme for Oxfordshire schools. Individual schools have struggled to develop their own projects in isolation but by working together the scheme will be able to gain economies of scale and raise funds for groups of school installations at the same time. This will provide cheaper, green electricity for the schools for 20 years as well as an ethical investment opportunity for the wider community. Other possible sites for similar projects include the park and ride car parks and other public sector assets.

Sources of funding and investment for low-carbon enterprise

*"Historical evidence shows that those countries who have, in recent decades, been successful in developing energy technologies, such as Onshore Wind or Solar Photovoltaic energy, have used a mix of direct and indirect public-sector funding to do so."*²⁵

The scale of investment in low carbon enterprise needed in Oxfordshire over the next 15 years is very significant. A figure of £100m annually will be needed to enable Oxfordshire to achieve the lower levels of ambition in current debates; and for Oxfordshire to become a leader in low-carbon enterprise, our most ambitious scenarios imply approximately £300m annually. These are large numbers, but entirely consistent with what is needed in a significant and growing part of the local economy.

One of the key issues about 'going low carbon' is the diversity of development and changes needed across the economy. So the scale of investment needed is large, but so is the number of potential sources of investment.

In **research**, universities and other research centres have well-established sources of funding, which are already investing many millions of pounds into low carbon research in the county. Basic research is largely funded by the UK's Research Councils (around £3 billion per year) and the Horizon 2020 initiative of the EU (79 billion euros between 2014-2020). Only a fraction of this research budget is available for low-carbon work, but it is worth noting that funding of energy and low carbon research has generally been protected or even increased in recent years, in recognition of its critical importance. This has been achieved against a background of shrinking overall research budgets. Oxfordshire's strengths in basic research make the scale of funding from these sources relatively secure, although individual projects are, of course, competitively won.

Once technologies pass out from the laboratory and into **development, testing and demonstration**, costs can increase significantly. The main UK Government

²⁵ LCICG, pg 16

source of funding for technologies at this point in the innovation chain is Innovate UK, with Horizon 2020 EU funding also available. There are other specialist sources of funding for low carbon innovation, including the UK Energy Technologies Institute, the EU Climate-Knowledge Innovation Community (Climate-KIC) and Ofgem's innovation funding for smart grid, the Low Carbon Network Fund. Individual projects funded from some of these sources can be quite large – many millions of pounds. There is usually some requirement for industry match-funding, and therefore strong local partnerships can be an important factor in securing support.

The financing of **innovative start-up and early-stage businesses** is much more dependent on private capital. Risks are relatively high, too high for most commercial banks, and therefore options include private venture capital and “angel investors”. Whilst a number of Oxfordshire start-ups have secured this type of investment, the stakeholder feedback we have received indicates this part of the innovation landscape remains a problem area for Oxfordshire. In contrast to Cambridgeshire, for example, there are no systems in place to support local entrepreneurs in the process of getting risk capital.

For **infrastructure investment**, even with relatively new technology, risks are lower, and therefore conventional finance is more available. Nevertheless, the investments needed are large, and therefore there is no guarantee that the main infrastructure providers will prioritise Oxfordshire. Low carbon infrastructure development in Oxfordshire on the scale envisaged in some of our scenarios will need significant investment through Network Rail, the Highways Agency, electricity Distribution Network Operators, housing associations and private sector developers. The key decision-making processes are different in every sector, but one common criterion is likely to be clear commitment from the local business community and public sector. There is a key role for the LEP and local Councils in building the key relationships and demonstrating that secure local commitment.

Renewable power generation will be a key part of the low carbon investment needed. To date, cooperatives and social enterprises have played a significant role in getting this sector off the ground in Oxfordshire. They can continue to do that, provided they can access the technical capacity, finance and human resources needed to match their innovation and commitment. Further thinking is needed about how this might be secured. At the upper end of the investment scale we envisage, private developers will also play a big role. Provided national Government incentives continue, developers will bring forward plans, but are likely to focus on areas where there is greatest clarity about the prospects for planning consent. A positive and supportive land use planning framework is therefore crucial to securing this investment.

Investment in low carbon technology in **households and the service sector** also forms a key part of the low carbon economy. This will be needed to refurbish buildings to improve their energy efficiency, to install renewable energy sources within them and to purchase the low carbon vehicles that are critical to decarbonising the transport sector. Civil society groups and social enterprise have a role to play in coordinating pockets of demand for these services, as well as providing education and awareness-raising.

National incentives are available in all cases, and therefore it is in Oxfordshire's economic interest to ensure households and businesses in the county take advantage of them. In some cases, households and businesses will be able to do this from their own resources; in other cases borrowing may be needed, and therefore it will be important to ensure that local branches of high street lenders are involved in and committed to the wider local carbon partnerships.

Where local authorities are involved in infrastructure provision, e.g. the County Council as local transport planner and provider and the City and District Councils as social housing providers, they will have a direct role in investing in low carbon infrastructure. However, as the previous paragraphs have shown, the overwhelming bulk of investment will need to come from elsewhere and will often depend on perceptions of risk that can only be mitigated through local partnerships that demonstrate broad community and business support for the low carbon agenda. Whilst individuals, businesses and other organisations can do much to develop these partnerships, there is no substitute for support from the representative institutions in the county. So the principal role of the LEP and local authorities is to lead, catalyse and coordinate the plans and the partnerships that are needed.

4. Catalysing low-carbon innovation

This chapter starts with a summary of current activity to foster enterprise and innovation in Oxfordshire's low-carbon economy. It then explores the key barriers to innovation and growth that are particular to low carbon, and suggests a model for overcoming those barriers, based on collaborative working among and between sectors, and operating at several scales. Development of these collaborative partnerships will contribute to creating a healthy low-carbon 'ecosystem' containing all the stakeholders needed to build a prosperous and low-carbon economy in Oxfordshire.

Introduction

The LEP's European Structural and Investment Fund (ESIF) Plan commits £16.5m for Oxfordshire to 2020 (subject to being match-funded from non-EU sources). Of this, £2m (12%) is to be used to support low carbon innovation, including the designing, testing, commercialising and mainstreaming of sustainable goods, services and processes. ESIF has targets for business support, job creation and training (Table 4.1)

Table 4.1 **Summary of enterprise and job creation targets for Oxfordshire in European Structural and Investment Fund plan**

Funding	Target no. enterprises supported	Target no. jobs created	Target no. people trained
£16.5m	1700	1000	2800

There is, therefore, a very timely opportunity to influence the allocation of these funds to capitalise on the opportunities for low carbon innovation and growth.

Oxfordshire expertise

Oxfordshire is reported by the Carbon Trust as one of the top five counties in the UK for low carbon entrepreneurial activity by total number of low carbon SMEs.²⁶ The SEP and ESIF both reference low carbon innovation as one of Oxfordshire's strengths as well as growth opportunities, with 'clusters' of expertise in Wallingford and Harwell.

After adjusting for population, Oxfordshire's LEP generated £2,000 worth of low carbon and environmental goods and services per capita and employed 1.6 per cent of the population in these sectors in 2012, while Greater Cambridge Greater Peterborough Enterprise Partnership performed only slightly better, generating £2,500 worth of sales per person and employing 1.8 per cent of the population.

26 Low Carbon Entrepreneurs: New Engines of Growth, 2013

Energy research has been an integral part of Oxfordshire's R&D landscape since the 1940s, when the Atomic Energy Research Establishment (AERE) was established at Harwell. Since the 1960s Harwell (and Culham) has been home to much of Oxfordshire's high tech research and development activity, of which energy is an integral part. Energy, its diffusion into other 'sectors', and the development of low carbon technologies, is part of our innovation and entrepreneurial landscape.

Invest in Oxfordshire reports that Oxfordshire is home to environmental technology expertise, with a niche water cluster around Wallingford and the Centre for Ecology & Hydrology. Such businesses include: environmental hydraulics, management of the maritime environment, agricultural development and research in terrestrial and freshwater ecosystems.

In addition, Oxfordshire has a number of companies that are leading the development of alternative power sources and energy storage; including Sharp Laboratories, PV Crystallox, Ceramic Fuel Cells, and Reaction Engines.

We have a strong high tech research base. Oxfordshire is amongst the top five 'technology innovation ecosystems' in the world, and is home to 1,500 high tech firms employing around 43,000 people; including 6,400 in Research & Development in knowledge intensive businesses.²⁷ Oxford University alone has over 500 researchers in energy and its related fields across a number of departments.

Longer term Growth Opportunities for a Low Carbon Economy

Reflecting our strengths and potential, the ESIF strategy highlights low carbon and sustainable energy solutions as a priority growth sector for Oxfordshire. Low Carbon funds will be allocated to support innovation driven solutions to the challenges of transition, focused on designing, testing, commercialising and mainstreaming goods, services and processes, which are sustainable in both business and environmental terms. But where should we invest our resources?

Low carbon innovation may be more extensive than the data reveals, even if it is not well joined up. Analysis of national statistics using Standard Industrial Classification (SIC) codes has identified 570 firms within Oxfordshire's low carbon economy, a bottom quartile LEP ranking relative to other parts of the UK. The Carbon Trust cites Oxfordshire as one of the top five hubs of low carbon entrepreneurship. Anecdotally, we believe the presence of SMEs engaging in low carbon activities to be far greater than SIC codes might suggest; and existing business support networks such as Invest In Oxfordshire and the LEP have not been able to map the local ecosystem. In addition, our universities, research centres and Isis Innovation are home to a significant number of R&D programmes that have the potential for commercial development.

²⁷ <https://www.oxfordshire.gov.uk/cms/sites/default/files/folders/documents/news/CityDealBriefing.pdf>

In addition to the water 'cluster' in Wallingford, the energy 'cluster' in Harwell, and the spinouts, the following SMEs are based in the city and county (not an exhaustive list):

- Agrivest
- Anakarta Windpower
- Cella Energy
- Ceramic Fuel Cells
- Earth Save Products
- Earth Wise
- Energenics
- Exhergy
- Hallidays Hydro
- Navetas
- Nexeon
- Oxford PV
- Oxford Renewables
- Oxis Energy
- Oxyntix Ltd
- Photon
- Pilio Ltd
- Preston Innovations
- PV Crystallox
- Rezatec
- Synergy Energy
- Tokamac Fusion
- Torftech
- Williams F1 Advanced Engineering
- Yasa
- Zeta Group

Oxfordshire is also home to globally focused environmental, resource and climate change, finance, policy, sustainability and supply chain services expertise – including the following (not an exhaustive list):

- 2Degrees
- Achilles
- Best Foot Forward – Anthesis
- CABI
- EcoSecurities
- Environmental Resources Management (ERM)
- Poyry
- Ricardo-AEA

There is also a growing number of SMEs such as Ethex, Aether, Kinetix, Bainton Capital Partners, Meteos, Joju Solar; and social enterprises working for social and environmental impact – such as Cultivate, R-ECO, Osney Lock Hydro and the Low Carbon Hub.

More background work is needed to understand the local landscape in terms of the innovators and SMEs developing low carbon products and services. We do not know the extent of the supply chain, or even the value chain. This problem is not unique to the low carbon ecosystem, with the 2013 SQW Innovation Engine report commenting on the 'paucity of data' in terms of insight into the high tech community. The LEP's Innovation Support for Business (ISfB) programme is addressing this gap through a team of 'network navigators' (including a low carbon champion) whose role is to increase the connectivity and visibility of the county's business communities.

Structural Barriers to Low Carbon Innovation

The challenges for innovative and entrepreneurial activity in Oxfordshire – regardless of sector – have been documented elsewhere.²⁸ As the ESIF strategy reports, at the level of innovation and encouragement of entrepreneurship, constraints on Oxfordshire's potential include:

- attitudes amongst graduates and others with necessary skills to working in start ups
- lack of adequate incubator space
- absence of particular sorts of funding, particularly moving from proof of concept to commercial viability
- low capacity to bid for external institutional funding
- entrepreneurs not finding the technologies that they can develop into new businesses
- inadequate support to businesses seeking investment
- inability of people offering services to find those who are looking for them
- lack of any forum to actively learn from others about what works
- inadequate links between existing research institutions and business.²⁹

It is the recognition of these often-structural barriers that informed the City Deal strategy and the current ISfB programme of 'network navigators'; including a low carbon focused network navigator.³⁰

Access to capital and our talent drain is a perennial and acknowledged problem for Oxford. Mark Evans, one of Oxfordshire's serial entrepreneurs, explains the impact of our fragmented low carbon ecosystem and its lack of depth:

"As fires require heat, fuel and oxygen an entrepreneurial system requires ideas, entrepreneurs and funding... One of many reasons why Silicon Valley is successful in attracting [Oxford's] talent is that much of the investment in start-ups is 'recycled capital' provided by successful entrepreneurs as they bring expertise and contacts as well... if we want to try to win the battle for clean tech we need to pump-prime an entrepreneurial ecosystem that can recycle its capital and draw in, rather than expel, entrepreneurs."

This is certainly true of Cambridge's experience, where 80 per cent of start-ups are still viable after three years, compared with 58 per cent nationally. An important reason for this success is that local angels repeatedly invest in local companies.³¹

But low carbon innovation faces its own challenges that can inhibit access to funding, expertise and even innovation itself. Innovations to respond to climate change are inherently multidisciplinary, multi-agency and require a long-term perspective.

It is a long-term commitment with significant risks. Many of these policies require upfront investment and will not produce tangible returns within traditional political cycles. Whilst cities like London, New York and Bristol benefit from having a Mayor who can instil a vision, and other cities such as Palo Alto, Chicago and Los Angeles that have their own Chief Sustainability

28 References to SQW and SEP.

29 Oxfordshire Accelerator Programme submission 2014

30 <http://www.oxfordshirebusinesssupport.co.uk/networking-and-events/network-navigators>

31 <http://www.independent.co.uk/news/business/analysis-and-features/why-cambridge-is-at-the-heart-of-britains-economic-recovery-9134717.html>

Officers, it is the culture and networks across businesses, residents and the public sector within a city region that ensure 'low carbon goals' remain a priority beyond political cycles. Achieving this requires skilful negotiation of many 'policy dilemmas', which are a matter of judgement and negotiation rather than pre-ordained 'right answers' (table 4.2). Maintaining this city-wide ethos requires significant community and business support. If low carbon values are held and shared, it is easier for local government and businesses to prioritise measures that drive green growth.³²

Table 4.2 Some policy dilemmas in managing innovation for sustainability goals³³

Issues	Policy dilemmas
Expectations, vision	Be flexible, engage in iterative visioning exercises BUT ... stick to the vision, persist when the going gets tough
Variety of innovation	Create variety to facilitate broad learning BUT ... too much variety dilutes precious resources, creates uncertainty and may delay choices/commitments (eg by consumers, policy makers)
Scale of innovation	'Bottom-up', step-wise learning has disadvantages in being slow and incremental BUT... big breakthroughs carry bigger risks
Incumbents	Incumbent actors have resources, competence and 'mass' BUT... also have vested interests against radical innovations
Incubating innovation	Protection is needed to enable nurturing of niche-innovations BUT... over-protection might lead to limited exposure to selection pressures (and the danger of creating white elephants)

EU analysis of eco innovation in SMEs (2013) found continuing market gaps and deficiencies in debt and equity markets for the financing of innovative enterprises, with 75% of SMEs dependent on external financing. In addition, Venture Capital fundraising and investment levels are at one quarter of 2006 levels.³⁴

This creates the problem of a second 'valley of death' i.e. at the commercialisation stage, and a 'fingers burnt' and immature clean tech VC market who see low carbon innovation as high technical and financial risk with uncertain payback.³⁵

32 [ref Centre for Cities 2013]

33 Adapted from Schot, J. & Geels, F.W. 2008, "Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy", *Technology Analysis & Strategic Management*, 20(5), pp. 537-554.

34 Europa: Promoting Eco Innovation in SMEs, Brussels, 2013

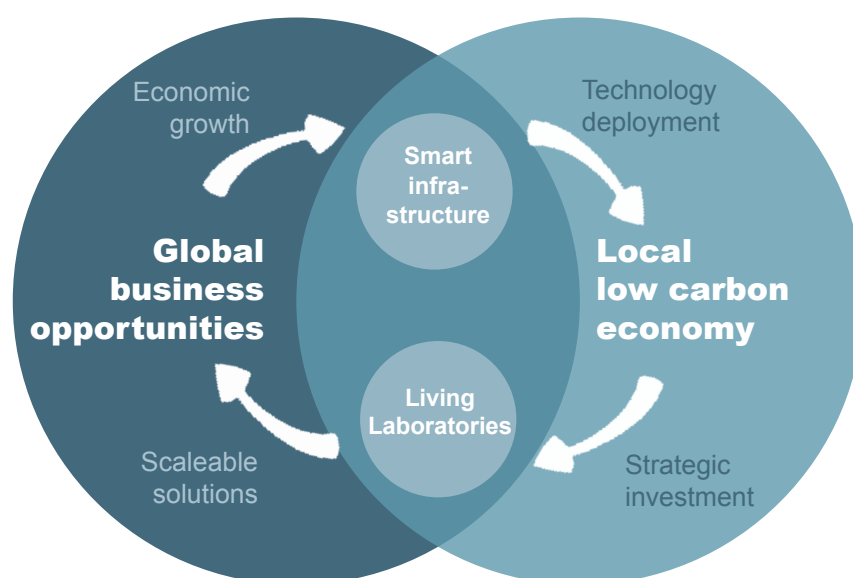
35 LCICG, London, 2013

Another barrier that low carbon and renewable energy technologies face to reaching the market is the complex nature of the energy sector, with technologies too large and too complex to be developed without high tech laboratories and large work spaces.³⁶ While we have these resources in Oxfordshire today, the City Deal's innovation centres will provide greater capacity and connectivity. In addition, the formation of the Energy Systems Catapult in 2015, the Future Cities Catapult, the existing Energy Innovation Centre, can help address these industry-level structural issues.

Creating a Low Carbon Ecosystem

Technology firms working in related fields benefit from being located close to one another, following the established model of economic clusters. For technologies which contribute to a low- carbon economy, the concept of clusters is both useful and relevant.

Figure 4.1 The low carbon living laboratories as a driver of Oxfordshire's economy



The transfer of learning and opportunities from innovation into other sectors (non-rivals) depends on the specificity of the innovation. Spill overs³⁷ are expected to be high if the innovation has multi and general purpose attributes and uses. Combinatorial technologies can lead to rapid and high value addition as they can be used in joint production. For example, Oxford University spin-out Oxford PV has pioneered the development of solar cells which can be printed onto glass and thereby integrated into the glazing units of a building.

However, a low-carbon economy is about more than technology, and a broader focus is needed in order to harness innovations for low-carbon goals. To help clarify how different partnerships relate to each other, we propose an outline of a low carbon 'ecosystem', based on three types of interdependent collaborations.

