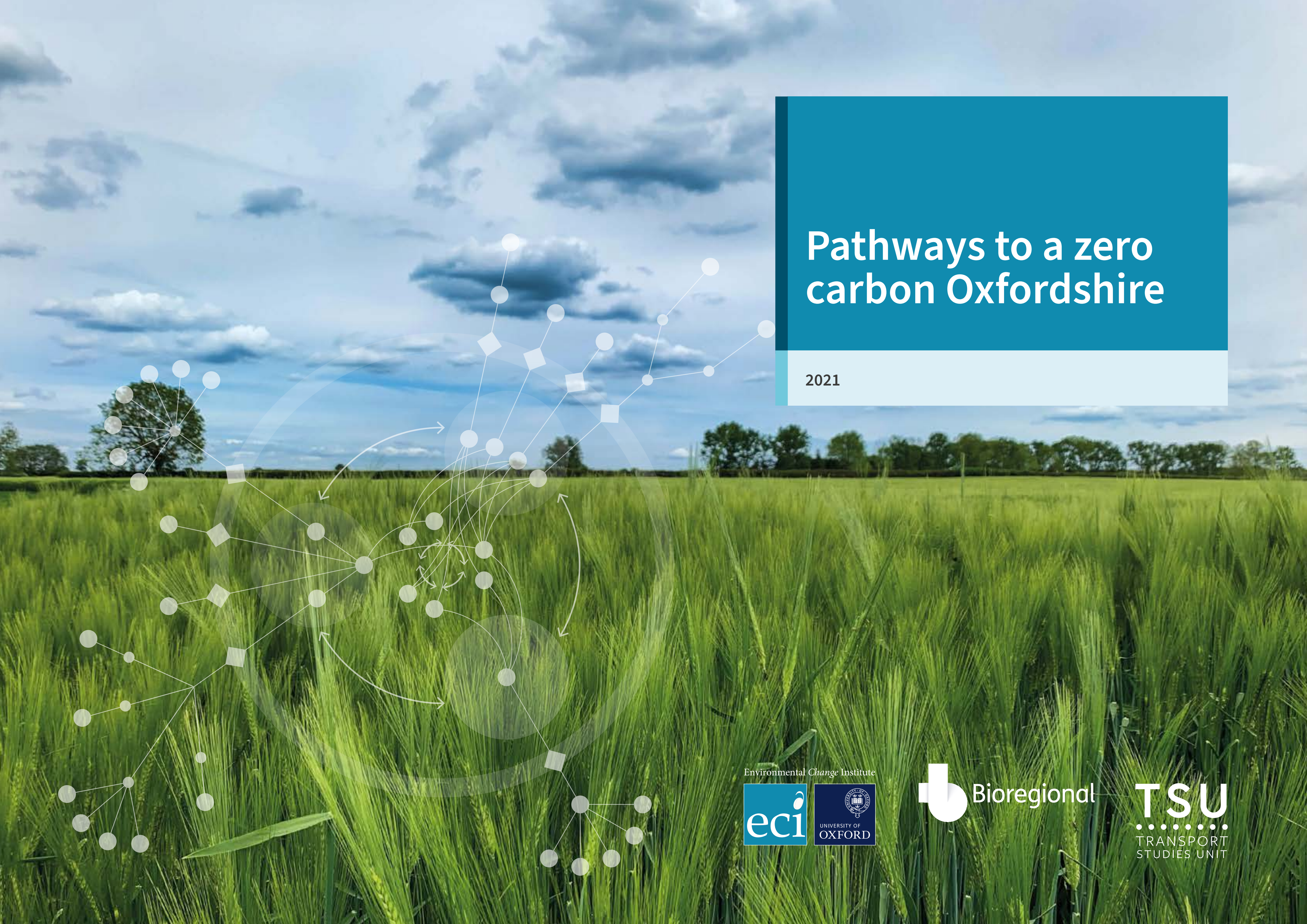

Pathways to a zero carbon Oxfordshire

2021

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Greater South East Energy Hub

Scottish & Southern Electricity Networks

Vale of White Horse District Council

South Oxfordshire District Council

OSI Oxford Sciences Innovation

West Oxfordshire District Council

Contents

Abbreviations

AONB	Area of Outstanding Natural Beauty
BECCS	Bioenergy with Carbon Capture and Storage
BEIS	Department for Business, Energy and Industrial Strategy
BEV	Battery Electric Vehicle
CCS	Carbon Capture and Storage
CHP	Combined Heat and Power
COP	Conference of the Parties
DECC	Department for Energy and Climate Change
DFES	Distribution Future Energy Scenarios
DNO	Distribution Network Operator
DUOS	Distribution Use of System
EPC	Energy Performance Certificate
ERDF	European Regional Development Programme
ESO	Project ESO: Energy Superhub Oxford
EV	Electric Vehicle
FES	Future Energy Scenarios
GHG	Greenhouse gases
GDP	Gross Domestic Product
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
LEO	Project LEO: Local Energy Oxfordshire
NDS	Nationally Determined Contribution
NG	National Grid
NGESO	National Grid Electricity System Operator
OxLEP	Oxfordshire Local Enterprise Partnership
OZEV	Office for Zero Emission Vehicles
PHEV	Plug-in Hybrid Vehicle
PV	Photovoltaic
SME	Small or medium sized enterprise
TUOS	Transmission Use of System
ULEV	Ultra-Low Emission Vehicle
UNFCCC	United Nations Framework Convention on Climate Change
VC	Venture Capital

Photo: Matt Seymour on Unsplash

Executive summary

Tackling climate change has become an urgent priority for governments, businesses and citizens around the world. In 2019, the UK Parliament passed legislation committing to a target of net-zero carbon emissions by 2050. In response, local authorities around the country have been scaling up their ambitions to tackle climate change. In Oxfordshire, all local authorities have acknowledged and responded to the climate emergency, and are developing plans to achieve net-zero carbon emissions by 2050 or sooner.