Firstly, there are technology 'clusters', where firms working on related technology innovations can benefit in a number of ways from being located in the same geographical place (sharing of ideas and resources; increased chance of 'breakthrough' moments). Secondly, the principle of 'networks' goes beyond the more narrowly technical focus of a cluster, bringing in other stakeholders who can help develop market opportunities for technology deployment. Thirdly, the model of a 'living laboratory' adds new layers of complexity, with a focus on innovation

36 Meeting note: Navigating the Valley of Death: Measurement to Support Low Carbon Technology Commercialisation. 3 September 2013, British Academy

37 Spill over effects are externalities of economic activity or processes that affect those who are not directly involved.

processes which are open, user-centred and made in real-life settings. The boundaries between these three types of collaboration are not absolute. Firms and organisations collaborate all the time, moving between different points of focus and different scales. Nonetheless, it seems helpful for strategic purposes to define more clearly what these collaborations involve, and where they fit into a broader framework.

Table 4.3 Types of collaborative partnerships in a low-carbon ecosystem

Name	Types of members	Focal point
cluster	firms	Technology development (how to create/improve a technology)
network	clusters, firms	Market development (how to increase technology deployment)
living laboratory	clusters, firms, networks, users, policy-makers	Outcomes in real-life settings (eg how to enhance a particular town or place?)

One or more of the three types of partnership may be relevant at any given time, and individuals may contribute to several of them. The ecosystem is made up of multiple partnerships at all levels – clusters, networks and living labs (Figure 4.2, overleaf).

Case study: Low Carbon Oxford

Low Carbon Oxford (LCO) is an organisational network, established by the Oxford Strategic Partnership in 2010. It receives its core funding from Oxford City Council, as well as the Low Carbon Hub. LCO focus on three main areas with its members: energy efficiency and carbon, local food systems, and behaviour change / public engagement. There are 40 organisational members, ranging from the Diocese of Oxford, to Oxford Bus Company, Oxford Brookes, Oxford University, Unipart, MINI Plant Oxford, Oxford City Council, Oxfordshire County Council, GreenSquare, Blake Morgan and an increasing number of SMEs. Since 2013, LCO's focus has extended further into the County – principally the knowledge economy hubs – to begin to develop a 'low carbon ecosystem' of innovators, entrepreneurs, investors, established businesses, local government and communities, all of whom supply, deliver and consume goods and services that can contribute to a low carbon economy. Part of LCO's work is now funded by the LEP, as the low carbon 'network navigator' within the Oxfordshire Innovation Support for Business programme. LCO was involved in consultation on the City Deal, Strategic Economic Plan and ESIF strategies, and in particular low carbon innovation. LCO's Board agreed that this ecosystem approach would increase the opportunities to stimulate an inclusive low carbon economy and reduce Oxford's carbon emissions.

Case study: The Eco-Bicester Living Lab

The Eco-Bicester Living Lab (EBLL) captures the learning and innovation that is happening in Bicester. It is jointly run by Oxford Brookes University and BioRegional Development Group, with many other stakeholders involved in specific projects. Lessons learned are fed back locally to benefit Bicester and also shared with the wider communities. The EBLL initiative will not only provide Bicester with evidence-based learning and innovation, but also contributes to transforming Bicester into a sustainable place to live and work. The EBLL offers independent review, leading expertise and academic integrity for:

- Producing policy-relevant, practice-oriented and academically rigorous research
- Capturing the learning for continuous feedback and improvement
- Telling the stories

Bicester is home to 30,000 people with plans for some 10,000 new homes by 2031. The Eco-Bicester programme, led by Cherwell District Council, covers the creation of an initial 6,000 home extension and a range of social, economic and environmental projects within the existing town so that it benefits from the major expansion and becomes a better, more sustainable place to live in, work in and do business.

Bicester was selected as 1 of 4 designated Eco-Towns in 2009. The successful Bicester Eco-Town proposal included a 6,000 home extension to the town called NW Bicester and also a group of demonstration projects across the town bringing eco town benefits to the existing residents. Specific projects in the EBLL programme include:

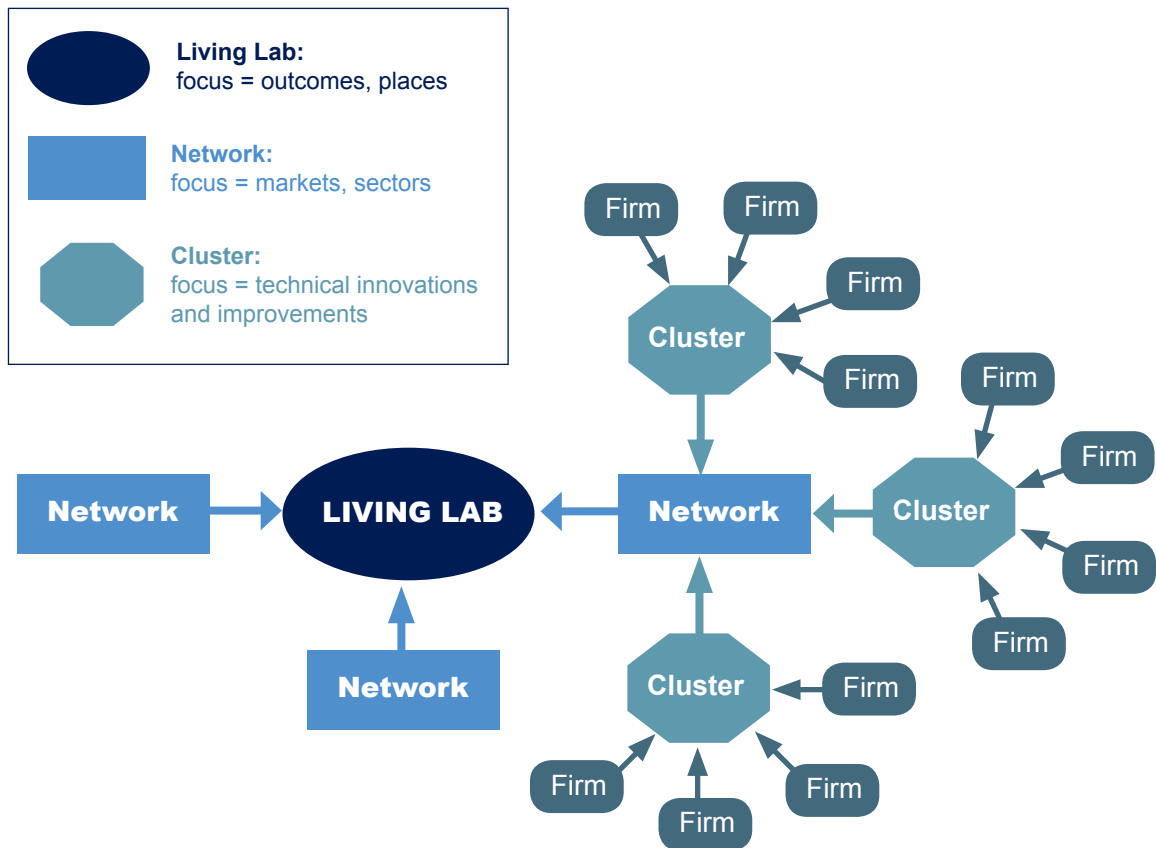
The Bicester Eco-Town Process Improvement Toolkit (BEPIT) – a four year research project, following all aspects of the build process and collecting data on the first 393 zero-carbon homes at NW Bicester. The project will lead to refinements to products, processes and specifications by engaging researchers in observing processes, testing the real-life performance of home, and finding solutions to problems collaboratively.

Innovative Refurbishment: The Garth, Bicester – a complete upgrade in the energy performance of Bicester Town Council offices, while respecting the historic aesthetic of the 180 year old building. Laser measuring technology creates a detailed and accurate plan for cutting insulation panels off-site, leading to 30% cost savings and far less disruption, allowing commercial activities to continue largely uninterrupted. Oxford Brookes University will monitor the building for a minimum of 12 months in order to evaluate the technical performance and user experience of the process and outcomes.

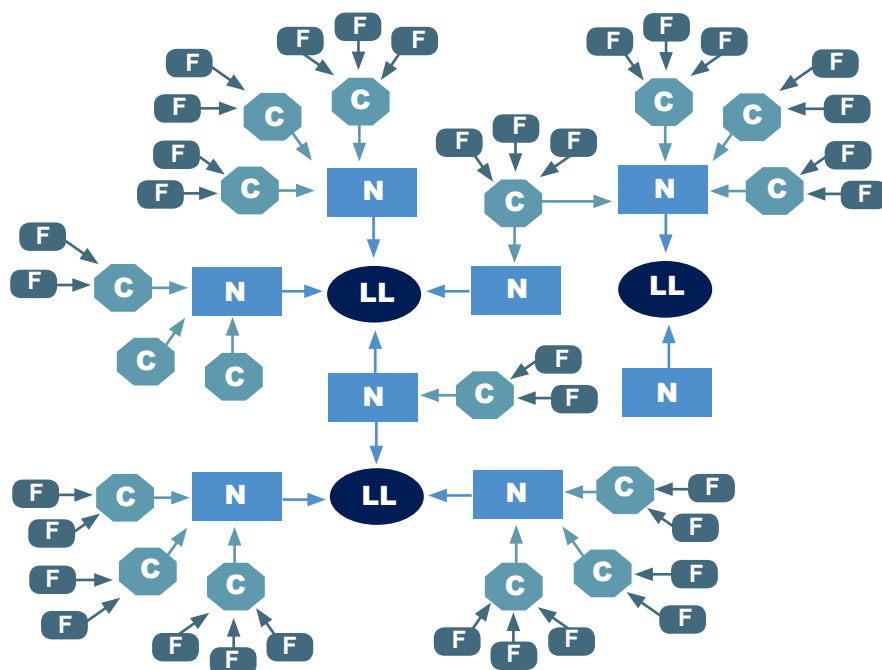
John Paul II Centre – designed to meet the Passive House energy standard, the centre utilises construction techniques which are far from standard in the UK. The contractors had to be extremely rigorous in ensuring no gaps or cracks were left in the external fabric, requiring additional training. Early performance was mixed, with lower electricity consumption than expected, but higher gas consumption. Over-heating has occurred at times. Lessons continue to be learned from ongoing monitoring and reviews of operations and energy system controls.

Further details on these and other projects can be found at:
<http://bicesterlivinglab.org/>

Figure 4.2 **Hierarchy of types of partnership**



An ecosystem composed of interdependent partnerships



Scaling up the response

The plans for growth in low-carbon activities, supported by European funding (ESIF, ERDF, EAFRD) are a first step in realising the full potential of Oxfordshire's low-carbon economy. The partnerships need to grow and mature much further if the idea of multiple living laboratories in a broad low-carbon ecosystem is to be achieved. Technology clusters and business networks have an important role to play, but greater coordination is needed to bring more of the stakeholders together, including ones who are currently unknown to the network coordinators. Expanding the collaborative partnerships creates a new management task, but it also provides access to bigger sums and a greater diversity of finance.

5. Scenarios for low-carbon innovation and infrastructure investment

In order to explore the different possible futures to 2030 for Oxfordshire's low carbon infrastructure, three scenarios have been developed. None of them should be seen as a forecast or prediction, but instead the scenarios allow different possible development and investment strategies to be explored and compared. The scenarios focus on key development measures for the county, including low carbon vehicle deployment, sustainable transport provision, new low carbon housing, low carbon renovation of existing homes, and increased renewable energy deployment.

The scenarios are briefly described here, with more detail in the following chapters on the specific implications for housing, transport, and energy systems.

Scenario A – Business as usual / low ambition for low carbon

In scenario A the underlying assumption is that development and investment plans will continue along the lines of recent trends, unless there is already strong evidence of a commitment to change. Committed new projects are included, but ones which are still in early stages of development are not. So, for example, the new Oxford-Marylebone rail line (which is part of the County Council's Local Transport Plan 2011 – 2030) is included in scenario A, but new transport links to connect possible new settlements are not.

Automotive cluster activity increases by 50% by 2030, in line with expected economic growth, but only 10% of this is from low carbon vehicles and fuels. Only 1-2% of new road vehicles are 'plug-in' in 2030; while this is 10 times more than now it is in line with recent growth trends. Less than 1% of all homes have an electric charging point installed.

Similarly, the figures for house-building are based on historic trends (37,000 new homes by 2030), rather than Local Plan documents. The Local Plans identify many possible new sites, but the majority of them would involve extensive Planning processes before development could take place. A very small number (40 per year) of existing homes are refurbished to a fairly advanced energy standard, led mainly by private home-owners and social landlords. In total, Oxfordshire would have 37,000 new homes by 2031 and over 700 homes refurbished. The number of homes would be insufficient to house both the existing population and the numbers expected to move to the county as part of the economic growth plans.

Local energy generation investment continues to be the exception, not the norm. Currently planned developments are implemented, with some solar and biomass use in new housing developments, but otherwise growth is stalled by planning constraints. Local renewables provide 15% of electricity and 1% of heat by 2030.

Scenario B – Incremental growth / moderate ambition for low carbon

Scenario B describes a possible future in which the levels of development and investment growth are higher than recent historic trends, leading to increased pressures on infrastructure. An effort is made to provide new infrastructure for sustainable transport provision and low carbon refurbishment. Infrastructure development is, however, at the lower end of what is currently being discussed.

Automotive cluster activity increases by 50% by 2030 (as in scenario A), but 25% of this is from low carbon vehicles and fuels. 10-20% of new vehicles are 'plug-in' in 2030, representing a moderate increase in uptake rates by private and fleet/company buyers. 10,000 new electric home and public slow/fast charging points are installed to serve the burgeoning plug-in vehicle fleet. 50km of new high quality walking and cycling infrastructure is installed, but public transport provision lacks the new mass rapid transit system needed to trigger sustained mode shift, relying heavily on optimising existing infrastructure through demand management and ICT.

The number of new homes is in line with the Local Plans published recently by the four District Councils and Oxford City Council, giving a total of approximately 50,000 new homes by 2031. The Local Plans indicate that this number can be accommodated in peripheral expansion of existing towns and large villages. In addition, it is assumed that the new homes are built to tighter energy standards than in Scenario A. Turning to the existing housing stock, it is assumed that a strategic effort is directed at increasing current levels of activity by a factor of ten (up to 400 low-energy home refurbishments per year). Even at this scale, the total number of refurbished homes by 2031 is less than 3% of the total housing stock in the county. The energy standard for refurbishment is also slightly more ambitious than in Scenario A.

Local energy generation investment continues to increase slowly through a range of business models including community projects and in low carbon housing, but only reaching 10-20% of the potential not already committed by 2030. Local renewables provide 23% of electricity and 5% of heat by 2030. Smart meters are fully rolled out by 2020, and new developments after that date incorporate smart grid technology.

Scenario C – Radical growth / high ambition for low carbon

This scenario does two things: it includes the most ambitious targets for infrastructure growth (in terms of what is currently being debated); and it assumes that the way in which that infrastructure is provided allows for ambitious, integrated low-carbon solutions, including such ideas as ‘pearl on a string’ new settlements built on greenfield sites, connected by high-quality transport links with an emphasis on sustainable modes.

For transport, Oxfordshire is making good use of its comparative advantage in the automotive cluster, with cluster activity doubling by 2030 (higher than in scenarios A and B) and 50% of this coming from low carbon vehicles and fuels. This reflects a major drive to invest in automotive vehicle and fuel production in the county, enabled by better infrastructure provision and institutional innovation around a number of ‘living labs’ (transport, housing, etc). 25-50% of new vehicles are ‘plug-in’ in 2030, representing a substantial increase in uptake rates by private and fleet/company buyers. 100,000 new electric home and public slow/fast charging points are installed to serve the plug-in vehicle fleets. New sustainable transport infrastructure has been built along the ‘string of pearls’ (Science Vale and North-South corridor), including a new mass rapid transit system, the 50km “Oxfordshire Busway”, and 200km of new high quality walking and cycling routes. To maximise the use of sustainable transport options, all homes (new and existing) have had a personalised travel planning assessment by 2030.

The figure for new homes is 100,000 by 2030, in line with the need for housing set out in the Strategic Housing Market Assessment. Given that the local authorities have together identified sufficient new development sites for 50,000 homes by in-fill and expansion of existing settlements, achieving 100,000 would mean assigning relatively large areas of Greenfield land for development. New homes are all built to standards which equate to the very best of current best practice. The refurbishment numbers rise again by a factor of ten compared with Scenario B (4,000 per year) and the energy standard assumed is once again slightly more ambitious than in Scenario B – in line with current best practice. In scenario C, enough homes would have been built by 2031 to meet the full SHMA target, and a quarter of the county’s existing homes would have undergone an extensive low-energy refurbishment.

Renewable energy becomes mainstream in the 2020s. All new developments are built with renewable energy as the main supply, and community wind and solar projects become normalised in the planning process. Costs of solar electricity solar continue to fall, so that it becomes commonly used on buildings, with large solar farms on low grade agricultural land. Biomass crops and anaerobic digestion become a significant part of the rural economy. Local renewables provide 56% of electricity and 40% of heat by 2030. Smart meters are fully rolled out by 2020, and smart grids technology is deployed very extensively thereafter.

Assumptions behind scenarios in numbers

Table 5.1 summarises the key numbers behind the assumptions for each scenario.