Oxfordshire has made rapid progress in reducing carbon emissions over the last decade, and is on track to achieve the target agreed by its local authorities of a 50% reduction by 2030.[1] While its GDP grew by 34% between 2011 and 2018, its usage of energy remained roughly constant, and CO_2 emissions fell by 17%.

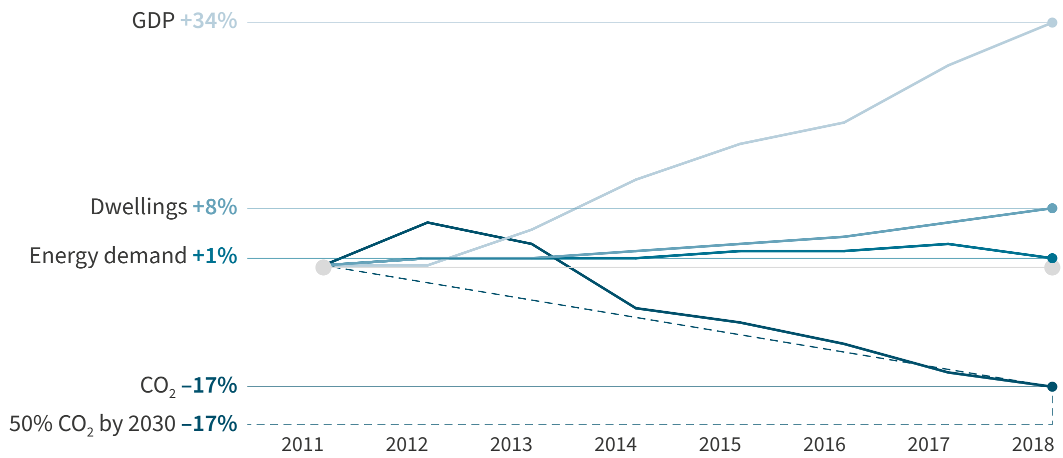
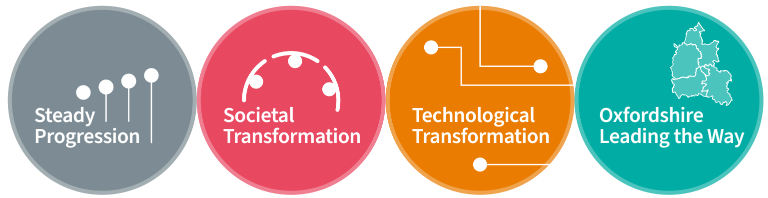


Figure 1: Relative change in GDP, number of dwellings, CO2 emissions and energy demand (2011=1)

This report addresses the question of how Oxfordshire can sustain the momentum of the last decade to achieve net-zero emissions. While substantial progress has been made to decouple economic growth from carbon emissions, driven by cleaner electricity supply and increased energy efficiency, there remains a significant way to go to decarbonise transport, reduce reliance on fossil fuels for heating, and protect and enhance carbon stored in the natural environment. Maintaining the same rate of emissions reduction in Oxfordshire will require relatively greater investment locally, in building retrofit, cleaner heating systems and electric vehicles; and cultural and behavioural changes such as active travel, dietary changes and reduced energy demand.

1 Against a 2008 baseline.



Our analysis shows that there are different routes to net-zero, and in presenting scenarios for the next three decades, we outline three distinct pathways to eradicating emissions from the economy.

Our **Steady Progression** scenario falls well short of stated climate aims, and illustrates the scale of change needed to achieve net-zero. **Societal Transformation** is led from the bottom up, with householders adopting new technologies and practices, and community groups corralling action. **Technological Transformation**, by contrast, relies on systemic changes driven at the national level, including the deployment of hydrogen for heating and other technical solutions which require the least change to individual behaviour. Finally, **Oxfordshire Leading the Way** mirrors the widespread cultural and behavioural changes seen in Societal Transformation, and combines this with high deployment of new local electricity generation using solar photovoltaics.

Which pathway Oxfordshire will take depends on a variety of factors, including technological innovation, macro-economic trends following COVID-19, public support, changing social norms and behaviours, and policy decisions taken at the local, national and international levels. While some factors are outside of local control, businesses, policy makers and residents in Oxfordshire have a crucial role to play in innovating, investing, strategising and implementing the changes needed for net-zero.

The second half of the report analyses the implications of net-zero for different sectors of the economy, as follows:

Low carbon innovation: Oxfordshire's low-carbon sector is thriving. Two of four national energy systems demonstrator projects are based in Oxfordshire, and its automotive sector continues to lead the way on innovation for autonomous vehicles, electric powertrain development and battery technologies. The University of Oxford has successfully generated 30 new cleantech spinout companies alone, with many more establishing a presence within the county and pioneering new technologies to address the challenges created by the climate emergency. The low-carbon sector is also thriving alongside high-tech industries, as community groups and SMEs develop solutions to reduce carbon emissions through alternative business models and the sharing economy.

Transport: Like the UK as a whole, Oxfordshire has struggled to reduce emissions from transport, despite successes such as accelerated uptake of electric vehicles in the county and increased cycling in Oxford City. There remains significant potential for more widespread walking and cycling, as the transition to net-zero cannot rely on electric vehicles alone. The key components of pathways to decarbonise transport are 'Avoid, Shift, Improve'. Switching to electric is an example of 'Improve', while telecommuting can be a way to 'Avoid' travel. A 'shift' to local, active travel can help increase footfall on local high streets and ease congestion as well as improving health. There is an urgent need for improved infrastructure for public transport and active travel; controlling and charging for parking; supporting digital connectivity that reduces the need to travel; requiring new developments to be compact and walkable; and encouraging the uptake of zero emissions vehicles.

Energy efficiency and heating in buildings: All pathways to net-zero require profound and widespread changes to the built environment. This includes upgrading the energy efficiency performance of the majority of buildings across Oxfordshire, and replacing heating systems which rely on fossil fuels (gas and oil), with low and zero carbon technologies (heat pumps, biomass, hydrogen). The markets for goods and services to create and maintain low-carbon buildings are small and immature. A much stronger focus on market creation and development is needed if existing technologies are to be deployed at the scale and quality required. Not only does this imply a need for a skilled workforce of installers, advisors and other intermediaries, but also regulated minimum standards to create demand, supported by a much more rigorous system of compliance-checking. There is a need to simultaneously stimulate demand and supply for high quality products and services to reduce emissions from the built environment.

Low Carbon Energy: Solar energy is Oxfordshire's greatest low carbon energy generation resource with the county already contributing more than 3% of the total UK solar photovoltaic capacity, more than double its share of population and land area. There is significant potential to expand local solar PV electricity generation. Each of our net-zero pathways includes substantial deployment: the most ambitious sees installed capacity expanded by up to 10 times. Increasing local renewable electricity generation is needed in response to an expected doubling of electricity demand due to the electrification of heating, transportation and high population growth, ensuring Oxfordshire takes a leading role in the decarbonisation of the electricity sector nationally. To maximise local benefits, Oxfordshire should develop local energy partnerships and the proven appetite for community energy.

As with all intermittent decentralised generation, high penetration can have significant impact on local networks with flexibility and data key to maximising system utilisation at the lowest cost to users. Oxfordshire is in the enviable position of hosting two national demonstrator projects (Project LEO and ESO) and a wealth of knowledge in this area which it must exploit.

Land use and carbon sequestration: Oxfordshire is dominated by intensive agriculture, with farmland occupying 70% of the county. With 14% being built-up, there is only 9% woodland and 7% other semi-natural habitats. We estimate that currently around 316,000 tonnes of CO_2 are sequestered each year (after accounting for at least 100,000 t lost annually when land is cleared for development); a small fraction of the 4 Mt produced through use of fossil fuels. However, around 85 Mt CO_2 are stored in the county's soils and vegetation and it is vital to protect and enhance this carbon store well as restoring soils, woodland and other ecosystems to enhance sequestration further.

Land is a finite and precious resource, and our scenarios reveal trade-offs between demand for land for food, bioenergy, solar, housing, carbon sequestration and biodiversity. For example, it would take 37–56% of Oxfordshire's land to produce the quantity of bioenergy envisaged in the National Grid scenarios in order to provide the 'negative emissions' (via BECCS, i.e. bioenergy with carbon capture and storage) needed to reach net-zero. Stringent energy demand reduction can reduce the need for such negative emission options. Shifting to a lower meat diet also has a vital role to play in freeing up farmland for sequestration.

Smart land-use planning with the participation of all stakeholders is essential in order to minimise trade-offs and maximise the substantial co-benefits that could be achieved through well-designed nature-based solutions, including a mix of ecosystem restoration and regenerative agriculture that enhances soil carbon storage, as well as integrating high quality green infrastructure into new developments. The proposed new Local Nature Partnership will have a critical role in developing a Natural Capital Plan for Oxfordshire that meets targets for both net-zero and Nature Recovery, as well as securing livelihoods for farmers and health and wellbeing co-benefits for local communities.

Conclusions and recommendations

All net-zero pathways will involve:

- the expansion of solar generating capacity in Oxfordshire
- a major programme of retrofit for existing homes and non-domestic buildings
- prioritising climate goals when planning for new homes and developments
- substantial increases in electricity demand, driven by heat and transport, requiring grid reinforcement *and* flexibility provided by various means
- the phase out of gas boilers and fossil-fuelled modes of transport
- a need for innovation in food production to maintain or increase output while agricultural land makes way for development, and Oxfordshire grows its fair share of biofuels.
- protection and restoration of ecosystems and natural capital, for enhanced sequestration and increased biodiversity.

Net-zero targets: While each local authority in Oxfordshire has set an aspirational date for area-wide net-zero emissions, some have chosen 2050 (County Council, West Oxfordshire DC), Vale of White Horse DC is aiming for 2045, Oxford City council for 2040 and others 2030 (Cherwell DC, South Oxfordshire DC). These differences partly reflect local circumstances, such as differences between urban and rural districts, but they have substantial implications for policy, investment and local action.

Although ambitious targets can be vital for driving policy change and investment, our models suggest that achieving the earlier targets will be extremely challenging, especially without significant devolution of additional powers to local authorities. However, there are additional ways to demonstrate leadership on climate change as well as target setting, such as in using planning powers to develop policies that align with net-zero carbon developments by applying 15-minute neighbourhood principles, implementing active travel infrastructure, and including ecosystem restoration.

Shattering myths

"We should plant trees to offset our emissions"

... we need to protect existing trees, but planting new trees can remove only a small fraction of current emissions, and we need to restore a mix of native ecosystems to reverse biodiversity loss.

"We need a more skilled & qualified workforce"

... the skills challenge is not just a supply problem, we also need demand for skills, driven by markets for zero-carbon solutions.

"Electric vehicles are coming to save us"

... switching to cleaner fuels is insufficient for net-zero. We also need to reduce our transport demand and complete more of our journeys by walking, cycling, public and shared transport.

"Net-zero can be achieved by 2030"

... without relying on offsets, the scale of investment, technological and lifestyle change, without national policy support, is unrealistic.

"Fossil fuels are needed for economic growth"

... renewable energy and other zero-carbon solutions represent opportunities for more efficient use of resources. Unlike spending on fossil fuels, investment can be kept local.

"It all comes down to individual behaviours"

... while lifestyle change and sustainable choices will be crucial, these are influenced by infrastructures, systems of provision and social norms. Reshaping these requires action from myriad actors.

Co-benefits: If the phase-out of carbon emissions is managed effectively, a variety of economic, social and environmental benefits can be achieved. These include the creation of high-skilled, well paid jobs in the zero carbon sector; creating cohesive and desirable places to live by empowering local communities and diverse individuals to drive action; and cutting air pollution. Restoring habitats, providing urban green infrastructure and shifting to regenerative agriculture can support wildlife while delivering ecosystem services such as natural flood management and urban cooling, and providing health and wellbeing benefits for local people.