Table 5.1 **Key assumptions and rationales for the three scenarios**

2030 Scenarios	A	B	C	Key assumptions/rationales
HOUSING				
New homes				
No. of new homes by 2030	37,000	50,000	100,000	
Energy standard for new homes per unit floor area, kWh/m ² year	50	40	30	NB. many building technologies can contribute to achieving the standard
Renovation of existing homes				
No. of existing homes renovated per year	40	400	4,000	
Energy standard for renovations per unit floor area, kWh/m ² year	100	80	60	NB. many building technologies can contribute to achieving the standard
TRANSPORT				
Alternative vehicles & fuels				
Average no. new vehicles per year	33,450	34,417	38,133	Most are new cars; figures also include new vans, trucks & buses
Share of EVs in new fleets	1%	10%	25%	
Automotive cluster activity				
Automotive production growth in 2030 (compared with 2014)	150%	150%	200%	
Proportion of new production that relates to low carbon vehicles	10%	25%	50%	
Infrastructure				
No. of EV home charging points installed by 2030	1,000	10,000	30,000	Up to 6,000 per district area, costing £700 each, spread over 15 years
No. of public DC fast and AC slow charging stations	10	100	300	Up to 5 DC and 55 AC per district area, spread over 15 years
Mass rapid transit (km)	–	–	50	Oxfordshire Busway modelled on Cambridgeshire Busway
Cycling infrastructure (km)	–	50	200	Includes cycle routes, bridges, tunnels, interchanges and a bike hire scheme
Influencing travel behaviour				
No. of personalised travel plans for all homes (new and existing)	3,100	32,300	373,000	Rising to 100% coverage in scenario C
ELECTRICITY SUPPLY				
Renewable heat supply, GWh	63	258	2183	
Renewable heat as a percentage of total heat demand	1%	5%	40%	
Renewable electricity supply	539	842	2052	A = committed projects + new buildings B = A+20% of other potential C = full potential
Renewable electricity supply as a percentage of electricity demand	15%	23%	56%	

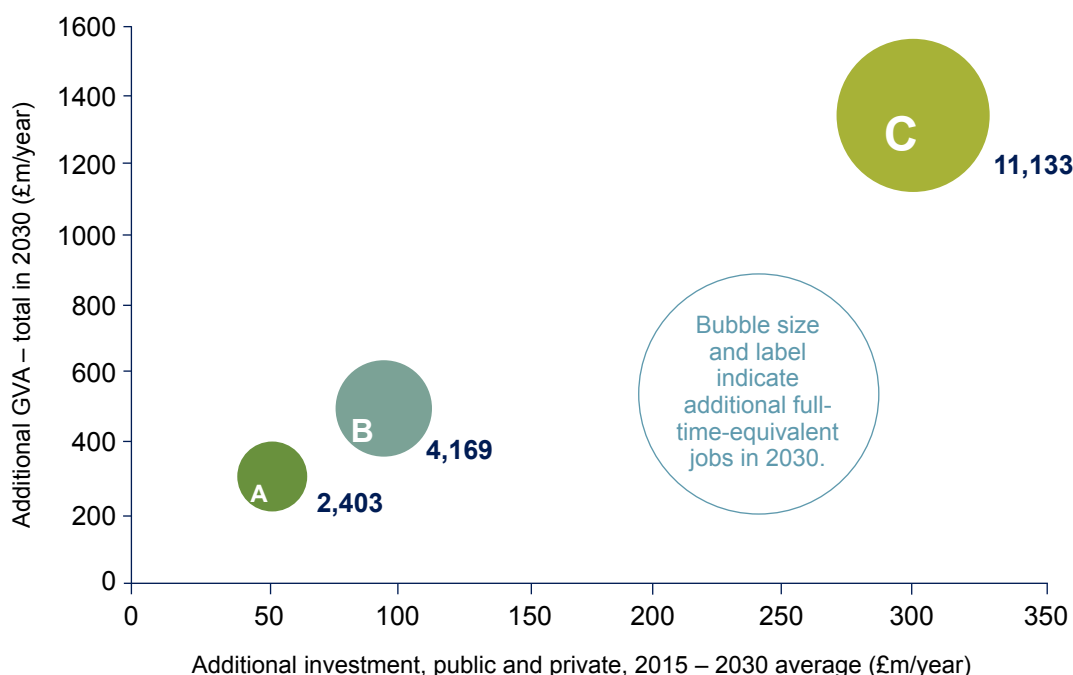
Outputs: investment, employment and value added

Based on the scenario descriptions and assumptions above the additional investments needed and potential employment and GVA impacts for each scenario are shown in Table 5.2. The results suggest that additional investment in low carbon business sectors and infrastructure can generate significant numbers of jobs and economic output. In the most ambitious investment and abatement scenario tested here (scenario C), additional investment of about £300 million a year could generate an additional 11,100 jobs, adding economic value (GVA) of about £1.35 billion a year in 2030. The return on investment is clearly favourable across all three scenarios.

Table 5.2 **Annual investment, employment and GVA, three scenarios**

2030 Scenarios	A	B	C
INVESTMENT, £m/year to 2030			
Transport	1	10	49
Housing	14	22	50
Renewable energy	39	65	199
Total	54	97	298
ADDITIONAL GVA, £m/year to 2030			
Transport	54	134	364
Housing	29	41	94
Renewable energy	219	330	889
Total	302	505	1,347
ADDITIONAL EMPLOYMENT, FTE jobs in 2030			
Transport	621	1,541	4,256
Housing	618	864	1,972
Renewable energy	1,164	1,764	4,905
Total	2,403	4,169	11,133

Figure 5.1 **Additional GVA and jobs over additional investment in transport, housing and energy infrastructure, three scenarios**



6. Transport

“We have a history of developing innovative and successful transport projects such as the world’s first park and ride, and now they are the biggest and best used in the UK. Oxford also has the greenest buses outside of London, and we have plans for a new park and ride for Bicester and innovative schemes such as smart ticketing and mass transit. With 80,000 new jobs and 100,000 new homes expected in the county by 2031, demand for transport will continue to rise. Doing nothing is not an option.”

(Ian Hudspeth, Oxfordshire County Council leader, April 2014)

Transport in Oxfordshire now

Transport is an essential ‘grease’ for Oxfordshire’s economy and society to function. A comprehensive and high-performing transport system is an important *enabler* of sustained economic prosperity³⁸ and accessibility. Good transport links are cited as one of the top five factors that influence business location decisions according to 500 business leaders surveyed as part of the 2011 European Cities Monitor.³⁹ Transport and communications infrastructure are important for local economies as they facilitate the integration of the local area into regional, national and international markets, allowing greater potential to exploit local comparative advantage.

Today, the A34 carries about 70,000 vehicles per day and the M40 carries about 100,000 vehicles per day.⁴⁰ 80,000 vehicles carry 130,000 people across the ring road in 12 hours every weekday. 17,000 vehicles go over Folly Bridge every day. Sixteen million rail journeys were undertaken to or from Oxfordshire stations in 2012/3 (up 3%), and 39 million bus journeys. Oxford’s High Street carries around 180 buses per hour, or one every 20 seconds. While this is a lot of vehicular traffic, volumes on routes into Oxford city centre has actually reduced by nearly a quarter (24%) since 1993.

A high proportion of people living in the city also work or study there, but there is a great deal of in-commuting to Oxford (40,000 people per day) from adjoining towns such as Witney, Bicester, Abingdon and Didcot. In part this reflects a historic policy of concentrating housing growth in the county towns around Oxford. While people living in Oxford commute more by sustainable transport (i.e. bus and rail – 18.6%, walking – 16.8%, cycling – 17.1%) than by car (35.6%) (Table 6.1 and Figure 6.1), most people who live outside Oxford currently use a car to get to work (64.5% compared to bus – 4.5% and bike – 4.3%), with travel-to-work patterns showing a major corridor of movement along the “knowledge spine”, which is not served well by public transport. Over the past decade, car commuting has decreased more in Oxford than in the county regions. South Oxfordshire has the highest rail shares, which reflects the good rail links into Reading, London and the South West.

This picture suggests that the chronic shortage of (affordable) housing is forcing people to live miles from their workplaces in country towns where inadequate public transport means they have to travel to work by car. This leads to severe traffic congestion and a poor quality of life for commuters, higher costs for businesses and increasing levels of pollution and carbon emissions.

38 Eddington, R., 2006. The Eddington Transport Study: The case for action: Sir Rod Eddington's advice to Government, Summary Report. HMSO, London.

39 Cushman & Wakefield, 2011. European Cities Monitor 2011, <http://tinyurl.com/85tdk6r>. Cushman & Wakefield LLP, London.

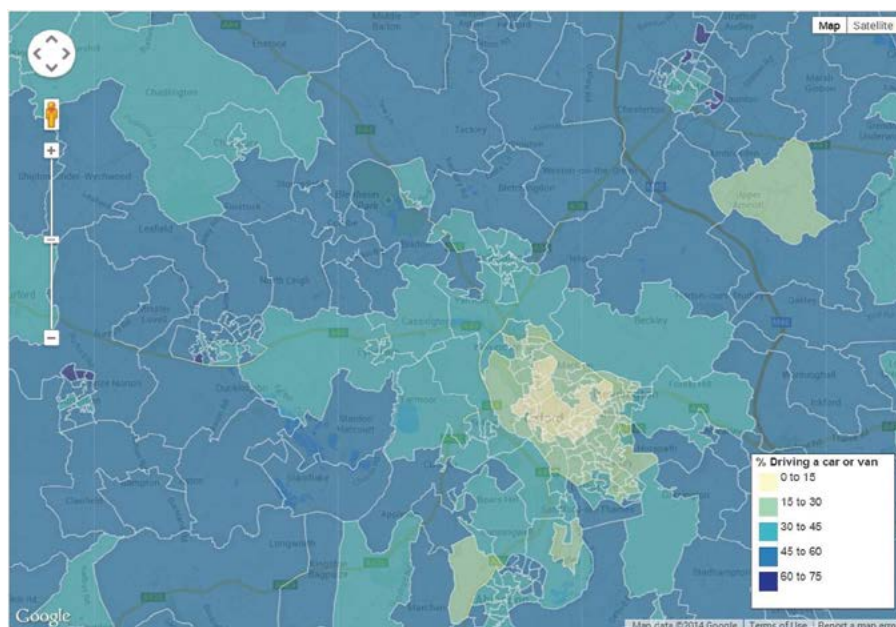
40 OCC, 2013. Automatic Traffic Count, Speed or Manual Count Surveys. Oxfordshire County Council, Oxford.

Table 6.1 Method of travel to work by local authority in 2001 and 2011

	Oxford		West Oxon		Cherwell		South Oxon		Vale of WH	
(%, apart from occupancy)	2001	2011	2001	2011	2001	2011	2001	2011	2001	2011
Work mainly at or from home	8.4	10.4	11.5	13.6	9.7	11.5	11.8	14.8	10.4	12.4
Underground, metro, tram	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.2
Train	1.8	2.4	1.5	1.7	1.7	2.8	4.3	4.7	1.8	2.2
Bus, minibus, coach	16.3	15.9	4.6	4.2	4.9	4.8	2.7	3.0	5.2	5.7
Taxi	0.4	0.4	0.2	0.2	0.4	0.4	0.2	0.1	0.1	0.1
Motorcycle, scooter, moped	1.1	0.7	0.9	0.9	1.0	0.7	1.1	0.8	1.3	1.0
Driving a car or van	37.7	32.4	61.7	61.6	60.9	59.8	61.9	59.2	60.2	59.6
Passenger in a car or van	4.2	3.1	5.7	4.5	6.6	5.3	4.9	3.8	5.4	4.1
Vehicle Occupancy Rate (raw)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Bicycle	14.9	17.1	4.9	4.0	3.9	3.4	3.8	3.6	6.7	6.2
On foot	14.7	16.8	8.5	8.9	10.6	10.9	8.8	9.4	8.3	8.2
Other method of travel	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4

Source: 2011 Census⁴¹

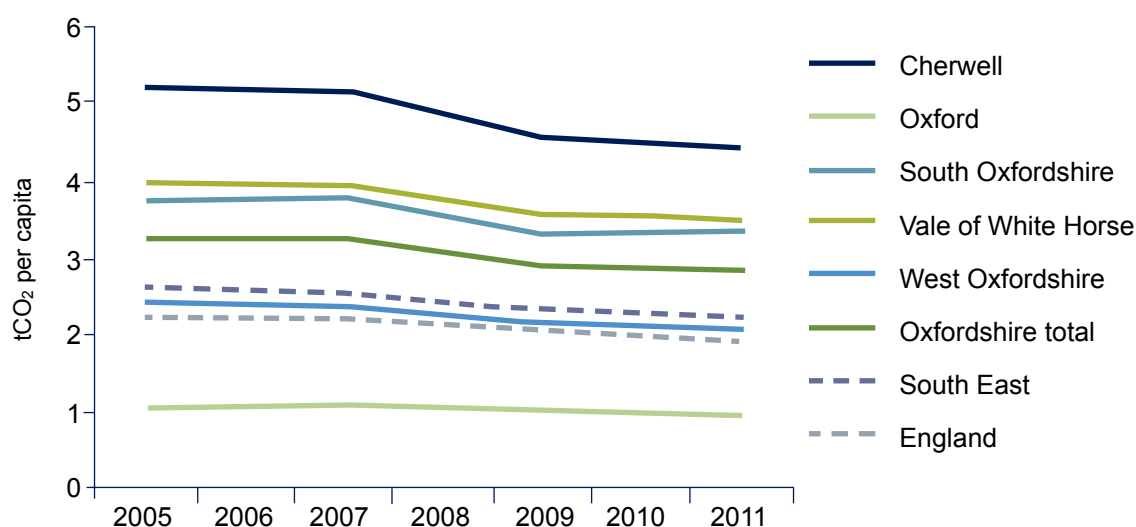
Figure 6.1 How people got to work in 2011
(% driving a car or van of all 16-74 year olds)



41 ONS, 2014. Census 2011, Method of Travel to Work data tables, last accessed 20/05/2014 at <http://bit.ly/1oMFb96>. Office for National Statistics, London.

Transport currently accounts for about 37% of total emissions in Oxfordshire; this compares to 35% in the South East, 29% in England and 29% in the UK.⁴² Mean CO₂ emissions per capita from all road and (diesel) rail transport in Oxfordshire were 2.9 tCO₂ per capita in 2011 and have decreased by 13% between 2005 and 2011, due mainly to a reduction in average distance travelled and technological efficiency gains (ibid). In 2011, Oxford accounted for the lowest (1.0 tCO₂ per capita) and Cherwell the highest (4.4 tCO₂ per capita) emissions levels (Figure 6.2) (ibid), largely reflecting variation in mode shares, existing road types and traffic levels in each local authority area. This compares to mean per capita emissions of 2.2 tCO₂ for the South East, 1.9 tCO₂ for England and 2.0 tCO₂ for the UK.

Figure 6.2 Per capita transport CO₂ emissions by Local Authority
(road and rail, excluding motorways)



Source: DECC⁴³

Transport prices have increased significantly over the last decade, mainly due to increased fuel (petrol, diesel) costs, higher parking charges and increases in bus and rail tickets well over and above inflation.⁴⁴ A typical 2.5 hour return trip from Abingdon into the city centre can cost £4.70 by bus, or about £6.30 by car via Redbridge P&R (£1.60 fuel cost, £2 parking fee, £2.70 P&R bus ticket), or £9.50 by car with parking 2-3 hours at Gloucester Green Car Park (£7.50, fuel cost £2), or for free if cycled all the way.

Transport policy and planning

National policies and drivers

The main national policy for mitigating climate change in transport (set out in the Government's Carbon Plan⁴⁵) is to support low carbon vehicle technology through grants and vehicle emission carbon targets for the automotive industry. This has been implemented as a mixed bag of financial incentives (graded vehicle excise duty – VED; a higher first-year registration VED,

⁴² DECC, 2013. 2011 carbon dioxide emission estimates at local authority and regional level. DECC, London.

⁴³ Ibid.

⁴⁴ DfT, 2013a. Transport Statistics Great Britain 2013. Department for Transport, London.

⁴⁵ DECC, 2011. The Carbon Plan: Delivering our low carbon future. Department of Energy and Climate Change, London.

essentially a graded purchase tax; fuel taxation), and (mostly EU) regulations and standards (mandatory new car/van CO₂ standards, air quality standards). Other national policies that indirectly influence carbon emissions include the provision of free bus passes for 60+ year olds and the legal framework for allowing local authorities to implement local schemes to charge for road-use, eg at peak times (but not taken up by local authorities outside London via the 'congestion charge'). The latter, in particular, has the potential to provide hypothecated revenue streams from road users to fund sustainable transport schemes. Other national sources of funding available to local authorities include the Local Sustainable Transport Fund.

Local delivery

The County Council, Oxfordshire's main transport authority, and the five District Councils are working on transport projects and strategies across the county (largely implementing the third Local Transport Plan, or LTP3, which covers the period from 2011 to 2030) to "improve accessibility to ensure its economy continues to thrive whilst also protecting and enhancing the county environment and communities".⁴⁶ Its primary objective for carbon emissions reduction is focused on encouraging trips to either not be made, or to be made by less carbon intensive transport modes (modal switch, providing for low and zero carbon vehicles).⁴⁷ Other objectives are expected to have an impact on carbon emissions reductions, including policies to reduce congestion and promote public transport, walking and cycling. The LTP3's £800 million (mostly private sector) investment out to 2020 is aimed at easing road traffic congestion, reducing rail journey times and better interconnections, including new and improved infrastructure such as:

- Northern Gateway roundabout improvements and new link road connecting the A40 and A44
- a 'piazza' on Frideswide Square (Oxford station) and surrounding area as 'gateway' to Oxford
- improvements at Junction 9 of the M40
- the new Oxford Parkway station at Water Eaton as part of East West Rail, with improvements to Oxford and Didcot stations
- new links and roundabout improvements around Science Vale Oxford at Milton and Chilton interchanges
- encouraging modal shift to sustainable transport modes, e.g. better routes and parking for active travel, promoting active travel in Oxford and county towns
- in county towns, encourage walking, cycling, bus services and local road capacity improvements. In Bicester, this includes better public transport connections between the eco development at NW Bicester, the town centre and Bicester Town Station – includes Bicester Park & Ride.

LTP3 further includes a number of Area Transport Strategies for the main county areas from Abingdon to Witney.⁴⁸

Beyond existing plans, the recently agreed City Deal will see the private sector invest £1.1 billion. The deal secures investment in major projects including improvement to the road network and first steps towards a new "Oxford science transit" public transport link from Bicester in the North

46 OCC, 2012. Oxfordshire Local Transport Plan 2011-2030. Oxfordshire County Council, Oxford.

47 Ibid.

48 Ibid.

to Science Vale in the South. Oxfordshire's SEP also refers to "strong transport connectivity" required in Oxfordshire and highlights the necessity of tackling congestion to enable growth.

As for the City, the Oxford Low Emissions Strategy⁴⁹ sets a city wide target of 35% reduction in transport CO₂ emissions between 2005 and 2020, representing a 2.3% annual decrease in emissions. The strategy has three priority areas relating to transport:

- 1.** To develop a city wide sustainable travel plan out to 2020, with an indicative target of a 10% reduction in car vehicle-km by 2020, equating to saving some 10 ktCO₂ annually
- 2.** Emission reduction measures for the freight sector, including a freight consolidation centre and extension of the low emission zone (LEZ) to freight vehicles (CO₂ emissions reductions of about 5 kt per year)
- 3.** To promote zero emission vehicles in both the business and private light duty vehicle fleets, including extension of the recharging infrastructure for electric vehicles.

Oxford City Council has approached its transport strategy by focusing on improving accessibility to key services and opportunities, with its Core Strategy emphasising willingness to partner with the relevant transport authorities (Oxfordshire County Council, Highways Agency, public transport operators) to improve Oxford's overall accessibility.⁵⁰

Similar strategies exist for the key county towns and areas through the LTP3's Transport Area Strategies.⁵¹

Beyond 2020, a long-term vision for transport in Oxfordshire was recently launched by the Oxfordshire County Council under the banner "Connecting Oxfordshire".⁵² The vision aims to "improve the network and consider new means of transport to create a 21st century transport system that connects people to places and jobs". It is currently out for stakeholder consultation and includes ideas such as:

- creating a passenger service on the existing Cowley branch line (currently used for freight only)
- a "mass transit system" (not necessarily trams) into Oxford
- a monorail connecting key locations around the county.