COVID-19 recovery: More than 1000 people in Oxfordshire have lost their lives to COVID-19, and the pandemic has had a severely detrimental impact on nearly all residents and businesses in Oxfordshire. In the short term, energy demand and carbon emissions have fallen sharply. As the economy gets back on its feet, it is imperative that the sustainable practices adopted by businesses and individuals, such as telecommuting and active travel, are supported and sustained.

Embodied carbon: This report focuses on direct emissions (Scope 1) and those associated with purchased energy (Scope 2). However, there are emissions 'embodied' in the goods and services imported into the county, including the materials used for constructing new housing, the batteries used in electric vehicles, and food and biofuels that must be produced elsewhere when land in the county is used for carbon-reducing activities such as planting trees. In the next decade, the priority must be on reducing Scope 1 and 2 emissions. However, as the emissions associated with energy and transport usage reduce over time, the relative proportion of embodied emissions will grow. Climate change will need to be increasingly factored into procurement decisions and supply chain governance, whether those are major investments in construction materials for new homes, or everyday purchases such as food. A shift towards a circular economy based on reducing waste and unnecessary consumption will play a large part in reducing the embodied emissions imported in material goods.

Infrastructure: The forthcoming update to the Oxfordshire Infrastructure Strategy is due to include climate related indicators when evaluating the need for strategic infrastructure. While it goes without saying that all investments in local infrastructure should be compatible with net-zero, there is also a need to systematically review the role of existing infrastructure in 'locking in' high carbon practices, and plan for change. More granular data on demand patterns will help enable the more efficient use of existing infrastructure. There is a need to expand the definition of infrastructure to include Oxfordshire's building stock, and to rank retrofit as a strategic priority alongside electricity grid reinforcement and the installation of new solar generation. Green infrastructure should also be integrated into the strategy, as it has potential to deliver multiple benefits for climate, health and biodiversity.

Financing the transition: Local authorities have experienced significant funding cuts in the last decade, and COVID-19 has led to further financial woes. While there is uncertainty over the future of core funding for programmes to drive down emissions, there are other options for raising investment in zero-carbon solutions. These include expanding the Low Carbon Hub's model for raising community investment; following West Berkshire Council's example of launching a Green Bond, and developing projects for investment by the Oxfordshire Local Government Pension Fund.

Partnership working: Stakeholders in the low carbon sector have a strong record of collaborating to attract investment and drive forward innovation. There is potential to expand networks such as Oxfordshire Greentech, Community Action Group network and Low Carbon Hub CIC. The Oxfordshire Growth Board recently proposed the creation of a new environment advisory group which was supported by all local authority leaders. If properly resourced, this could drive forward the agenda set out in the Oxfordshire Energy Strategy, and begin to develop an action plan to meet climate goals. It is hoped that the evidence and modelling in this report will directly inform this advisory group, as well as the work of the proposed Local Nature Partnership.

Photo: Li An Lim on Unsplash

1 Introduction

Aims of the report

- Set out the new context for Oxfordshire's climate goals
- Report on recent progress on emissions reduction
- Spotlight the low carbon innovation ecosystem, which will be key for enabling the transition of all economic activity to zero emissions
- Review progress made and further changes needed in transport, building energy efficiency and heating, energy supply, and land use
- Outline different potential pathways to achieving a zero carbon economy in Oxfordshire by 2050, with milestones for 2030

1.1 Background

Tackling climate change has become an urgent priority for governments, businesses and citizens around the world. In 2019, the UK Parliament passed legislation committing to a target of net-zero carbon emissions by 2050. In response, local authorities around the country have been scaling up their ambitions to tackle climate change. In Oxfordshire, all local authorities have acknowledged and responded to the climate emergency, and are developing plans to achieve net-zero carbon emissions by 2050 or sooner.

Reaching this goal is a mammoth task, but momentum is building. Despite uncertainty relating to Brexit and COVID-19, Oxfordshire is on a steep growth trajectory with major foreign direct investment flowing into its businesses and research base and, with it, increased international attention from around the world. It is widely seen as a global hub for innovation, discovery and tackling the most pressing challenges facing society. Since 2014, Oxfordshire's GDP has grown by more than 20% and its number of homes has grown by more than 10%. However, carbon emissions have already been decoupled significantly from economic and population growth, and the county is on track to achieve the target set out in the Oxfordshire Energy Strategy, of a 50% emissions reduction by 2030.[2]

In 2014, Low Carbon Oxford, in partnership with the Environmental Change Institute at the University of Oxford, published a report evaluating the scale and potential of the low carbon economy in Oxfordshire. Since then, that growth has been realised, with substantial investment being made in research, innovation and deployment of low carbon solutions.

Two of four national energy systems demonstrator projects are based in Oxfordshire, and its automotive sector continues to lead the way on innovation for autonomous vehicles, electric powertrain development and battery technologies. The University of Oxford has successfully generated 30 new cleantech spinout companies alone, with many more establishing a presence within the county and pioneering new technologies to address the challenges created by the climate emergency. The low-carbon sector is also thriving alongside high-tech industries, as community groups and SMEs develop solutions to reduce carbon emissions through alternative business models and the sharing economy.

1.2 New context, new approach

Seven years on from the Low Carbon Economy report, the economic, environmental and policy context is very different, illustrating the speed with which the landscape is changing. This requires a new approach to assessing Oxfordshire's contribution to mitigating climate change. Although the businesses and communities often referred to as the 'green sector' will have a crucial role to play in delivering the products and services needed to decarbonise the economy, it is imperative that activity across the economy is compatible with a zero-carbon future. This report therefore expands its scope to address the question of how Oxfordshire's entire economy can achieve net-zero emissions by 2050, or sooner. It highlights the enormous challenges ahead in transforming our energy and transport systems, substantially upgrading our building stock, and using our land for enhanced carbon sequestration. Progress since 2014 has been uneven, and the report points to areas where change and investment is urgently needed.