The City Council's longer term ideas include measures such as:

- remote Park and Ride sites at locations closer to journey *sources*, which connect to new development sites (e.g. Bicester)
- improved cross-city (orbital) bus services, directly linking areas outside the city centre, including district centres and the Headington hospitals, to help address the inconvenience of changing buses in the city centre
- re-opening the Cowley branch line for passenger transit (in line with Oxfordshire County Council's thinking)
- an intelligent traffic-management system, which prioritises bus movements
- further restrictions on non-essential traffic in the City Centre

49 OCityC, 2013. Low Emission Strategy. Oxford City Council, Oxford.

50 OCityC, 2011. Oxford Core Strategy 2026. Oxford City Council, Oxford.

51 OCC, 2012. Oxfordshire Local Transport Plan 2011-2030. Oxfordshire County Council, Oxford.

52 OCC, 2014. Connecting Oxfordshire: a vision for transport in Oxfordshire. Oxfordshire County Council, Oxford.

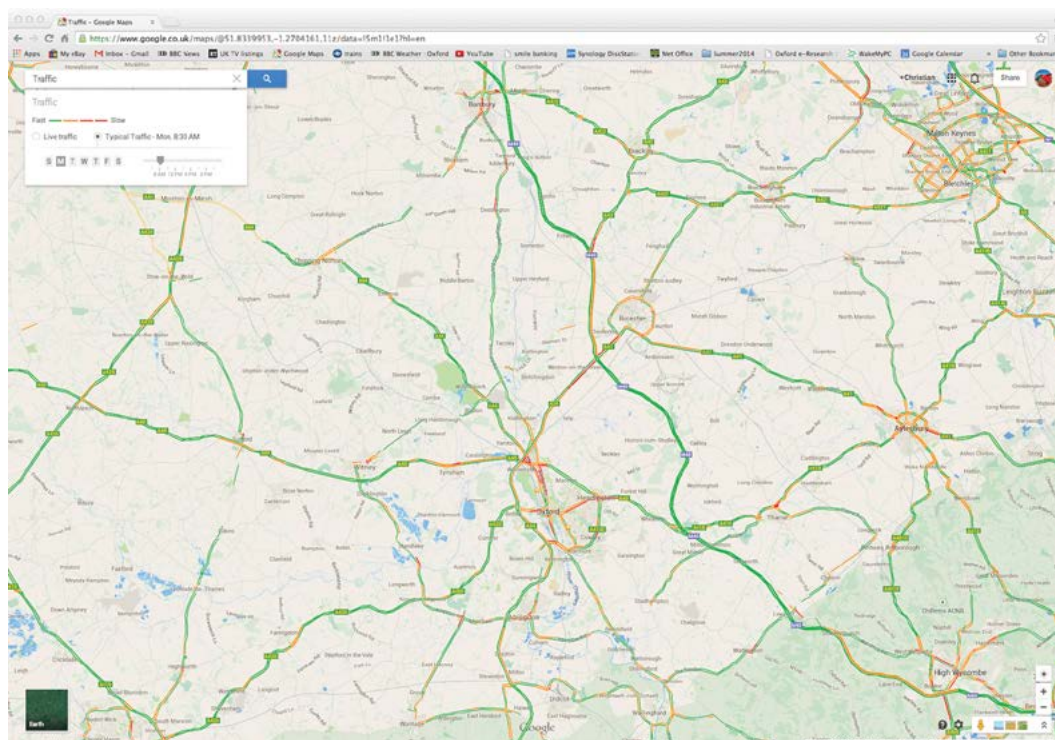
- further measures to reduce the environmental impact of buses, which could include statutory controls
- a workplace parking levy, or congestion charge.

These visions and ideas will feed into the recently commissioned Oxford Transport Strategy to bring existing work together and provide “an ambitious, innovative and robust strategy” to help the city meet its future challenges. There is also an Oxford Cycling Vision and Strategy in preparation; however, we did not have any details at the time of writing of this report.

Transport issues and challenges

Oxfordshire faces major transport challenges, and arguably the biggest and most politically charged one is traffic congestion, both on the roads and on the railways, with negative social, environmental and economic impacts. Operational capacity has already been reached or exceeded on much of the road network (the A34 and A40 trunk roads in particular), resulting in frequent congestion and delays (Figure 6.3).

Figure 6.3 Google map of major road and rail infrastructures – with typical traffic delays



Source: Google Maps⁵³

Substantial growth in housing and commercial development is planned in the city and in the rest of Oxfordshire, which will only increase these pressures, particularly at peak times. The challenge is to restrict traffic growth and manage additional traffic burdens induced by new infrastructure without causing further congestion on the network. A particular short term challenge in the City is the planned Westgate redevelopment, which will reduce the number of parking spaces available in the city centre by about 400 from 1100, further increasing the need

⁵³ Google Maps, last accessed 19/05/2014

for better alternatives to car travel, in particular during the Saturday (shopping, leisure) peak when the Westgate car park currently reaches near capacity. This challenge can also be an opportunity to do something different, something better – a point that is taken up further below with the ‘integrated transport living lab’.

Population growth and new employment centres are exerting a real pressure on the transport system. Planned new housing, such as at Barton Park and NW Bicester, and expansion of the technology and knowledge industry ‘Science Vale Oxford’ located outside existing urban areas or close to the strategic transport network pose the challenge of people commuting over longer distances, mode shift to more motorised travel and increasing congestion.⁵⁴

Good accessibility to a range of facilities is an important element of planning sustainable communities. However, good accessibility by walking, cycling and public transport is largely limited to the city as well as within and between county towns such as Bicester, with more rural areas of the County falling somewhat behind and therefore relying much on the car and road network. Within the county, the planning authorities require a Transport Assessment and comprehensive Travel Plan to accompany all “major development proposals” (40 or more dwellings, or over 1,000 square metres for non-residential development)⁵⁵ in order to reduce, and rigorously manage, the need to travel, especially by private car. This includes a policy on encouraging low-parking development and car clubs in locations highly accessible by walking, cycling and public transport. This sort of policy is a challenge for the districts where first-rate accessibility to sustainable transport remains an ambition, not reality.

Finally, another major challenge is the fragmented governance structure of Oxfordshire’s transport system. The County Council holds responsibility for strategic transport planning, while local designated trunk roads are managed by the Highways Agency, and public transport investment and operation lies within the province of Network Rail, the franchised train operating companies and private bus operators. This makes strategic planning, policy delivery and coordinated investment in innovation and infrastructure more challenging than what could be achieved elsewhere. In particular, it has been recognised that any solution will require strong public and private sector partnership, working through the LEP, amongst others.

Success stories of low carbon innovation, infrastructure and investment

Despite these challenges Oxfordshire and, in particular, the city have had some important successes in promoting sustainable transport and low carbon innovation in transport. This section highlights some existing success stories of low carbon innovation, infrastructure and investment in Oxfordshire.

1. Low carbon vehicle technology for the automotive industry

Chapter 3 highlighted vehicles as a particular area of strength and opportunity for Oxfordshire. Oxfordshire’s long history in the automotive industry continues to this day, from early innovators and investors such as William Morris to current employers such as BMW Mini and a healthy and burgeoning supply industry of innovators in low carbon technology.

54 Headicar, P., 2000. The exploding city region: Should it, can it, be reversed?, in: Williams, K., Burton, E., Jenks, M. (Eds.), *Achieving Sustainable Urban Form*. Spon, London.

55 OCityC, 2011. *Oxford Core Strategy 2026*. Oxford City Council, Oxford.

For example, Zeta Automotive, formed 25 years ago, is an electronic development company based in Bicester. Zeta Automotive designs, develops and supplies a range of leading edge products that enable fleet operators to reduce fuel consumption and emissions. It also provides a wide range of innovative electronic vehicle management solutions (see case study).

Case study: Zeta Automotive – automotive carbon reducing technology

Background

Zeta Automotive, formed in January 1989, is a spin out from Oxford University and develops carbon reducing technology. With several awards for innovative technology, Zeta is a tier one supplier to the motor industry. DB Arriva, one of the largest transport services organisations in Europe, recently acquired a majority stake in Zeta worth about £3m having approved one of its latest products for roll out across its fleet of buses.



Figure 6.4
**Zeta Automotive's
'Econospeed' device**

How it works

“Econospeed” is a patented device that reduces fuel consumption and associated CO₂ emissions by up to 15% (see figure 6.4). Developed with the aid of an Innovate UK grant, Econospeed works by limiting the acceleration of commercial vehicles. It is a dynamic throttle controller that enables customers to define criteria to limit vehicle engine speed and maximum rate of acceleration. The development of Econospeed has taken a lot of refinement with some very clever software algorithms that ensure smooth, even, efficient driving performance independent of the driver activity.

The economic opportunity

The take up for Econospeed has been dramatic. Having demonstrated the product successfully to Arriva plc, the large bus operator, Arriva have placed orders for over 3,000 units for deployment in the UK. This investment means that Zeta will now grow very quickly; other trials with port authorities, local authorities and vehicle delivery drivers are also proving successful with sales into these sectors now topping 1,000 units.

The payback for the units is less than 12 months with savings of over £1000 per vehicle per year being typical for Econospeed users.

Zeta now plans to offer this product into Europe and expand its sales team greatly over the coming months.

Philip Shadbolt, MD of Zeta has commented, “*Saving money and reducing carbon go hand in hand with Econospeed, it really is a no brainer if you want to improve your carbon footprint and save money at the same time*”.

2. Low carbon (and air quality emission) buses in Oxford

The main bus operators serving Oxford run one of the lowest emission bus fleet of its size in the UK.⁵⁶ The Oxford Bus Company now has 37 electric-hybrid buses, or 36% of their fleet, while Stagecoach Oxford invested in 26. Electric-hybrid buses can cut fuel consumption, fuel costs and carbon emissions by 30%-40%.⁵⁷ For both operators the new hybrid bus fleets represent the biggest single investment in green hybrid bus technology thus far, driving innovation across their national operations. They form part of a package of improvements in the city under a partnership between Oxfordshire County Council, Stagecoach and Oxford Bus Company. For Stagecoach, British bus manufacturer Alexander Dennis and BAE Systems provided the technology behind the electric-hybrid buses, which feature an innovative regenerative braking system and advanced lithium ion energy store. The buses also produce up to 50% less nitrogen oxides (NO_x) compared to traditional diesel engine buses, making them compliant with the recently introduced Oxford Low Emission Zone (LEZ), which requires all buses operating within the LEZ to meet the stringent 'Euro V' standards for NO_x emissions. The creation of the LEZ has been a success in joint governance between the County Council, City Council and bus operators. The collaboration between Oxford Bus Company, Oxford Brookes University and Williams Hybrid Power to invest in the new low carbon 'flywheel' technology is an example of cross-sectoral corporate innovation and investment which is expected to achieve both carbon reductions and cost savings (see case study).

Case study: Oxford Bus Company, Brookes Bus and Williams Hybrid Power

Background on Oxford Bus Company

Oxford Bus Company can trace its origins back to 1881, when the first horse trams operated in the City. Today it directly employs more than 550 staff at its Cowley headquarters and contributes to the employment of many others, both through carrying commuters to their places of work and shoppers into our City Centre, and through purchases of goods and services from many other local businesses.

The company provides high frequency local services within Oxford, including the famous Park & Ride service, as well as express coach services to central London and Heathrow and Gatwick airports. In the current financial year it expects to carry more than 20 million passengers – with a journey beginning every 1.6 seconds.

Initiatives such as electronic driver behaviour monitoring, active buildings management and sustained investment in new low carbon vehicles (including 37 hybrid diesel-electric buses, see Figure 6.5) have helped the company deliver more than a 20% reduction in CO₂ emissions per passenger journey since 2007.



© Oxford Bus Company

Figure 6.5 One of Oxford Bus Company's hybrid electric buses

⁵⁶ OBC, 2013. Oxford Bus Company: About Us, last accessed on 20/05/14 at <http://www.oxfordbus.co.uk/about-us/oxford-bus-company/>. Oxford Bus Company, Oxford.

⁵⁷ See Oxford Bus Company, 2014. Electric-hybrid buses, last accessed on 20/05/14 at <http://www.oxfordbus.co.uk/hybrids/> Oxford Bus Company, Oxford, Stagecoach Oxford, 2013. STAGECOACH LAUNCHES FIRST GREEN HYBRID BUSES IN OXFORD, last accessed on 20/05/14 at <http://www.stagecoachbus.com/hybrid%20about.aspx>. Stagecoach Oxford, Oxford.

Oxford Bus Company, Brookes Bus and Williams Hybrid Power

In 2013, Oxford Bus Company was awarded a new contract by Oxford Brookes University to continue to provide its “Brookes Bus” network of services for a further 5 year period from 2014. To fulfil this contract the company has ordered 14 new Euro VI-rated buses from UK manufacturer Alexander Dennis. These buses, along with 6 existing Euro V vehicles also used on the contract, will be the first in the UK to be fitted with the production version of Williams Hybrid Power’s “Gyrodride” product.

Williams Hybrid Power (WHP)⁵⁸ was established in 2008 to develop a new flywheel energy recovery system for the Williams F1 Team. After FIA regulation changes led to the flywheel technology being made redundant from a racing perspective, Oxford Bus Company’s parent company Go-Ahead plc established a partnership with WHP in 2012 to develop a potential application for the flywheel on buses, making available six buses, and associated engineering expertise to help trial this technology. This project received funding from Innovate UK which covered 75% of the cost of retro fitting the buses. Go-Ahead were also prepared to invest as they identified the potential to achieve competitive advantage over the other major bus groups through early adoption of the technology, and had also identified several shortcomings in the long term viability of the existing battery-based technology used for hybrid buses.

Environmental and financial benefits

Through these trials WHP and Go-Ahead were able to successfully achieve up to a 30% reduction in fuel usage and emissions through utilising the flywheel compared to a standard bus. The flywheel, which can be retrospectively fitted to existing buses, has been shown to offer bus operators a similar fuel and emissions reduction to that achieved by existing battery-based diesel-electric hybrid vehicles, such as those currently operated by Oxford Bus Company. However it is able to do this at a significantly reduced initial cost premium, and is also expected to have a lower lifetime cost of operation than a battery-based hybrid, where expensive batteries are expected to require replacement every 5-7 years.

The use of the flywheel on the Brookes Bus contract is expected to lead to a reduction in CO₂ emissions of more than 250 tonnes per year, when compared to the existing fleet used to operate the contract. The reduction in fuel cost, and additional fuel duty incentives available from central government from operating low carbon vehicles such as these is expected to lead to fuel cost savings of more than £110,000 per year, which are shared between Oxford Bus Company and the University.

The order from Oxford Bus Company is the first commercial order received by Williams and represents an investment of more than £750,000, with money staying within the County. This order, along with others in the pipeline from Go-Ahead group will enable WHP to scale up its production facility, creating further jobs within the County’s economy. It will also help to fund further research into alternative applications for the flywheel by WHP which could have even wider-ranging commercial potential than the bus application.

⁵⁸ Williams Hybrid Power was recently sold to GKN, the global engineering group.

3. Two decades of the Oxford Transport Strategy

The difference in mode shares between the city and the surrounding districts shown above can be traced back to the ‘carrot and stick’ policies implemented in the city (but not outside the ring road) as part of the Oxford Transport Strategy (OTS) since the mid-1990s. The strategy included policies where growing travel demands should be met by a combination of restraint on car use (through parking control and traffic management) and promotion of more sustainable alternatives (walking and cycling, bus services and P&R car parks at the city’s periphery). While the OTS was perceived by some as a “war against motorists” and therefore fiercely debated at the time, it led to a more sustainable transport system while improving Oxford’s place on the map as a major tourist, leisure and shopping destination. Through a combination of demand management and accessibility measures, the OTS has significantly reduced the number of car trips to the city centre. Today Oxford has a well-developed bus system, including a comprehensive park and ride (P&R) network, with benefits to jobs (e.g. public transport operators employ hundreds of people locally) and the local economy (e.g. improved accessibility to key services and opportunities). In particular, Oxford has a significantly higher cycling prevalence than most of the rest of the country,⁵⁹ only topped by Cambridge. According to the 2011 Census, around 10% of adults usually travel to work by bicycle (2% in England). 28% of adults cycle at least once a week (10% in England), and 14% cycle at least 5 times a week (3%).⁶⁰

4. Park & Ride

A key part of the OTS was the promotion and expansion of the bus based P&R system that was first introduced to Oxford in 1974. Oxford recognised that P&R was able to address two sets of policy goals, i.e. to boost local economies by adding parking capacity whilst also reducing levels of traffic in the city centre. More recently, the greening of the P&R bus has addressed the environmental policy goals of reducing carbon emissions and energy use and improving local air quality. However, there has been the view that P&R in its current guise may actually be exacerbating *overall* traffic levels, so any redesign and expansion of the Oxford system should look at alternative models (e.g. integrated, demand-led, remote-site, hub-and-spoke or link-and-ride concepts) that potentially offer considerable improvements.⁶¹ The proposed Bicester P&R is based on the remote-site concept that extends the portion of the trip made by public transport whilst reducing the access distance by car.

5. Electric charging infrastructure and vehicles

While Oxford is still in its infancy in terms of building a network-wide electric vehicle (EV) charging infrastructure, it has set a good example of fostering partnership across e-businesses, infrastructure planners and knowledge leaders. The Oxford EV Partnership⁶² was set up to stimulate the uptake of EVs and accelerating e-mobility in Oxfordshire. This partnership followed the successful trial of MINI E, building on the work of the MINI E consortium. Projects included the launch of the POLAR Network in Oxford in 2012 with ChargeMaster, Hertz and Nissan.

59 DfT, 2013b. Local area walking and cycling statistics: Statistical Release. Department for Transport, London.

60 ONS, 2014. Census 2011, Method of Travel to Work data tables, last accessed 20/05/2014 at <http://bit.ly/1oMFb96>. Office for National Statistics, London.

61 Meek, S., Ison, S., Enoch, M., 2009. Stakeholder perspectives on the current and future roles of UK bus-based Park and Ride. *Journal of Transport Geography* 17, 468-475.

62 A consortium made up of Oxford Brookes University, Qualcomm, ChargeMaster, Oxford City and Oxfordshire County Councils, Sutherland Campbell, SSE, Hertz, Cryox, Bosch, British Chamber of Commerce and Verdant Automotive.

6. EV car club and car pool in Oxford

Oxford's first Electric Car Club was launched in North Oxford in late 2013. The North Oxford E-Car Club is one of the UK's first wholly electric pay-per-use car clubs, designed to "provide local businesses and members of the community with the convenience and flexibility of a full-sized electric car without the cost of owning one". The car club's Renault ZOE (with fast charge) is based in Summertown and has a specially designated parking space and electric charging point in Diamond Place car park provided by Oxford City Council. The range of the battery-only EV when fully charged is around 60 miles, which makes it suitable for local journeys. The car club teamed up with community group Low Carbon Oxford North to provide the service locally.

The City Council is developing an electric vehicle car pool for its own fleet, supported by plans to install further electric vehicle recharging infrastructure. The city council currently has 14 electric vehicles in its fleet, along with nine electric bikes and three hybrid electric vehicles.

The economic and climate challenge: future emissions reduction from transport

Inventory of options available to Oxfordshire

Given the scale of the challenge, it is doubtful that the existing strategies, plans and measures will deliver the carbon emissions reductions needed to meet our ambitious climate mitigation goals. More can be done, and Oxfordshire is well placed to innovate further, invest more and develop the necessary infrastructure into a world-class, sustainable and high quality transport system that supports economic growth whilst reducing carbon emissions. Low carbon transport options typically focus to **AVOID** making a trip or delivery altogether (or over shorter distances), **SHIFT** transport to low carbon modes or **IMPROVE** carbon efficiency per unit of service (passenger-km, tonne-km).