2 Based on a 2008 baseline.

Oxfordshire's economy is highly connected to the wider UK economy and beyond. It relies on free flows of people, capital, goods and services, and the outputs of its knowledge economy are exported around the world. As well as making a significant contribution to global climate goals through its innovation and research expertise, Oxfordshire's transition to zero-carbon will rely on developments elsewhere, including advances in technology, progressive climate policy, and broader changes to social norms and practices.

1.3 Scope

This document builds on the 2014 low carbon economy report which included chapters on innovation, transport, housing and energy supply, as well as provided scenarios for low carbon growth to 2030. Reflecting the new context, this report expands its scope in several ways. We expand our analysis of the built environment to include non-domestic buildings in Oxfordshire, focusing on energy efficiency and heating, and we include a chapter on land use and carbon sequestration. Although the emissions associated with food production and consumption are substantial, an analysis of Oxfordshire's food system is excluded from this study.

The scenarios in this report focus on two milestones: 2030 and 2050. The Oxfordshire Energy Strategy sets a target for 50% reduction in carbon emissions by 2030, while achieving net-zero by 2050 is now UK law. Several local authorities in Oxfordshire have stated ambitions to achieve net-zero before 2050, and we discuss the implications for earlier action in the concluding chapter.

The UK government's target refers to 'net-zero', rather than 'zero carbon', as it assumes that some residual emissions will remain beyond 2050 in very challenging sectors such as aviation and high-temperature industrial processing, requiring negative emissions solutions to counteract their continued contribution to global warming.

In the context of Oxfordshire, without a major airport nor heavy industry clusters, the implications all emissions associated with transport, buildings, energy and land use must be eradicated. As a rural county, Oxfordshire must contribute its fair share of carbon sequestration via bioenergy production and nature-based solutions, but the emphasis of this report is on achieving a zero-carbon economy without relying more than absolutely necessary on negative emissions. This emphasis is reflected in the report title, and our use – wherever feasible – of 'zero-carbon' rather than 'net-zero' to refer to the actions needed.

1.4 Report structure

The report is structured into nine chapters. **Chapter 2** discusses the new context for climate ambition with a focus on policy at global, national and local levels. **Chapter 3** revisits the 2014 scenarios and examines the latest available data for Oxfordshire to take stock of recent progress. **Chapter 4** then summarises the detailed analysis which follows in later chapters by setting out three pathways for eradicating emissions from Oxfordshire's economy. To illustrate the scale of change and investment required, these are compared with a **Steady Progression** scenario in which net-zero is not achieved. **Chapter 5** focuses on Oxfordshire's innovation ecosystem and the low carbon sector. **Chapters 6 and 7** examine two sectors where there remains significant distance to travel: transport and the built environment. **Chapter 8** discusses energy supply with a focus on different technologies for generating electricity and heat. **Chapter 9** reviews the role of land and carbon sequestration in achieving climate goals. The report concludes with a discussion of the implications for local policy and investment, and provides recommendations for a wide range of stakeholders.

2 A new context for zero-carbon ambition

Chapter author: Sam Hampton

This chapter sets out the global, and then the national, context for Oxfordshire's aims to achieve zero carbon. This includes developments in climate, energy and environmental policy, public opinion and corporate action which all influence what can be achieved locally. It discusses the Oxfordshire context for achieving net-zero, with a focus on local policies.

2.1 Global context

The effects of climate change have started to be observed and experienced around the world. Global average temperatures are now 1.1°C higher than pre-industrial levels, and extreme events such as wildfires and tropical cyclones are increasing in intensity, size and duration. In response, climate change has risen up the international policy agenda, and the 2015 'Paris Agreement' committed all signatories to "keep the increase in global average temperature to well below 2°C above pre-industrial levels; and to pursue efforts to limit the increase to 1.5°C".

Among national governments, climate policy ambition has been accelerating in recent years. In 2019, the UK was the first major economy to pass legislation to reach net-zero emissions by 2050. In 2020, China,[3] Japan and South Korea made similar pledges, joining the EU and much of Africa in doing so. However, no major industrialised country is currently on track to meet its goals under the Paris Agreement, and the Climate Action Tracker predicts that current policies represent a warming pathway of around 2.9°C,[4] with disastrous implications for ecosystems, human and animal populations.[5]

Many sub-national governments around the world have been proactive on climate. Initiatives such as C40 Cities and the Covenant of Mayors have driven climate leadership amongst urban municipalities, and cities have in many cases moved faster, with more ambition, than national governments. Madrid, Athens and Mexico City, for instance, have committed to banning diesel vehicles by 2025.

There has been a substantial increase in public concern for climate change in recent years. A survey of 10 countries in 2020 found that 76% of citizens see climate change as a 'major threat', compared with 55% in 2013.[6] Media coverage has grown, and movements such as *Extinction Rebellion* and the *School Strike for Climate* have given prominence to issues such as climate justice and net-zero. However, attitudes towards climate change remain polarised in many countries, which is problematic given the need for collective action.

The international corporate sector has been developing its decarbonisation ambitions too. While firms such as IKEA, John Lewis and Unilever have been championing climate action for decades, some of the world's largest companies are now taking meaningful action. Facebook and Apple have made commitments to becoming carbon neutral by 2030, and Microsoft and Google have declared plans to offset all company emissions retroactively, including by investing in geological sequestration. In the financial sector, the world's largest asset management firm, Blackrock, has begun to incorporate sustainability assessments into its investments, and in 2020 used its shareholdings to vote for climate action on the boards of 53 major corporations.[7]

3 China's target is for 2060.

4 climateactiontracker.org.

5 IPCC (2018), Long-term Climate Change: Projections, Commitments and Irreversibility.

6 Pew Research Centre (2020), Summer 2020 Global Attitudes Survey.

7 FT (14/7/20), BlackRock punishes 53 companies over climate inaction.

COVID-19 has caused unprecedented disruption to the global economy, with significant implications for climate goals. Although it is estimated that CO_2 emissions may have fallen by as much as 7–8%[8] during 2020, what drives climate change is the *total stock of greenhouse gas emissions*, rather than their annual rate. To use an analogy, what matters is the total quantity of water in the bath; turning the tap down for a short while has negligible effect. The bigger implications of COVID-19 are what it might mean for investment in zero-carbon technologies and the willingness to generate far-reaching and effective climate policy. Whilst the global recession associated with COVID-19 has been predicted to hit spending on renewable energy and zero-carbon innovation,[9] many governments are determined to pursue a 'green recovery', with unprecedented levels of public investment and new ambitious policies.[10]

Global emissions trends

In 2019, global primary energy consumption was more than 24% higher than in 2014. Due to declining emissions from the power sector, greenhouse gas emissions have increased at a slower rate, of less than 1% per year. As a result of COVID-19, the International Energy Agency estimates that CO_2 emissions may have been up to 8% lower in 2020 than in 2019.[8] However, the rate of change in global carbon emissions is likely to become positive once again as the global economy emerges from recession following the pandemic.

8 www.globalcarbonproject.org; and IEA (2020), Global Energy and CO_2 emissions.

9 Gillingham et al. (2020), The Short-run and long-run effects of Covid-19 on Energy and the Environment. *Joule*.

10 European Commission (2020), The EU budget powering the Recovery Plan for Europe.

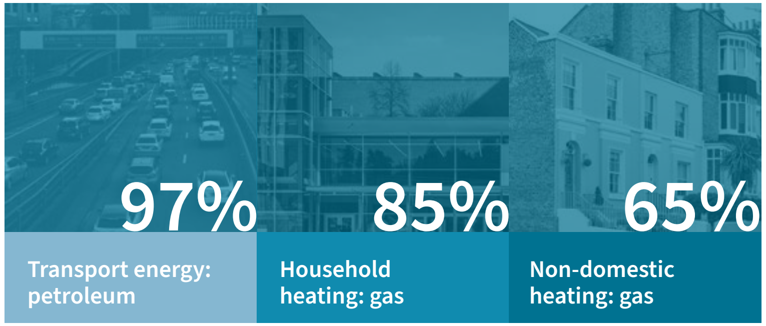
2.2 National context

Climate policy has evolved substantially since the publication of the Low Carbon Economy report in 2014, with some contradictory measures introduced that have undermined the ability to make significant and meaningful progress. In 2015, the Renewable Obligation subsidy which had led to significant deployment of solar photovoltaics was phased out, whilst an effective moratorium was imposed on onshore wind installations. In the domestic sector, plans for all new homes to be zero-carbon from 2016 were reversed, and the government's flagship energy efficiency programme, the *Green Deal*, was plagued with issues and saw negligible take-up.[11] There was also a revision to the Vehicle Excise Duty, reducing the incentive to purchase more efficient petrol and diesel cars, and in 2019, all subsidies for small-scale solar installations were cut.

Although these policy changes undoubtedly slowed progress towards achieving a zero-carbon economy in recent years, the overall trend in the UK still is one of rapid emissions decline. Since 1990, the UK has reduced its carbon emissions by 38% – the fastest rate of any major economy,[12] despite seeing steady population growth. Several factors explain this, including energy demand reduction from efficiency measures in buildings, the decline of heavy industry, improved product design, and vehicle efficiency. The UK's electricity generation mix has become substantially cleaner as firstly, gas and renewables replaced coal as the primary means of supply, and then renewables ate into the share of gas generation.

11 Rosenow, J. & Eyre, N. (2016), A post mortem of the Green Deal: Austerity, energy efficiency, and failure in British energy policy. *Energy Research & Social Science*, 21, 141–144.

12 Carbon Brief (2019), Analysis: Why the UK's CO_2 emissions have fallen 38% since 1990.



Whilst electricity decarbonisation is an undoubted success story from the last decade, our reliance on fossil fuels for heating buildings and for transport remains high. Petroleum accounts for 97% of transport energy consumption, while 85% of UK households and 65% of non-domestic buildings use natural gas for heating.[13] Progress on tree planting and other options for using land to sequester carbon dioxide has also been insufficient, with an average of 9,000 ha of new woodland planted per year from 2010 to 2018, compared with a previous target of 27,000 ha[14] and a new target of 30,000 ha to be reached by 2030. Despite the growing interest in nature-based solutions to climate change, land-use change creates risks associated with complex trade-offs between food production, bioenergy, biodiversity and ecosystem services, which are explored further in Chapter 9.