To give some examples, **AVOID** options include measures such as:

- promoting/providing tele-shopping, tele-working, tele-conferencing, tele-socialising, e.g. promoting tele-working at NW Bicester
- integrated land use planning, including denser housing developments that are co-developed with job opportunities and major services (shopping, leisure, education, etc) along existing or new transport corridors that are served by low carbon, sustainable transport services (e.g. guided busways)
- high occupancy lanes at peak times on the trunk road (and ring road) network
- new business models in transport provision.

SHIFT options with potential to be implemented in Oxfordshire include measures such as:

- pricing incentives that favour low carbon travel choices (e.g. car parking charges, higher mileage rate for rail or cycling in company travel claims) or low carbon technology (e.g. car/van grant)
- promoting smarter travel choices, e.g. walking and cycling infrastructure and promotion, particularly for mode shift from short car trips to active travel
- integrated ticketing across transport providers *and* modes
- real time, integrated traffic and parking information systems (in-vehicle, smart-phone, etc.)

- integrated land use planning (as above)
- congestion charging
- workplace, school, residential and personal travel planning aimed at mode shift.

IMPROVE options include:

- investment in zero or low carbon vehicles, fuels and infrastructure
- more efficient public transport vehicles and operations
- smart traffic management to promote smoother traffic flow and reduce excessive speeds
- eco-driving programmes for car drivers (similar to the Dutch national programme), but also bus, van and truck drivers (using GPS and accelerometry devices).

Technical and market potential of carbon reduction options

The technical potential for carbon emissions reductions from Oxfordshire's transport system by 2030 is significant. Technically, zero or low carbon vehicles such as plug-in electric cars, flywheel hybrid electric buses and battery electric delivery trucks could replace the entire vehicle fleet of cars, buses and vans over the next 15 years. Technically, the electricity fuelling this demand could become low carbon over that timeframe (e.g. wind and domestic solar). Technically, we could have an on-demand, autonomous pod transport system linking the growth areas by 2030. The challenge is market breakthrough, not technological breakthrough (although product innovations may help the overall process). The market potential is lower because (even if we internalise the benefits) most new, low carbon technology typically costs more, is perceived to perform worse than incumbent technology, lacks market presence and consumer awareness, and often requires significant investment in the necessary infrastructure (e.g. EV charging at home, work, public, fast charging stations). Business, fleet and public transport operators are often driven by cost minimisation and provision of quality standards appropriate to the target audience. Innovators who can provide an existing or new service better and cheaper than others will succeed.

Further market barriers include system capacity constraints that are exacerbated by future increases in demand (e.g. new housing, commercial property, schools, etc.), calling for large investments needed on infrastructure (which is slow) and in vehicles (faster). The perceived (non-) performance of alternatives to the car and the lack of knowledge of smarter travel choices is another key barrier to market transformation. Future smart city transport, ICT, data sharing and freight telematics can overcome some of these awareness/knowledge barriers, requiring investment in infrastructure and innovation in delivery.

Provided the market barriers are overcome the potential benefits can be significant, including economic (high tech jobs, reduced congestion, electric Vehicle-to-Grid / Vehicle-to-Building as peak electricity storage options), environmental (reduced energy use; reduced carbon, local air quality and noise emissions), social (improved long term health through physical activity, improved accessibility to jobs, shops, public transport) and equity impacts (improved accessibility for previously excluded communities).

Oxfordshire's economy has a considerable potential for low carbon transport innovation, investment and infrastructure. The next section highlights some of the opportunities identified by the project team.

Transport opportunities: innovation, investment, infrastructure

Oxfordshire could gain competitive advantage in a number of ways by building on its strengths while overcoming some of the barriers that are common in other regions and cities.

Oxford Integrated Transport ‘Living Lab’

One of those opportunities has emerged from an Innovate UK-funded feasibility study, the “Oxford Transport Laboratory”, which aims to create an “integrated transportation living lab” that is used to manage and optimise transport and accessibility in the city of Oxford. The short term goal is to minimise the transport, economic and environmental effects of the Westgate Centre redevelopment scheduled to start in 2015, with the longer term goal of increasing economic activity in Oxford while reducing traffic congestion. The project aims to create know-how and technology that can be transferred to similar city centres in the UK that operate within the context of challenging built environments and governance regimes, and then to develop economic benefit by expanding this expertise to the world. A team of business entrepreneurs, local authority planners, engineers, researchers and scientists from both universities is addressing real life transport integration issues facing regions with medium sized cities at their core (100,000 to 250,000 population), and the basic approach adopted has been to combine the technological opportunities with the views of the users of those services. The six key short term solutions identified are (see also Figure 6.6, overleaf):

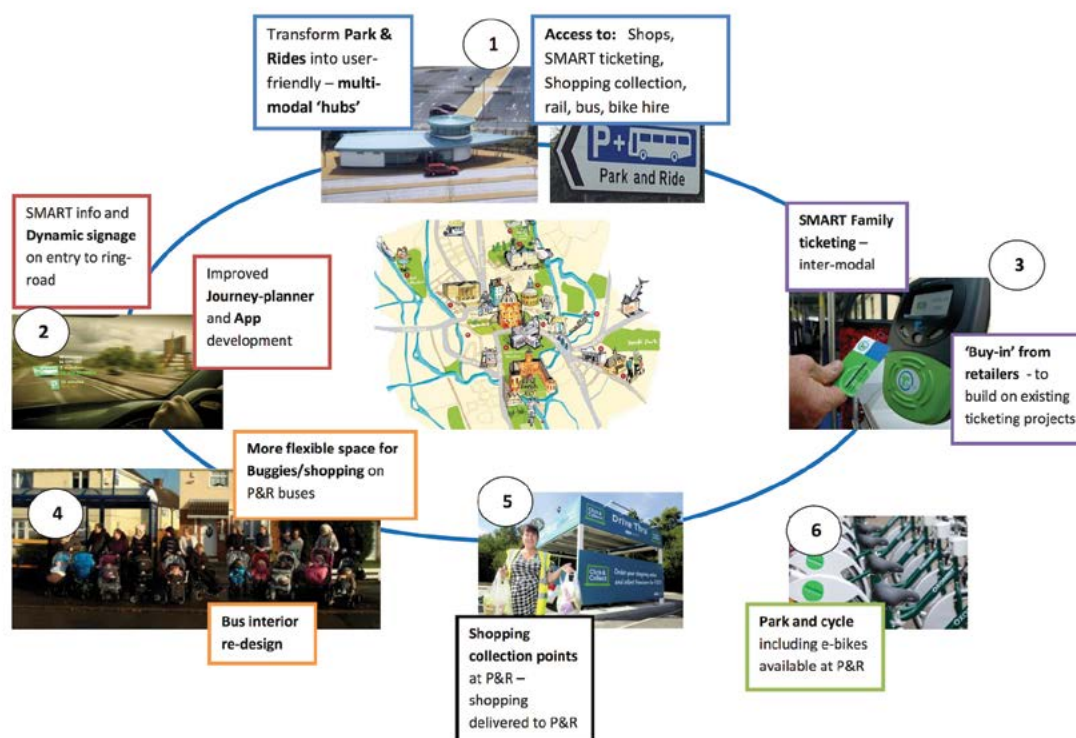
- 1.** transform Park & Rides into user friendly multi-modal transport-retail-shopping hubs
- 2.** SMART traffic and parking availability apps, providing pre-travel information as well as on-route real time information on dynamic signage on entry to city via ringroad and major radial routes. Dynamic signage shows real time information on parking and traffic congestion (live times and costs to get to main destinations, availability and cost of parking, buses, alternative modes including cycle hire, e-bikes)
- 3.** SMART payment options on public transport, including P&R family tickets on weekends
- 4.** adapt a bus: more flexible space for buggies/shopping on P&R buses, plus bus interior re-design
- 5.** shopping collection points at P&R sites and transport interchanges/hubs (railway station, bus station, etc.)
- 6.** P&R extensions to other modes and business models: e.g. Park & Cycle (one way, both ways) and Train & Cycle, linked with cycle hire scheme or e-bikes.

Low carbon technology innovation

Williams F1 and the Oxford Bus Company (see case study) are developing hybrid electric buses that use flywheel technology to store and regenerate braking energy. These new flywheel buses have the potential to diffuse into urban public transport systems across the globe, with potential inward investment in high-tech jobs. The technology could also be transferred to flywheel hybrid electric delivery trucks that exhibit similar stop-start driving patterns and can make most use of regenerative braking technology.

The Oxford bus operators also use GPS and accelerometry devices installed on buses to detect and feedback (in)efficient driving behaviour to the drivers and fleet operators. This is linked to a driver benchmarking exercise that aims to encourage more efficient driving, thus saving fuel and carbon emissions. Eco-driving can typically save about 10% of fuel in real world application. Again, this is a technology and practice that could be exported across the UK and beyond.

Figure 6.6 Short term solutions proposed for the 'Integrated Transport Living Lab'



Source: MobOx project team

New inward investment and hi-tech jobs have come out of the emerging transport technology clusters, building on partnerships between the existing knowledge economy (e.g. Oxford University's autonomous vehicles), vehicle manufacturers (BMW Mini, Mini-E) and the automotive supply chain economy (some of which is based in Oxfordshire, e.g. Zeta Automotive).

The economic analysis in Chapter 3 has highlighted alternative fuel vehicles as a particular area for future development and growth in Oxfordshire, with potential to build on the current strengths of the automotive cluster.

Sustainable transport and jobs

A recent study by the World Health Organisation⁶³ concluded that there are many opportunities for job creation in public transport, cycling and walking – not just in the hi-tech automotive sector. Specifically, city-wide bike-share schemes have proven to provide opportunities for creating jobs in cycling. Interestingly, the study also concluded that investing in sustainable transport generates more jobs than investing in roads.

Integrated multimodal transport provision

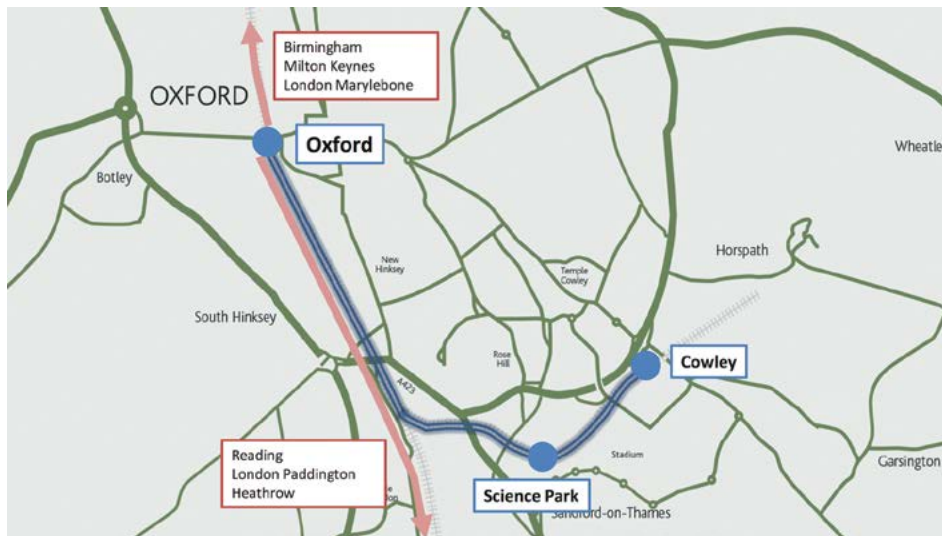
Transport innovations such as heavily integrated transport systems (as realised in the Netherlands and Germany) can be hard to replicate. Any new public transport network needs

63 WHO, 2014. Unlocking new opportunities: Jobs in green and healthy transport. World Health Organisation, Copenhagen.

to be complemented with parking controls and measures to make walking and cycling easier, so that alternatives to the private car become the preferred choice of transport.

The planned link to East West Rail via the new Oxford Parkway station at the Water Eaton P&R site is a good example of how to integrate different forms of public transport in order to increase accessibility to multiple destinations (Oxford, Bicester) and trip purposes (commuting, shopping, leisure). A new express link into commercial/employment centres such as city centre, hospitals and 'Eastern Arc' businesses could also transform transport provision in areas of lower accessibility to sustainable transport, with further links to regional and national public transport services (Figure 6.7).

Figure 6.7 Potential reopening of the Cowley branch rail line to passenger services



Source: OCC⁶⁴

In the medium to longer term Oxfordshire will need to develop and deploy innovative solutions to the increasingly congested North-South and West corridors (A34 and 'Science Vale Oxford'; A40 to Witney) across all modes of travel. Significant investment in sustainable infrastructure will be needed, including multimodal hubs and corridors (Figure 6.8 overleaf), low energy/carbon transport modes, a comprehensive network of high quality cycling infrastructure, new mass rapid transit along those corridors (along the lines of the Cambridgeshire Busway) and the development and deployment of autonomous pods/vehicles where the universities have significant expertise and intellectual property rights.

Use of public transport can be promoted by a convenient ticketing system which rewards frequent users, as demonstrated in London with its Oyster Card. Outside London, Oxford has led the way nationally in introducing combined ticketing and smartcard systems on bus services within the city but the same principle needs to be extended to rail, bus and public parking facilities across central Oxfordshire.

64 OCC, 2014. Connecting Oxfordshire: a vision for transport in Oxfordshire. Oxfordshire County Council, Oxford.

Figure 6.8 Part of the County Council's Vision of a 21st century transport system



Source: OCC⁶⁵

Smart ticketing – towards a more seamless journey experience

Smart ticketing schemes exist in Hong Kong, Korea and a number of other centres. The Oyster scheme in London has been operating very successfully since 2003. A new multi-operator integrated smartcard ticketing system is being introduced to Oxford in 2014.

Governance and planning

There is an urgent need to better coordinate planning of where we live and work and how we travel. For instance, coordinated planning should provide attractive alternative transport options to the car *before* homes are occupied.

To combat the large increases in car-based travel generated by population growth in the country towns, new development should be concentrated around public transport nodes and corridors within the wider sub-region. Town extensions and new settlements should be conceived in the form of 'beads on a string' rather than the traditional pattern of peripheral, poorly-served rings around established built-up areas. Any new development and transport service improvements then go hand-in-hand, reducing vehicle miles travelled and carbon emissions. Freiburg in South West Germany is one of a number of historic university cities that have led the way in demonstrating how to plan expansion and to build housing fit for the 21st century. Its growth has been planned along extensions to the tram network with the result that 84% of residents live within 250 metres of a tram stop.

There is considerable scope for enhancing travel by public transport between towns and workplaces, not just in central Oxfordshire but also outside the county, as well as making full use of buses for local transport. Potential opportunities include P&R sites on the edges of country towns to enable motorists to switch mode at an earlier point in their journey, coupled with interchange hubs in and around Oxford to make it easier for people to reach final destinations

65 Ibid.

which are not in the city centre. More employment could be provided at sites next to the stations, which increases usage and therefore the viability of public transport. This means that the area around Oxford station should be developed to much higher densities and in ways that exploit its prime regional and local accessibility, for example as a conference and business centre. To make this happen would require stronger collaboration between all the stakeholders, as well as major shifts in attitudes on the part of the wider public, thus overcoming two major barriers to success.

7. Housing

Oxfordshire's ambitious plans for economic growth are set to attract more people to the county, placing new pressures on housing at a time when the entire UK is suffering from decades of under-provision of homes. New housing will be required to be 'zero carbon' by 2016 (and commercial buildings by 2019) and this provides an opportunity for low carbon investment.

New housing is only part of the picture, however. The size and poor energy efficiency of the existing housing stock means that any plan to make real emissions reductions in this sector needs to include ambitious renovation of existing homes, incorporating technologies such as insulation and solar panels. Advanced energy standards have been proven in exemplar demonstration projects for new and existing homes, but these projects also show that success depends on good quality of design and workmanship, and a degree of integration across professions and trades which is still not the norm. New technologies may help, but the challenge of low-energy buildings is as much about changing practices and processes as it is about products: 'for the construction industry "new" technology means new to the company rather than new per se'.⁶⁶

The social and economic benefits of such a strategy are significant, with lower household energy bills and some protection from future energy price rises. For the most vulnerable groups, including those living in fuel poverty, the low-energy refurbishment of homes is a key action, reducing hardship, health problems and excess winter deaths. Moreover, built environment investment generates many types of jobs from high-tech to manual. The knowledge and skills needed to deliver genuinely low-carbon buildings are far from widespread, so there is a need for significant investment in vocational education and training.

Housing in Oxfordshire

There were 272,900 homes in Oxfordshire in 2013.⁶⁷ The Strategic Housing Market Assessment (SHMA) for the county estimates that an additional 100,000 homes will be needed by 2031 (37% growth in less than 20 years). To set that number in context, the SHMA target is equivalent to building 1.8 times the dwelling stock of Oxford city (estimated at 55,000 homes). The SHMA figure is based on an assessment of several factors: the backlog of unmet demand for housing (many people who currently share accommodation would set up new homes if they could); demographic trends leading to more people living in smaller household units; accommodation needs for new workers attracted by committed economic growth plans.

The local councils in Oxfordshire (Oxford City and four District Councils) have given their own assessment of how many homes could be built (and where) in recently published Local Plans. Taken together, these documents identify sites for 50,000 new homes to 2031, largely through

⁶⁶ Abbott, C., Sexton, M., Jones, V., Lu, S-L (2007), Action learning as an enabler for successful technology transfer with construction SMEs, RICS research paper series 7 (16), October 2007, RICS Research. Page 10. Available: http://usir.salford.ac.uk/18366/1/40379_construction_smes.pdf [2011, December 9]

⁶⁷ DCLG Live housing table 100 <https://www.gov.uk/government/statistical-data-sets/live-tables-on-dwelling-stock-including-vacants> (accessed 4/4/2014)

expansion of existing towns and large villages, as well as by using previously-developed land. For reference, current rates of house-building (based on an average of the nine years 2004-2013) would deliver 37,000.⁶⁸

Nor is this just a question of housing: households and communities also need local services and amenities (schools, GP surgeries, local shops, green open space etc) if they are to have a good quality of life.

Housing energy Policy & Planning

The Building Regulations are revised approximately every five years, and the requirements of Part L (Conservation of fuel and power) cover major refurbishment works and new buildings. In 2007 the then Labour government announced that all new homes would be 'zero carbon' from 2016 (with a date of 2019 adopted for commercial buildings). The exact meaning of 'zero carbon' has been debated extensively in industry and policy circles, with the 2014 revision to the regulations allowing trade-offs to be made through the advent of 'allowable solutions' – imposing less tight standards on developers to build to the most advanced standards in return for investments in renewable energy generation projects.

For refurbishment, the regulations only apply to major works and are (necessarily) expressed in terms of 'reasonable efforts' being made to comply, given that there are often many practical constraints when working on existing buildings. Compliance with Part L of the Building Regulations is not policed very assiduously: a 2004 study found that the only reasons for which a Building Control inspector might refuse to certify a building was if there were doubts over its structural safety or fire hazards.⁶⁹

The Building Regulations have helped to improve energy standards but they also tend to act as a maximum standard, as well as a minimum: the regulations are needed but they can be a brake on innovation.⁷⁰ Innovative construction projects adopt more stretching (but voluntary) standards, such as those set out in the Code for Sustainable Homes, the AECB, and Passive House. One or more of these advanced standards could become the focal point of activity and investment in housing infrastructure in Oxfordshire.

The Green Deal and Energy Company Obligation

Policy for energy efficiency in housing has focused for decades on cost-effective and relatively easy-to-install measures like cavity wall insulation and loft insulation. However, long-term climate change targets require more ambitious programmes of work than can be achieved by 'cheap and quick' measures applied one at a time. The Green Deal (GD) was conceived as a way of making investments with longer payback periods (up to 25 years) more attractive to property owners. However, the detailed design of the GD has been widely criticised, and the financing model (a legal charge on property deeds with a 6-7% interest rate) has proved to be unattractive to property owners.⁷¹ The Energy Company Obligation (ECO) places an obligation on energy companies to finance energy efficiency measures.

68 DCLG Live housing table 122 <https://www.gov.uk/government/statistical-data-sets/live-tables-on-dwelling-stock-including-vacants> (accessed 4/4/2014)

69 Grigg, P. (2004) Assessment of energy efficiency impact of Building Regulations compliance BRE client report 219863, Building Research Establishment, Garston

70 Gann, D., Wang, Y., Hawkins R. (1998) 'Do regulations encourage innovation? - the case of energy efficiency in housing' Building Research & Information 26(5): 280-296

71 Rosenow, J., Eyre, N. (2013) The Green Deal and the Energy Company Obligation *Proceedings of the Institute of Civil Engineers – Energy*, 166(3): 127–136

Feed-in tariffs

The principle of feed-in tariffs is to provide a financial reward to those who install renewable electricity equipment, based on a scale of amounts (the tariff) given for electricity generated by different technologies at different scales and in different contexts. In spite of changes to the amount of financial reward on offer, the Feed-in Tariff (FIT) has proved popular since it was introduced in 2010, leading to significant growth in solar photovoltaics (PV).

Social issues and challenges

Fuel poverty in Britain is a chronic problem arising from the fact that those who can least afford high energy bills tend to live in some of the least thermally efficient dwellings. The fuel poor, especially the elderly and vulnerable, are exposed to health risks from their living conditions, with an average of 26,000 excess winter deaths per year in the last five years. Investing in energy efficiency is an answer to this chronic, long-standing problem.

Examples of innovation and good practice for low-carbon housing

Building energy use is a complex interaction of factors, none of which can be ignored or treated in isolation:

- the physical properties of the building (eg how well it is insulated to reduce heat loss) and its relation to the immediate environment (eg orientation in relation to the sun)
- the addition of building-integrated renewable energy technology (eg solar panels) helps reduce CO₂ emissions but it also adds complexity to a building's energy systems
- the number and efficiency of lights and appliances
- the behaviour and lifestyle choices of building occupants (eg different preferred internal temperatures; energy-intensity of leisure activities; habits of leaving appliances on or turning them off when not in use, etc).

The task of achieving real-life, sustained performance requires a concerted effort to tackle all these issues in an integrated way.

Technical and market potential

Good design for low-energy buildings follows a hierarchy of strategies:

1. reduce the need for energy (eg. insulate in order to reduce heat loss)
2. increase the efficiency of energy use by getting more service from each unit of energy (eg. change to low-energy light bulbs)
3. use less harmful sources of energy (eg. switch from oil or coal to gas; add renewable energy technologies, such as solar).

Case study: Oxford Whole House Carbon Reduction Project

The house at 56 Nelson Street underwent deep low carbon refurbishment, funded by Innovate UK's Retrofit for the Future programme, aiming at an 80% reduction in CO₂ emissions in existing homes. The design prioritised energy demand-reduction measures ('fabric first'), and then used low- and zero-carbon technologies that can be easily integrated into the urban fabric. All materials and building techniques used are currently available but very few houses are retrofitted to such high standards.

More than 60% of the energy savings are made through improvements made to the building fabric (insulated loft and walls, triple-glazed windows). There is a high efficiency gas boiler for central heating, low energy appliances and lighting, an array of solar photovoltaics for electricity and a solar thermal system for hot water. Mechanical ventilation with heat recovery provides fresh air.

The project resulted in a significant increase in occupant satisfaction regarding comfort, internal light levels, reduced energy bills, and less noise. Actual carbon emissions reductions were 80% in the first year post-retrofit and 75% in the second year over the predicted baseline emissions.

Lessons learned and next steps

- open and frequent communication between project team members was key to success
- sealing the home for air tightness proved to be more difficult and time consuming than expected: understanding among site staff of the importance of achieving good air-tightness is vital – difficult areas should be checked and re-checked
- occupant behaviour is very important and can greatly influence the success or limitations of a carbon reduction project - Engage residents early and frequently in the process; occupant involvement in the process proved to be a motivator towards reduction in energy consumption
- handover and guidance also helps influence behaviour – helping residents to understand how to manage their homes at different times of the year by explaining system controls is essential
- predictive performance modelling can be used as a tool for choosing packages but is not recommended for predicting actual reduction
- case study showcase homes are effective in public awareness and can be helpful for demonstrating behavioural change. In the case of this retrofit, relatives and friends took away DIY retrofit ideas after visiting the house
- feedback from the project will be used to replicate work and improve results in subsequent retrofits throughout the UK.

Project partners

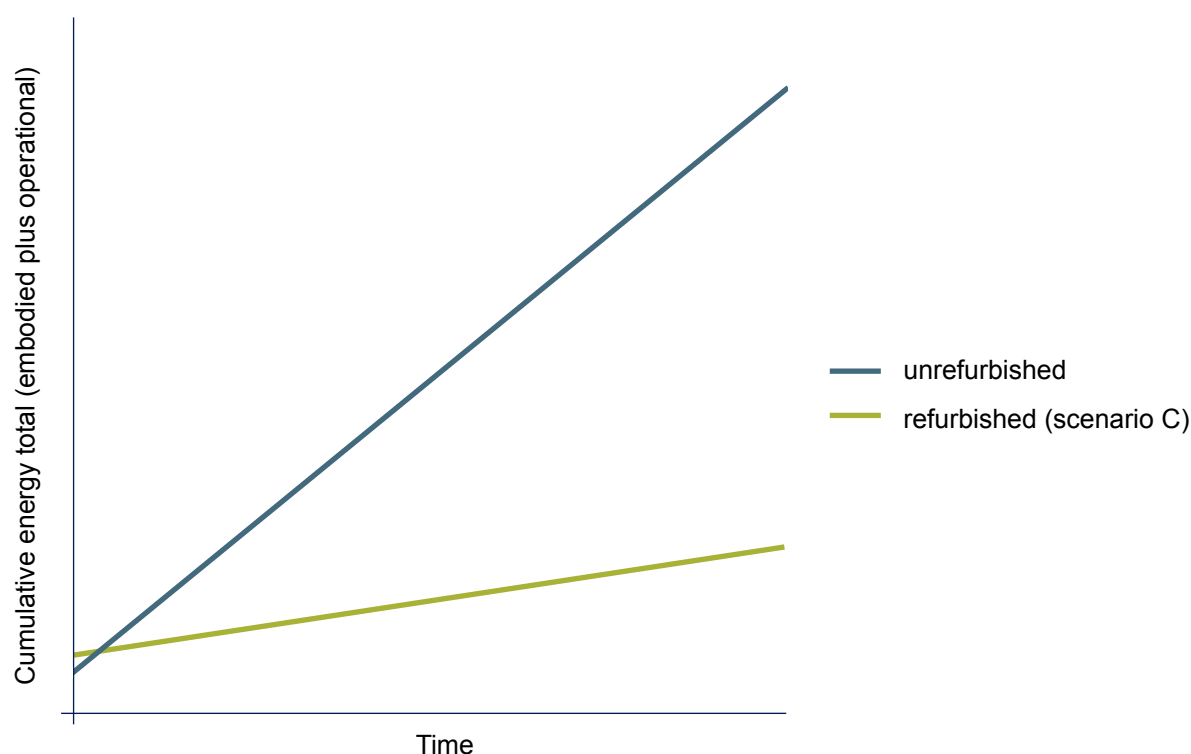
Leadbitter, Ridge and Partners LLP, Low Carbon Building Group of Oxford Brookes University

More information at Oxford Brookes University online:

<https://www.brookes.ac.uk/microsites/eco-house/>

A related issue is that of embodied energy, in other words the energy required to make a product and deliver it to its end-user. Life-cycle analysis (LCA) provides a way of comparing the relative impacts of technologies and materials from the extraction of raw materials, through processing and manufacture, and finally across distribution networks to end consumers. The figures used in LCA are often hard to find or be certain of. Nonetheless, for products like insulation and PV panels the embodied energy is more than compensated for by the lifetime energy and CO₂ savings in the operational phase. In this perspective, embodied energy can be seen as an inevitable short-term penalty followed by longer-term gains. There is an additional environmental impact in the early months or years, followed by net positive impacts over the lifetime of the product or technology. In figure 7.1 this is shown in terms of two lines which cross over at a certain point in time. The line for a refurbished property starts off higher than the line for an unrefurbished property, reflecting the embodied energy of the refurbishment. However, as time goes on, the operational energy savings of the refurbishment mean that its total life-cycle energy consumption is significantly lower.

Figure 7.1 Combined impacts of embodied energy of refurbishment and operational energy over time (figures are indicative)



While individual households can vary considerably, it is generally true that energy for space and water heating dominate the mix, with electricity for lights and domestic appliances representing a relatively small (but growing) proportion of the total (Figure 7.2). Despite decades of policies to support 'quick and cheap' insulation measures (loft and cavity wall insulation) the UK housing stock is still thermally inefficient (Figure 7.3).

Figure 7.2 Annual energy demand for a typical (unrefurbished) UK home

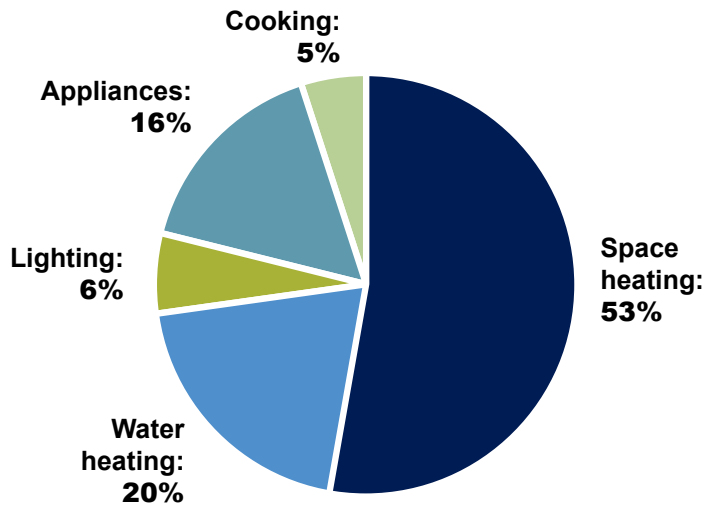
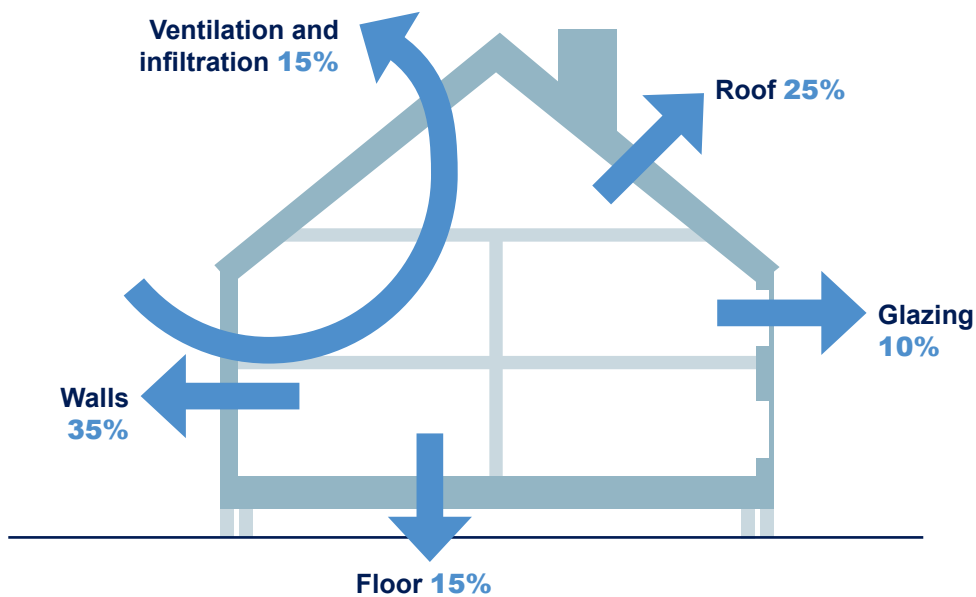


Figure 7.3 Breakdown of heat loss from a typical (unrefurbished) UK home



Going beyond the 'quick and cheap' requires a different, more integrated approach. In this domain there are new business models which have the potential to provide good-quality services and increase the market for innovative low-energy projects. The benefits for customers lie in reduced environmental impacts, reduced energy costs over time and greater resilience to future energy price rises. The benefits to service providers derive from 'up-selling' (persuading a customer to buy additional services) and in tying customers to ongoing service agreements. The success of either strategy depends to a large extent on the quality of service on offer.

Case study: The Low Carbon Hub: Retrofitting for Sustainability

The Low Carbon Hub seeks to enable communities, households and businesses to be actively involved in the production and consumption of the energy we all need to live our lives. This means not only the production of local, sustainable energy, but changing the way in which energy is used. Energy efficiency is a vital part of balancing the books.

The Hub, in partnership with Oxford City Council, has run a number of pilots using government incentives – most notably in providing free external insulation to fuel-poor houses in Barton. These initiatives have demonstrated that delivery of energy efficiency measures to fuel-poor houses is challenging if it relies on complex and potentially changing government incentives. Energy efficiency can pay for itself and is therefore investable. The Hub believes that a workable model needs to create sufficient certainty over the outcomes of a given spend on energy efficiency measures, and manage credit risk for community investors.

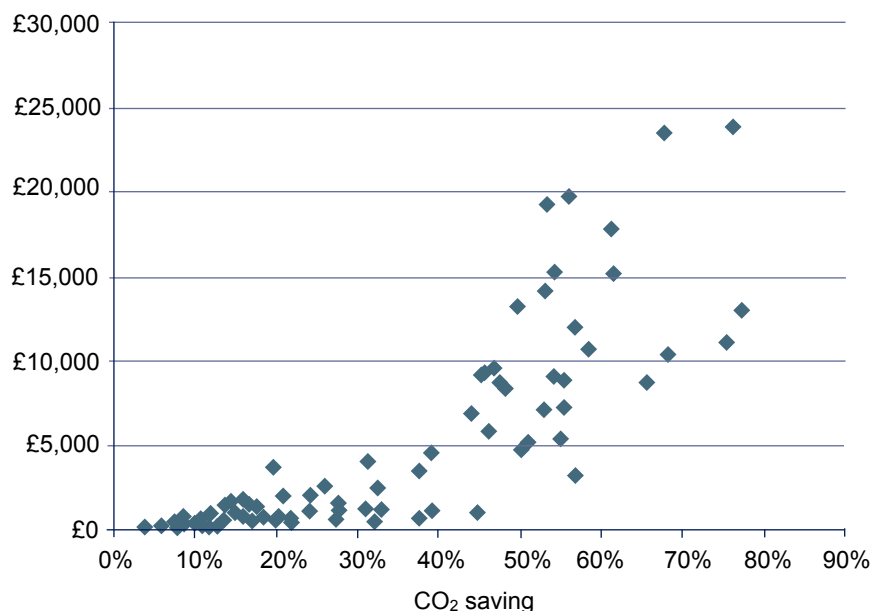
The Hub currently has three main initiatives underway to develop such models:

1. Organising the funding and programmes to retrofit LED lighting: the Hub has developed a number of business models for implementation and are running a pilot on three Oxfordshire schools to retrofit LED lighting. If successful, the programme will be rolled out across Oxfordshire.
2. Retrofitting tenanted buildings: given the large rental sector in Oxford, the Hub is looking at models where the City Council can use its powers to encourage and enable energy efficiency measures to be retrofitted in tenanted buildings.
3. Systemic energy efficiency: the Hub is working to create a complete system for implementing and funding more complex energy efficiency measures in domestic and commercial buildings. Following extensive consultation the Hub has identified the following issues that will need to be address to develop a workable model:
 - a. Surveying and establishing baseline (fabric, air leakage, use)
 - b. Technical package(s) or solution(s) – whole system rather than parts (e.g. not only wall insulation, but a package of measures that deliver a specified outcome: in terms of comfort, energy use etc)
 - c. Ensuring best practise in installation
 - d. Quality control process: get it right first time
 - e. Monitoring kit for energy use, fabric/thermal performance
 - f. Data analysis and feedback process/protocol

The Hub is working with a number of implementation and regulatory groups to design and roll out this system.

The question of how much a low-energy building costs is dependent on many things, including the relative ambition of the low-energy standard being targeted. Generally, as the standard becomes tougher to achieve, so the costs rise ever more steeply (Figure 7.4).

Figure 7.4 Marginal cost of low-carbon refurbishment against CO₂ emissions reduction for 30 houses



Source: Smith 2010 Pers. Comm.

Costs are very variable, but recent research on pioneering low-energy refurbishment shows that there are several common factors required for success:

- **Opportunity** – instead of doing ‘energy efficiency’ as a stand-alone task, there are many types of building project which can be done in a low-carbon way (eg when a new kitchen is being fitted, that is a good time to insulate floors and walls at the same time, making the cost and disruption marginal).⁷²
- **Access to capital** – if the money is not available to pay for improvement works, then arguments about long-term financial savings through reduced energy bills are immediately lost.
- **Knowledge and skills** – linked to the fact that this type of work is still a niche activity, there is a high investment of time and applied knowledge in researching products and methods, at least at first.

The so-called ‘design-performance gap’ is an enduring problem. On the relatively rare occasions when building energy consumption is monitored in real life, the energy consumption is significantly higher than anticipated at the design stage. Reducing the gap requires a concerted effort to increase knowledge and skills, as well as addressing problems of communication and uncertain boundaries of responsibility between different firms and members of the workforce.⁷³

⁷² See, eg, Fawcett T & Killip G (2014) ‘Anatomy of low-carbon retrofits: evidence from owner-occupied Superhomes’, *Building Research & Information* 42(4): 434 – 445. This special issue is available for free download until 30 September 2014: <http://www.tandfonline.com/r/bri-energy-retrofits>

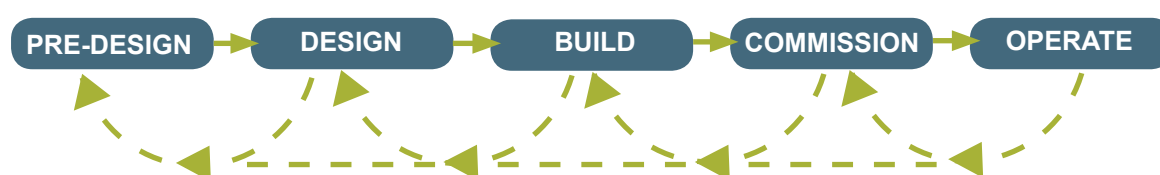
⁷³ For a good summary, see the Zero Carbon Hub’s report ‘Closing the Gap between Design and As-built Performance’, published in March 2014

The low-energy building agenda requires different firms to do three things which go against mainstream practices:

- work collaboratively on finding and implementing solutions
- learn mistakes from previous projects and apply them to future projects
- engage with the variability of building occupant behaviour (ie rather than blaming building users for incorrect use of technical systems, firms need to view users as integral to the systems, not separate from them).