13 BEIS (2018), Clean Growth – transforming heating. Overview of current evidence.

14 Committee on Climate Change (2018) Land Use: reducing emissions and preparing for climate change.

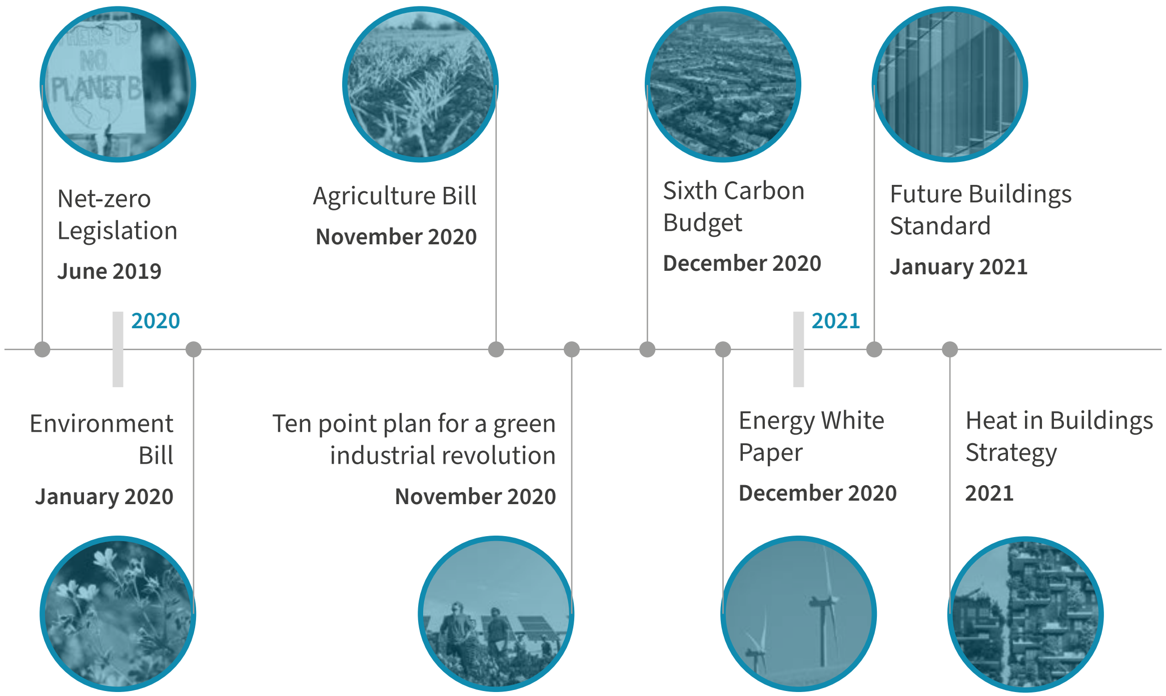
2.2.1 A new impetus

There are signs that national government is now incorporating emissions reductions into its core strategies, rather than treating climate change as a separate policy challenge. In 2016, the Department for Energy and Climate Change (DECC) was dissolved and its functions integrated with the business department and the creation of a new Department for Business, Energy and Industrial Strategy (BEIS). It published in 2017 the UK Industrial Strategy which includes four 'Grand Challenges' of which two relate directly to climate change: achieving '*clean growth*' and becoming a world leader in shaping the '*future of mobility*'. Meanwhile, the Department for Environment, Food and Rural Affairs (Defra) has been incorporating climate change into agricultural, food and land use policies.

With the UK due to host COP26 in November 2021, and with a need to formulate energy and environmental policies for the post-Brexit era, 2019 and 2020 saw the publication of various policies, commitments and targets made by local and national governments. In response to renewed public support for action on climate change,[15] the UK has increased its target set out in the 2008 Climate Change Act for an 80% reduction on CO_2 emissions by 2050,[16] to a net-zero goal. In an experiment in deliberative democracy, the first UK-wide UK Climate Assembly was convened, subsequently releasing a report calling for education, fairness and inclusivity to be at the heart of the path to net-zero. Meanwhile, 300 (87%) local authorities have declared a climate emergency.

15 Polling by BEIS in 2019 found that 80% of the British public are concerned or very concerned about climate change: a record high.

16 Based on 1990 levels.



In late 2020, the government published its *Ten Point Plan for a Green Industrial Revolution*, setting targets for producing 40GW of offshore wind capacity by 2030, installing 600,000 heat pumps every year by 2028, banning the sale of new petrol and diesel cars by 2030, and planting 30,000 hectares of trees every year starting in 2024. While ambitious on energy supply, vehicle electrification and tree-planting, there remains concern and uncertainty over the level of funding and strategic direction for accelerating the reduction in demand.[17]

17 CREDS (2020), Our response to the government's 10-point plan for a 'Green Industrial Revolution'

This policy document was followed soon after by a far-reaching report on the UK's *Sixth Carbon Budget*, issued by the Committee on Climate Change. This offered detailed policy advice including phasing out fossil fuelled vehicles, investigating the potential for using hydrogen for heating, and advancing afforestation and CCS. It also called for an ambitious target of 68% emissions reduction to be achieved by 2030, to which the government quickly responded by including this in its renewed NDC.

Overall, the UK has a strong record on climate policy, having made substantial progress on decarbonising electricity supply, investing in low carbon technologies, and setting ambitious emissions reduction targets.[18] Nonetheless, the UK government's own projections for energy and emissions indicate that the rate of decarbonisation seen in the last 10 years will slow. In 2018, 23% of final energy demand was met by electricity or renewables. Projecting a gradual decline in fossil fuel reliance in transport but an increase in domestic buildings, BEIS estimates only modest progress by 2040, with electricity and renewables reaching 28% of final demand.[19]

There is now an urgent need for policy intervention to drive decarbonisation across heat, transport and land-use to meet climate goals, and national policies will continue to have significant influence over Oxfordshire's ability to decarbonise its economy.

18 Economist (2021), Britain has reduced its carbon emissions more than any other rich country.

19 BEIS (2020), Updated energy and emissions projections 2019.

2.3 Oxfordshire context

Oxfordshire is a global centre for research and innovation, and the 2014 Low Carbon Economy report estimated that the low carbon economy generated £1.15 billion/year in sales, representing 7% of the county's economy. Our research institutions, manufacturers and community organisations continue to be at the cutting edge of low carbon innovation, pioneering new technologies to tackle climate change (see Chapter 5 for further detail).

Climate change has attracted significant concern and attention from local policy-makers. The 2019 Oxfordshire Energy Strategy[20] set the agenda for increased ambition on climate goals and energy innovation, establishing a target of 50% emissions reductions for the county by 2030. To achieve this and go on to reach net-zero by 2050, the Strategy aims to support new local renewable energy projects, and initiatives to drive demand reduction. For instance, it specified the need for a major domestic retrofit programme to bring all Oxfordshire homes up to EPC Band C by 2035, in line with targets set in the UK's Clean Growth Strategy, and for 40% of heat demand to be met by renewables.

Building on the Energy Strategy, the Oxfordshire Local Industrial Strategy[21] features clean growth as a central goal, setting out a vision for sustainable growth and enhanced productivity in the county, enabled by greater connectivity and a skills support system which provides opportunities for young people in the low carbon economy.