The underlying issue is that construction is typically a linear process, which needs (but does not yet have) feedback loops between all steps – from a ‘pre-design’ engagement with users to better understand their needs and uses in a building, all the way through the design and construction process until final hand-over back to the users (Figure 7.5).

Figure 7.5 The conventional linear process of construction and the feedback loops needed to understand and minimise the design-performance gap



Source: Adapted from an original by Bill Bordass/Usable Buildings Trust.

Specific projects provide convincing detail to back up these conclusions. Innovate UK supported 86 advanced low-carbon renovations of houses in its Retrofit for the Future programme. Each project was monitored for two years, and most missed their energy performance targets. The monitoring report concluded that the most advanced energy standards require not just good design (although that is important), but also a fastidious attention to detail and a commitment to integrating the different tasks/trades on site.⁷⁴ If any of these elements is missing or weak, the result is a significant drop-off in energy performance. Similarly, on the Stamford Brook housing development, there was an unexpected and significant under-performance because a new building technique was used. Problems only came to light because a team of university researchers were invited to do some monitoring in order to find the root cause of the problem.⁷⁵ The common ‘weak link’ in the research findings from these two very different programmes is the lack of learning between stages in the construction process, and the lack of integration between different tasks and workers.

Some researchers have taken the idea further, arguing for much greater collaboration between researchers, practitioners and policy-makers in developing the ‘feedback loop’ concept into a programme of innovative field trials – built around monitoring and evaluation of real-life projects, and focused on new practices and processes as much as on new products.⁷⁶

The importance of renovating existing homes for climate change targets

Oxfordshire’s house-building targets have dominated local headlines in terms of how much new development should take place – and where. In terms of policy to reduce CO₂ emissions, however, the overwhelming bulk of the problem lies not in new homes, but in the existing housing

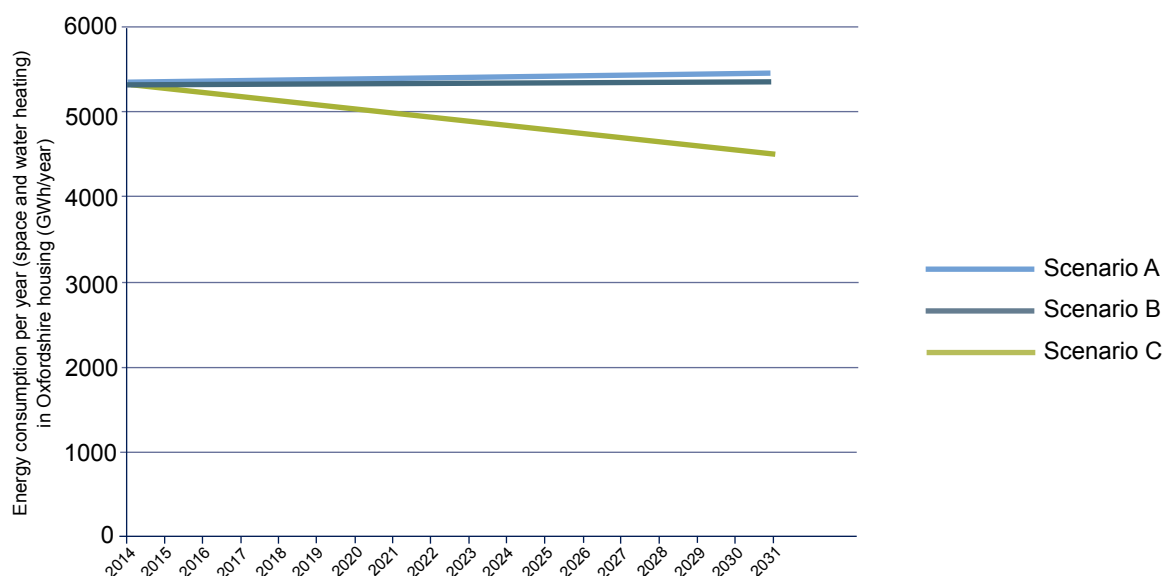
⁷⁴ www.innovateuk.org/retrofit-analysis

⁷⁵ The National Trust, Redrow Homes, Bryant Homes (2008) Volume – delivering sustainable housing: learning from Stamford Brook http://ntplanning.files.wordpress.com/2012/02/volume_delivering_sustainable_housing-2.pdf

⁷⁶ Lowe, R., Oreszczyn, T. (2010) ‘Challenges for energy and buildings research: objectives, methods and funding mechanisms’ *Building Research & Information* 38(1): 107-122

stock, which is both large (272,900 homes in Oxfordshire in 2013) and generally very energy-inefficient. A few exemplar homes have shown what can be achieved with a concerted effort, but the level of activity remains very small compared with the total number of homes.

Figure 7.6 Energy consumption from new and existing homes to 2030, three scenarios



The combined energy consumption of new homes and existing homes is illustrated in Figure 7.6, which summarises the three scenarios for housing. The only one of the three which shows a drop in energy consumption across all homes by 2030 is scenario C. This is achieved by increasing activity from a few tens of low-energy renovations per year to several thousand, leading to 30% of homes having been improved in this way by 2030. Scenario C also includes the highest number of the three scenarios for house-building (100,000 new homes by 2030), and the additional impacts of these new homes is outweighed by the investment in energy efficiency in the existing stock.

A way forward: innovation networks for low-carbon buildings

Achieving even modest levels of housing growth at the same time as absolute reductions in energy consumptions and CO₂ emissions will require a concerted effort to build better homes and refurbish a significant proportion of the existing housing stock. Investing in such an enterprise at the level of a county or city-region opens up a market which is arguably at the right scale: big enough to attract a wide variety of stakeholders; but small enough to be manageable. The challenge is not just to increase the amount of activity, but to simultaneously improve the quality of service offered in the buildings sector (new-build and refurbishment). The challenge is not solely (or primarily) technological, but is more about market transformation. This means stimulating demand for the low-carbon goods and services on offer, whilst simultaneously building up the capacity to deliver (developing skills, knowledge and supply chains).

By focusing on reducing the design-performance gap through a programme of monitored field trials, it should be possible to find robust combinations of new technologies and new working practices. This is the model of the living laboratory, which is being followed in Bicester, and which could be replicated elsewhere. Replication would mean bringing together stakeholders from different sectors, including local authorities, property owners, and firms offering goods and services. It could build on some of Oxfordshire's diverse existing strengths, including in research, building technology, and the county's many active low-carbon community groups.

8. Low carbon energy

Low carbon electricity is expected to be central to the decarbonisation of the economy – globally, nationally and locally.

Oxfordshire has been a centre of excellence in energy research and technology since the 1940s. Harwell was the location of the first nuclear reactor in Europe, built by scientists and engineers returning from the Manhattan project in the USA. The site became the principal laboratory of the United Kingdom Atomic Energy Authority (UKAEA) and therefore the pioneering centre of UK and European nuclear fission research. The Culham site was first used by the UKAEA in 1960 and remains a global centre of fusion research with the Joint European Torus (JET) project beginning there in 1978.

In addition the south of the county is home to conventional, fossil-fuelled power generation at Didcot. The 2000 MW coal-fired Didcot A power station was constructed in 1964 by the Central Electricity Generating Board (CEGB) and transferred at privatisation to National Power and subsequently RWE. National Power constructed the 1360 MW gas-fired Didcot B power station, beginning in 1994.

These historic investments in energy research and generation give the south and centre of the county a comparative advantage in power generation and high technology. However, the future of specific sites and investments is less certain. Basic nuclear research has declined at Harwell since the 1980s. Culham remains important in UK nuclear fusion research, but the next generation of international fusion research will be at Cadarache in France, not in the UK. Oxfordshire is not a likely site for a nuclear power station because coastal locations are preferred for cooling water access.

Didcot A closed in 2013 and future coal generation investment is very unlikely, as the carbon capture and storage (CCS) technology would be needed to make coal into a low carbon technology and there is no convenient site for disposing of large volumes of carbon dioxide. Didcot remains open, although RWE plans part-closure in 2023. Some continuing or replacement gas generation is possible because of the need for power generation capacity, especially in central southern England. Apart from this, the likelihood of external investment in major electricity generating projects is very low in the clean fossil-fuel and nuclear sectors.

This does not mean there are no opportunities in the electricity sector. Oxfordshire's comparative advantages lie principally in intellectual capital, research and development rather than deployment. As our analysis shows, there is a strong residual nuclear expertise, which could grow if there is a UK nuclear renaissance, but such a renaissance depends on decisions made largely outside the powers of Oxfordshire. However, Oxfordshire's history in energy research and technology provides a firm foundation for a strong role in the transition to a low carbon energy sector. Activities on the Harwell site, in particular, have already diversified in this direction. As early as the 1970s, through its Energy Technology Support Unit, UKAEA provided the main source of expertise and project management in renewable energy and energy efficiency for the UK Government. The individuals involved, and the resulting expertise and commitment to clean energy created, have played a major role in the very significant strength in civil society energy projects in the south and centre of the county. And there is a similar, although perhaps weaker, effect in the north of the county from the work of the Milton Keynes based National Energy Foundation. There is also a very large energy research activity

in the University of Oxford (over 180 senior researchers spread over many disciplines) and significant energy-related research on buildings and planning at Oxford Brookes University. Taken together these provide an exceptional base in energy research and development in the county.

Further along the innovation chain, there are some ground-breaking developments in Oxfordshire, e.g. the University of Oxford spin-out Oxford Photovoltaics, which has world leading expertise in perovskite PV technology with huge global potential. Other strengths include research expertise in energy storage (e.g. batteries and hydrogen), synthetic fuels, control systems and data analysis.

Renewable electricity

Oxfordshire's own renewable energy capacity is not outstanding compared to the rest of the UK. As a land-locked county, we have no direct access to offshore wind or other marine resources. Our onshore wind resource is not as good as more westerly and upland parts of the country, although viable in places at current levels of support. There is currently only one significant wind farm in the county at Westmill (see case study).

There is interest and activity in developing the hydropower resource of the Thames in several locations, with two existing commercial schemes at Mapledurham and Osney Mill, a community-owned scheme underway at Osney Lock (see case study), and the Low Carbon Hub now working on a pipeline of community hydro projects along the Thames. But the total usable resource on the Thames is relatively small.

Oxfordshire's forest cover is modest, limiting the traditional wood fuel resource. Production of 'first generation' biofuels from food crops (ethanol from cereals and biodiesel from oil seeds) has been undertaken to some extent, but is likely to remain limited, and is associated with some well-known environmental issues. However, this does not mean the bioenergy potential is negligible. Second generation biofuels are likely to be made from wastes and/or woody crops (such as poplar, willow and miscanthus), and these provide potentially significant opportunities in areas with pastoral agriculture traditions as well as more traditionally arable parts of the county.

Initial bioenergy interest has focused on wastes, driven by the need to find better methods of waste disposal. Agrivert's Cassington and Wallingford plants already use anaerobic digestion to produce renewable electricity (and high quality fertiliser) from much of the county's food waste. Viridor's Energy from waste plant draws on the larger stream of post-recycling waste. The initial energy output will be electricity only, but Cherwell District Council are developing the business case for a heat network connection to the North West Bicester development. Many farms also have a significant stream of wet organic waste suitable for anaerobic digestion, although further work is needed to explore the economics of this.

Oxfordshire's geothermal resources are not exceptional. Large scale generation based on deep 'hot rock' resources is therefore unlikely. But use of sub-surface heat via heat pumps is an increasingly viable technology. Ground source heating (and summer cooling) is a viable means of meeting tightening energy regulations in large new buildings, and therefore already being used, e.g. in the University of Oxford's Science Area. And the onset of the Renewable Heat Incentive (RHI) makes ground source heat pumps (GSHP) a viable technology for home heating in rural areas, where there is sufficient space to install the heat exchangers and the competing fuels are expensive (oil and electric resistance heating). Oxfordshire is home to the UK's leading ground source heat pump supplier, ICE Energy, and therefore well-placed to benefit from the growth in GSHP use.

Solar is by far the largest renewable resource in the county, as it is globally. The insolation levels (solar power per unit area) are similar to neighbouring counties, and a little worse than south west England, but better than most of the UK. Photovoltaic power generation is economically reasonably attractive, with current national support mechanisms, both on rooftops and as larger solar farms, so that it is potentially both an urban and rural technology. Solar currently provides the largest contribution to renewable power generation on Oxfordshire through a combination of roof-top installations (homes and commercial installations), and larger solar farms. These include community projects (such as Westmill), but also the recently completed East Hanney Solar Farm of 45 MW, and there is planning permission to build a solar farm at Kencot Hill, in West Oxfordshire.

Most importantly, there is existing silicon manufacturing strength in the county in PV Crystallox, as well as innovative technology in Oxford PV. Oxfordshire is therefore well placed to benefit from the current, and expected future, huge growth in use of PV technology.

The scale of support mechanisms for installations of wind, solar and biomass electricity generation is considered controversial in some quarters. In this analysis we neglect this issue, for the simple reason that the governance of it lies outside Oxfordshire. There is cross-party agreement to the arrangements for Electricity Market Reform, so that there is a very strong likelihood of wind, solar and biomass schemes remaining bankable investments. Electricity consumers in Oxfordshire, as elsewhere, will continue to provide financial support for low carbon generation across the UK through various levies on energy bills. The question for businesses, planners and policymakers in Oxfordshire, is to what extent those payments are made to electricity producers in Oxfordshire, as opposed to elsewhere in Britain.

Increasing world demand for renewable energy (and electricity in particular) presents a huge economic opportunity for research institutions and energy businesses in Oxfordshire. Government incentives combined with new business models of energy generation and supply ownership can allow a wider range of Oxfordshire stakeholders (local authorities, businesses, communities and individuals) to benefit directly and act as a living laboratory for innovation.

Oxfordshire has made a start down the road to low carbon energy. The Low Carbon Hub estimates Oxfordshire has the installed renewable capacity to produce 139 GWh per annum of electricity (about 4% of demand), with an additional 310 GWh (8% of demand) in the pipeline. However, the OxFutures programme (jointly managed by the City Council, County Council and the Low Carbon Hub) is aiming to bring £400 million of investment in renewable energy infrastructure into the county by 2020, i.e. in excess of £50 million per year. At typical investment costs for onshore wind and biomass power generation, this might generate an average of approximately 80 MW of power, supplying approximately 700 GWh/year which is 20% of the county's electricity demand. A recent renewable energy capacity study commissioned by the Low Carbon Hub⁷⁷ identified particular opportunities for solar PV, agricultural waste (anaerobic digestion) and woodland/biomass, suggesting that renewable energy has potential to generate up to 1190 GWh/year (30% of Oxfordshire demand) as well as up to 2560 GWh of thermal energy (50% of gas demand).

Smart grids and meters

Whilst there are major opportunities to invest in renewable energy, large scale deployment will encounter a number of barriers. In particular, grid access and the development of a 'smart grid' has been identified as a key challenge for Oxfordshire, as elsewhere. However, as in other sectors, challenges present major opportunities for innovation.

⁷⁷ Alkaviades, A. and McCulloch, M. Oxfordshire Capacity Study <http://www.lowcarbonhub.org/wp-content/uploads/2012/06/Oxfordshire-Capacity-Study.pdf>

Smart meter roll out is planned nationally in the period 2015 to 2020. They will allow more accurate billing and customer information – themselves worthwhile benefits. But the real prize is a ‘smart grid’ in which distribution network operators (DNOs), consumers and small generators play a much bigger role in balancing electricity supply and demand in real time. Smart grids are widely seen as key to decarbonising the UK electricity system at least possible cost, whilst ensuring security of supply, as they allow the connection of new types of electricity uses (e.g. electric vehicles and heat pumps) as well as large number of small and distributed generators. Smart grids, demand response (real time management of electricity use) and energy storage will be essential to delivering electricity systems with high levels of intermittent generation (wind and solar). This opens up innovation and new business opportunities.

Oxfordshire has very significant potential for developing activity in this field. Whilst heavy power engineering is not an Oxfordshire strength (in either the research or business sectors), there is engineering expertise in many relevant areas, including batteries and other forms of energy storage, control systems, ‘big data’ and energy management software. The development of smart grids sits at the interface between electricity and ICT, which are both areas in which Oxfordshire is strong. Future housing and transport developments provide opportunities for ‘smart grid’ technology, and there would be synergy with the wider deployment of electric vehicles and charging points (both electrification ‘smart systems’). This combination of technical expertise and the scale of planned growth provides a comparative advantage to Oxfordshire in smart grid technology.

However, initiatives and capabilities are currently disconnected. Hook Norton’s recent attempts to move in this direction highlighted the need for social innovation and stronger engagement by and with DNOs to support technological advances. Some key players (notably the largest DNO, SSE) are not significantly involved in thinking about opportunities at the Oxfordshire level and need to be engaged.

Changes to electricity regulation in recent years provide far more encouragement to DNOs to undertake innovative projects in order to prepare for the challenges that electricity networks face. The Low Carbon Network Fund (paid for by electricity consumer across the country) is already providing benefits in other counties, but not, despite the opportunities, in Oxfordshire. A ‘smart grid cluster’ looks feasible on the basis of strengths and opportunities, but more work is needed to investigate how such an initiative might be taken forward. This should be an early priority.

Renewable heat

As well as renewable electricity opportunities, the Oxfordshire Capacity Study highlights the potential to develop renewable heat within Oxfordshire. Oxford City and Bicester are both exploring the feasibility of district heating networks based on a range of energy sources including combined heat and power (CHP) and energy from waste, while Oxfordshire County Council is investing in biomass boilers in its schools. There is a largely untapped potential for new business development in renewable heat.

Case study: Smart Hooky

Working with Western Power Distribution (WPD), Hook Norton, a community with significant engagement in climate change issues, set up a project to see how householders might be able to switch peak usage of electricity in response to online information provided at the substation level (14 substations for a population of 2500 residents).

The project sought to provide this information through powerline communications – using the low voltage electricity lines in the village to act as “carrier” for the information on the usage from individual household “nodes” to the local substation for the home. Although this type of technology is used in Europe (eg. Germany), unfortunately the level of background noise and spikes in the low voltage lines in the WPD network meant that this was not possible for Hook Norton at the individual substation level.

Whilst the technological barriers were accepted in the context of the trial nature of the project, the community also found the level and frequency of communication from WPD to the community to be poor, despite frequent efforts by partner organisation the National Energy Foundation (NEF) to extract information from WPD.

For Hook Norton, a key lesson from the project is, therefore, that Distribution Network Operators (DNOs) such as WPD need to engage fully with communities and community intermediaries such as NEF. It was felt that DNOs are typically too remote from their end customers and as a result lack the in-house competencies to run an engagement project involving communities unless they commission specific specialist input.

Case study: Bicester District Heat Network

Energy from Waste Plant in Ardley/Cherwell to Heat Homes in Bicester

In October 2013 the Department of Energy and Climate Change (DECC) announced the £7million Heat Networks Funding Stream with the aim to encourage and support the development and growth of heat networks in England and Wales through the provision of grant funding and specialist support to Local Authorities.

Cherwell District Council secured DECC funding to develop a detailed business case and delivery mechanism for investment in the heat network infrastructure, utilising waste heat from Viridor's landfill and Energy from Waste (EfW) Plant at Ardley, delivering low carbon heat to 6000 homes in North West Bicester EcoTown and potentially also extending it into the wider town.



Figure 8.1 **Ardley Energy from Waste plant**

The Ardley and eco-town sites are located about one mile apart and would require an insulated pipe network to transfer the heat from the plant to the homes. The feasibility study, which will be part managed by sustainability charity BioRegional, is expected to provide

an in-depth examination into the project and the potential to extend the pipe network to larger developments within the town.

By utilising Ardley EfW plant to supply energy to new and existing homes and buildings within Bicester, the project will be making use of a heat source that would otherwise be wasted and will deliver significant carbon savings and potentially cheaper consumer energy bills.

Initial feasibility studies demonstrated the connection to Ardley EfW is viable and will provide a good rate of return to an investor when NW Bicester EcoTown is fully built out. There is also significant growth potential beyond the NW Bicester EcoTown both to existing heat users in the town and to planned new housing developments around Bicester.

The Government estimates that by 2030, 14 per cent of UK heat demand could be met through heat networks such as this.

However, the phasing of the housing developments in NW Bicester and across the town requires a more detailed analysis in order to understand the optimum time to invest in the connection and the optimum steps for the extension of the heat network.

Cllr Nigel Morris, lead member for clean and green, said: *“The core foundation of the north west Bicester eco-town is to create sustainable living and by effectively recycling wasted heat to provide low carbon energy for homes, this project fits that criteria perfectly. However, while the idea works in principle, the practicalities of delivering this scheme need to be investigated further and this money will enable us to do just that before we proceed.”*

Case study: Westmill

Westmill is home to two co-operatively owned renewable energy projects, located on the Oxfordshire-Wiltshire border.

Westmill Wind was the result of a 15 year planning battle. The five turbines were erected in 2008 and have been successfully generating around 11GWh a year since then, powering around 2,500 typical homes.

The community raised the £8 million construction cost, with a £4.6 million share offer and a £3.4 million 12-year loan from the Co-operative Bank, allowing them to buy and erect the turbines. The wind-farm is democratically managed – with a seven person board elected by members.

Returns have varied with wind speeds and electricity prices but to date have been around 3%, rising significantly once the bank loan is repaid.

Westmill Solar comprises 21,000 panels generating around 4.5GWh a year. The community exercised an option to buy the project from the developer at an agreed price of £15 million. 1,650 members together raised about £6 million in equity with a further £12 million of 24 year bond finance provided by the Lancashire Pension fund.

The wind cooperative created and funds WeSET – a charity which uses arts and education and provides funding, all to support local low energy initiatives. Drawing on local volunteers and trustees the charity has run open days, educational programmes and has helped welcome 8,600 visitors (and rising) to the site.



Figure 8.2 **Westmill Solar Park: community investment in large-scale renewable energy**

Case study: Osney Lock Hydro

The Low Carbon Hub supported Osney Lock Hydro (OLH) to launch and market their share offer for the first community-owned hydro scheme in Oxfordshire. The scheme will harness the power of the Thames to generate 159,000 kWh of renewable electricity in the heart of Oxford, enough to power 50 homes, and save 83 tonnes of CO₂ per year. The income from the sale of electricity and the feed-in tariff will give investors a financial return for their support and fund future community initiatives. The share offer aimed to raise investment of £250,000 over a month but, in fact, OLH reached more than double their target in just three weeks. The scheme aims to generate £2 million over 40 years to fund energy demand reduction programmes to further reduce carbon emissions.

Figure 8.3 **Osney Lock Hydro: an example of community crowd-funding in Oxfordshire**



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Artist's impression: *Osney Lock Hydro microhydro installation once completed.*

9. Conclusions and next steps

This chapter summarises the key messages of the report and outlines a number of recommendations and priorities for action.

Summary of findings

The global challenge of climate change is a business opportunity on a vast scale – measured in trillions of dollars per year. Oxfordshire's knowledge-based economy is well placed to benefit from this opportunity and to become a leader in a variety of low-carbon goods and services. Particularly promising technology sectors include building technologies, alternative fuels, alternative fuel vehicles, solar PV and wind energy. Consulting and professional services are also areas where Oxfordshire has expertise related to low-carbon economic activity.

The county's economic growth plans will require infrastructure investment in order to cope with the added pressures on transport and housing, and to continue to make Oxfordshire attractive to business. There is a golden opportunity to bring together the economic strengths of the county's low-carbon sectors with the plans for new infrastructure, creating a virtuous circle of innovation and investment, leading to both economic growth and reduced CO₂ emissions.

Seizing the opportunity will require strong leadership and a greater effort to foster cross-sectoral links. Particularly important to this endeavour is the need to look beyond technology clusters and to foster collaborations between business, researchers and civil society around a series of living laboratories. Examples of these partnerships already exist in Oxfordshire and the model could be replicated and refined. The benefit to firms based in Oxfordshire will be to have local test-beds for their products and services. For local infrastructure investment, the framework of living laboratories allows for intense rounds of monitoring and evaluation of technologies in real-life settings.

Such multi-sector collaborations require coordination across many disparate sectors of activity. Although the task can appear daunting, one of the benefits of working across so many sectors is that it opens up new opportunities for funding and investment – from both the public and private sectors. Venture capitalists, business angels, government-backed Research Councils, European Commission programmes, UK government economic development grants, infrastructure providers, large businesses, and even local households and business owners – they can all contribute to a future in which economic growth objectives and low-carbon solutions are strategically aligned.

Existing local strategies and funds create an opportunity to catalyse low carbon investment into the wider innovation and growth agenda, including:

- Innovation Support for Business Programme
- City Deal
- Strategic Economic Plan and Strategic Environmental Economic Plan
- European Structural and Investment Fund
- OxFutures
- Local Transport Plans 3 and 4

Recommendations

Building on existing strengths, there is the potential to do much more to harness these opportunities, using Oxfordshire's networks, funding streams and partnerships, and learning from successes elsewhere.

Developing a well-connected low carbon ecosystem is likely to be complex. Support will be needed for low carbon clusters, networks and living laboratories, supported by strong leadership to marshal the evidence and arguments, create demand for low carbon solutions, create a shared vision and drive forward a coherent agenda.

Our research suggests that developing Oxfordshire's low carbon economy and ecosystem needs a three-pronged approach, underpinned by collaborative leadership:

- First, support should focus on identified growth sectors and areas of strong business opportunity, in particular alternative fuel vehicles and renewable and smart electricity innovations, as well as appropriate cross sector collaborations.
- Secondly, there is an opportunity to drive and support leadership in these sectors through investment in decarbonising Oxfordshire's infrastructure and the development of living laboratories to deploy existing and developing technologies tailored to the Oxfordshire context and needs. This is likely to require support for demonstration projects, testbeds and field trials as well as positive engagement from stakeholders in order to maximise the living laboratories' chances of success.
- Thirdly, public strategies (including land use planning), funding and cluster support (eg. smart cluster branding and a cluster champion) are needed to develop the cross-cutting enabling infrastructure and networks to nurture the full range of innovation, growth and infrastructure opportunities.

More research work is needed to develop specific business cases for public and private sector investment in innovation, business growth and infrastructure.

Based on this broad approach, we set out below suggested areas of focus and recommendations to help Oxfordshire make the most of the economic opportunity and tackle infrastructure challenges effectively, followed by four suggested priority actions and next steps.

	Recommendation	Organisations/ funding
1	<i>Support RD&D in low carbon vehicles, building technologies, and low carbon and smart electricity solutions</i>	
a	Work with the existing automotive and motor sport cluster, ICT and other high tech sectors to support R&D and innovation	Local: LEP, supported by national: Automotive Council UK, Innovate UK, Advanced Propulsion Centre, OLEV
b	Ensure sufficient and appropriate space for science and technology based companies	LEP, County Council, District Councils, universities
c	Further improve cooperation between industry and government	Local: LEP, supported by national: Automotive Council, Innovate UK, Advanced Propulsion Centre, OLEV, Venturefest, KTN
d	Support future skills needs throughout the supply chain (especially automotive, electricity generation)	Automotive Council; SMMT; LEP; SSE; WPD; industry, government and relevant skills bodies; universities; FE colleges

	Recommendation	Organisations/ funding
2	<i>Support demonstration projects and Oxfordshire's living laboratories</i>	
a	Transport: Take the lead in demonstrating and stimulating the uptake of EVs and accelerating e-mobility in Oxfordshire	LEP to catalyse; Oxford EV Partnership, ⁷⁸ SSE, major employers, Local Authorities, North Oxford E-Car Club
b	Transport: develop the structure of a transport living laboratory around three elements: 1. the formation of a regional research centre within Oxford's two Universities – the "Living Transport Lab Institute"; 2. the formation of "Living Transport Lab Services" to prepare low carbon solutions with key stakeholders; 3. "Living Transport Lab Capital" – provides an interface with local government and low carbon service providers, to deliver large scale transport infrastructure and capital solutions.	LEP, Local Authorities, service providers, universities, "cluster champion" Funding through private/public sponsorship, research grants, Innovate UK / Catapult, etc.
c	Housing: Learn from and build on Eco-Bicester Living Laboratory	Cherwell DC and other local authorities; Housing Associations
d	Housing: support demonstration projects and training to foster skills, support new business models and new building processes	All DCs; Housing Associations
e	Housing: Develop model for community engagement with housing growth and 'new town thinking'	Oxford Futures, Low Carbon Hub; DC and CC planners; CC transport planners; Housing Associations
f	Electricity: develop plans for smart grid demonstrations, linked to housing and transport infrastructure and involving the universities, National Grid & DNOs, Oxfordshire County Council and Oxfordshire's Spatial Planning and Infrastructure Partnership.	SSE Energy Supply Ltd; Western Power Distribution; Universities; LEP
g	Use corporate plans to invest in energy efficiency and renewable energy, helping to stimulate high tech solutions and build a local low carbon supply chain.	University of Oxford, Oxford Brookes University, Oxford City Council, Oxfordshire County Council, and other major organisations

⁷⁸ The partnership includes international companies such as Qualcomm, Bosch, Verdant Automotive, Chargemaster, Hertz, SSE, British Chamber of Commerce, Oxford Brookes University and Sutherland Campbell International as well as local organisations including Cryox, Oxford City Council and Oxfordshire County Council.

	Recommendation	Organisations/ funding
3	<i>Public strategies, land use planning</i>	
a	Develop a shared, multi-stakeholder vision of low-carbon to drive delivery of Oxfordshire's economic development plans	LEP/ ESIF / LCO
b	Embed carbon reduction and sustainable growth as core principles of all infrastructure investment plans (including the Strategic Economic Plan, City Deal and ESIF).	LEP
c	Plan for investment in charging stations and infrastructure to support adoption of EVs and accelerating e-mobility in Oxfordshire	Oxford City Council and Oxfordshire County Council, Oxford EV partnership
d	Buildings: investigate opportunities for local authorities to lead a market for low-energy buildings in Oxfordshire (eg through planning and procurement policies).	All local authorities
e	Renewable energy: clearly designate land as appropriate for renewable energy development in Local Plans	District Councils
f	Develop a strategic land-use plan for Oxfordshire for 2030, showing how much future growth is expected and how infrastructure will be upgraded	All local authorities
g	Ensure coordination of transport and land use planning	All local authorities
4	<i>Network & cluster support</i>	
a	Explore feasibility of targeted cluster support e.g. branding and champion.	LEP/ ESIF
b	Buildings: establish a multi-sector innovation network for low-energy buildings	LEP
c	Continue and extend the low carbon network navigator role to build the soft infrastructure	LEP, LCO
d	Further work to map low carbon cluster(s) and wider ecosystem and capture low carbon economic activity	LEP/ ESIF

	Recommendation	Organisations/ funding
5	<i>Business cases for public and private sector investment</i>	
a	Transport: invest more heavily in sustainable transport options along “knowledge spine” and congested corridors – to improve accessibility to jobs and services	Oxfordshire County Council, Network Rail, Highways Agency, public transport operators
b	Housing: explore new business models for financing (especially private-sector refurbishments);	LEP, LCO, LCH
c	Housing: develop procurement models, building on lessons from the Living Labs, for local authorities to lead an ambitious programme of housing refurbishment	LEP, LCO, LCH
d	Investigate the feasibility of an angel investors club for high tech low carbon innovations.	LEP
e	Investigate feasibility of Oxford Investment Bank (based on examples like Silicon Valley Bank and Cambridge Bank) that could raise significant finance through the issue of public bonds, focused on bigger infrastructure projects	LEP
f	Reduce risk and increase rewards for low carbon clusters and innovators to increase confidence in investing in low carbon	LEP, local authorities, Automotive Council, OLEV
6	<i>Leadership, visioning, engagement</i>	
a	Carry out a multi-sectoral visioning exercise to bring in new ideas and build up support for the growth plans	LEP
b	Develop a communications strategy for ‘Oxfordshire 2030’ for key constituencies: existing residents and businesses; key businesses in target growth areas	LEP

Priority actions and next steps

The following priority actions and next steps are suggested over the next six to twelve months, to start implementation of the recommendations listed above and maintain momentum for this agenda.

	Action	Organisations and funding
1	Work to map and capture Oxfordshire's low carbon cluster(s), economic activity and wider ecosystem, and their needs	Oxfordshire Innovation Support for Business Programme and LCO, funded by the LEP and possibly ESIF
2	Develop a shared, cross-sectoral vision and strategy on low carbon infrastructure, investment and innovation	LEP, local authorities
3	Further research to understand and develop more specific business cases and models for investment by the public sector, private sector investment, household investment and internal corporate investment.	LEP, Universities, LCO, Oxfordshire Innovation for Business Support Programme, key businesses, Oxfordshire County and Oxford City Councils, Spatial Planning and Infrastructure Partnership; Network Rail; Highways Agency; DNOs
4	Further research to: • understand opportunities in more detail; • understand the implications of and for land use planning; • explore other sectors including agriculture and food; • identify and learn from examples of success elsewhere; • explore links and collaboration with other centres of low carbon expertise in the UK; and • explore further the implications of low carbon growth for other policy objectives and wider quality of life.	Universities, LCO, Oxfordshire County and Oxford City Councils

“... it is the culture and networks across businesses, residents and the public sector within the city that ensure ‘low carbon goals’ remain a priority beyond political cycles. Maintaining this city-wide ethos requires significant community and business support. If low carbon values are held and shared, it is easier for local government and businesses to prioritise measures that drive green growth.”⁷⁹

⁷⁹ Centre for Cities (2013), “Delivering change - How cities go low carbon while supporting economic growth”, p.37.

List of stakeholders

List of stakeholders who attended a workshop to review and discuss interim findings, 10 June 2014

Invited stakeholders:

Brenda Boardman (Environmental Change Institute, University of Oxford)
Catherine Bottrill (Pilio Ltd)
Sam Clarke (New Economics Foundation; Low Carbon Hub; Low Carbon Oxford North)
Jo Colwell (Oxford City Council)
Nicholas Falk (URBED; Oxford Futures report author)
Anne Gwinnett (Oxford Brookes University; incoming Chair of Oxford Strategic Partnership)
David Hartley (Oxford Brookes University Knowledge exchange team)
Peter Headicar (Oxford Brookes University)
Malcolm McCulloch (University of Oxford)
Liz Reason (Charlbury and formerly Ilex)
Craig Simmons (Best Foot Forward)

Steering Group:

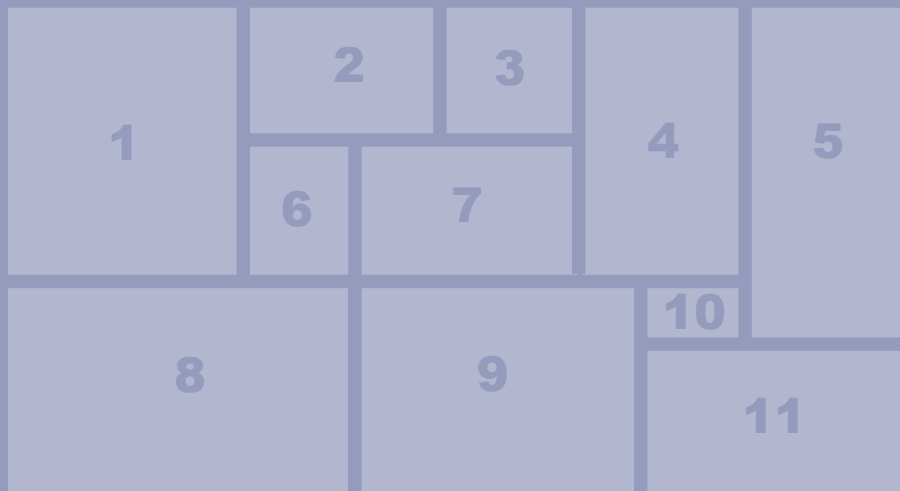
Barbara Hammond (Low Carbon Hub, Low Carbon Oxford)
Rob Hetherington (Oxford City Council)
Cameron Hepburn (Smith School)
Nick King (Oxfordshire County Council)
Luke Marion (Oxford Bus Company)
Dave Waller (Oxfordshire Local Enterprise Partnership)
Stuart Wilkinson (Oxford University Knowledge Exchange & Impact Team)

Project Team:

Anne Augustine (Low Carbon Oxford)
Ian Curtis (Environmental Change Institute, University of Oxford)
Nick Eyre (Environmental Change Institute, University of Oxford)
Gavin Killip (Environmental Change Institute, University of Oxford)
Julia Patrick (Environmental Change Institute, University of Oxford)

Facilitator:

Saskya Huggins



Front cover photographs (by Ian Curtis, except where stated):

- 1.** Hybrid bus on the Park & Ride service
- 2.** Oxford University research into new perovskite technology for solar photovoltaics (Oxford University)
- 3.** Osney Lock Hydro – a community-owned renewable energy project on the river Thames
(© Wandrille Madelain)
- 4.** R&D for solar-thermal-powered water pump technology at Oxford University
- 5.** Electric vehicle charging point
- 6.** Westmill Co-operative Ltd – wind farm and solar park
- 7.** Electric Mini trials in Oxford
- 8.** One of Oxford University's new science buildings
- 9.** Remote energy monitoring device developed at Oxford University
- 10.** Thermal imaging reveals heat loss and energy wastage from homes in Oxford
(Ian Mawditt/fourwalls)
- 11.** Innovations in motor technology and efficiency at Milton Park (Tim Woolmer/Yasa Motors)

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