20 OxLEP (2019), The Oxfordshire Energy Strategy.

21 OxLEP (2019), Oxfordshire Local Industrial Strategy.

Climate Emergency

All Oxfordshire Local Authorities have declared a climate emergency, and most have set targets for emissions reductions which exceed national goals (Table 2.1). In 2020, Oxford City Council achieved a 40% emissions reduction based on 2005 levels, and was the first UK city to hold a citizens assembly on climate change in 2019. Members of the assembly expressed a desire for Oxford to be a climate leader, reaching net-zero before 2050 by boosting biodiversity, reducing car use, and maximising the use of renewable energy. The Council responded by agreeing an emergency budget and establishing the Zero Carbon Oxford partnership to work with partners and major emitters to take action on climate. This complements other ambitious plans being developed by the City Council, County Council and partners such as the Zero Emissions Zone and all-electric bus fleet.

The other local authorities have also taken substantial steps towards climate action since 2019. A Cabinet Advisory Group on Climate has been created by Oxfordshire County Council, and a new Climate Action Framework has been agreed. This outlines priorities for action within its sphere of influence, including supporting schools, achieving net-zero operations by 2030, and working with suppliers to decarbonise the goods and services procured, as well as a commitment to work with others to deliver a zero-carbon county. The County Council are also working closely with Cherwell District Council (CDC) through a new joint climate action team, and CDC have incorporated several climate policies in their Local Plan, with a focus on driving carbon reduction through the planning process. West Oxfordshire DC have created a Cross-Party Climate Action Working Group to oversee climate action, while South Oxfordshire and the Vale of White Horse DCs have ambitions for achieving net-zero well in advance of the national target.

Table 2.1: Net-zero targets set by Oxfordshire Local Authorities

Local Authority	Carbon neutral council operations	Area-wide goal
Oxfordshire County Council	2030	2050
Cherwell District Council	2030	2030
Oxford City Council	2030	2040
South Oxfordshire District Council	2025	2030
Vale of White Horse District Council	75% reduction by 2025 Aspires to net-zero by 2030	75% reduction by 2030 Net-zero by 2045
West Oxfordshire District Council	2030	2050

In declaring a Climate Emergency, the councils have publicly committed themselves to expending more resources on enabling a low carbon transition, with particular emphasis on updating infrastructure to make it fit for 21st century living and commuting, signing off on ambitious zero-carbon developments, and assigning budget to sustain initiatives such as Oxfordshire's Living Labs.

2.3.1 Decoupling growth from emissions

Compared with other regions of the UK, population growth in Oxfordshire is rising more rapidly, with implications for transport demand, energy use and ecosystem services. As we discuss in the following chapter, the construction of 100,000 new homes in Oxfordshire between 2011 and 2031 appears to be on track, with more than 27,000 homes built since 2014, and a further 66,000 included in local authority plans. While no plans have been agreed beyond this, the National Infrastructure Commission[22] speculated on a target for one million new homes along the Oxford-Cambridge arc by 2050. The 2017 Oxfordshire Infrastructure Strategy forecasts house building rates to continue at least the same rate past 2031, adding 38,500 new dwellings to Oxfordshire's housing stock between 2031 and 2040. We estimate that Oxfordshire's population could increase by 25% between 2019 and 203128 and it is essential that growth of population, housing and economic output do not lead to higher carbon emissions. In other words, CO_2 emissions must be 'decoupled' from growth. To achieve this at a rate which achieves zero-carbon by 2050, new dwellings must produce zero or even negative carbon emissions, and new demand for heat, electricity and transport must be provided by zero-carbon sources.

22 NIC (2017), Partnering for Prosperity: A new deal for the Cambridge-Milton Keynes-Oxford Arc.

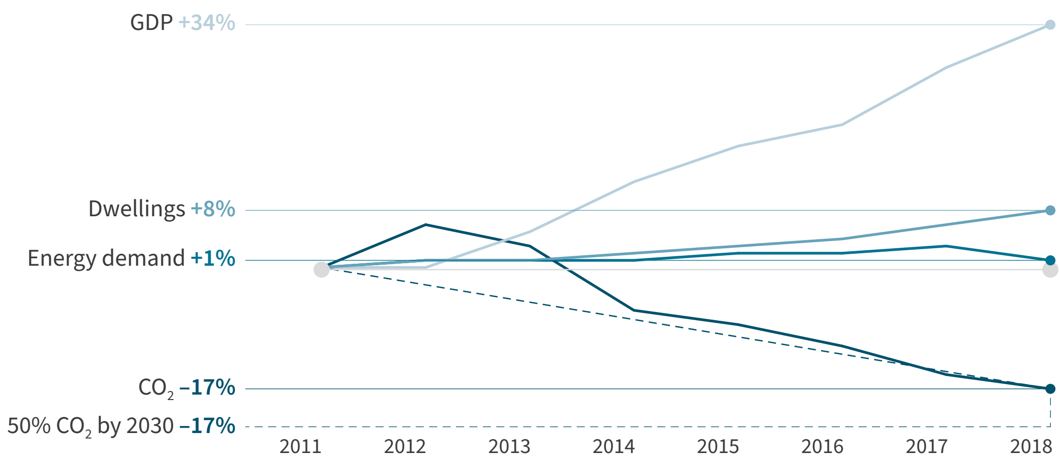


Figure 2.1: Relative change in GDP, number of dwellings, CO2 emissions and energy demand (2011=1)

Recent evidence highlights that decoupling has begun in Oxfordshire. Between 2011–18, over 26,000 new dwellings were built, leading to a population increase of 5% in the county. GDP grew by 34% over the same period. However, as shown in Figure 2.1,[23] demand for gas, electricity and transport remained roughly constant over this period, representing an annual reduction in energy intensity of around 5%. *CO_2 emissions fell* by 17% over this period, which indicates that in 2018 Oxfordshire was on track to achieve the target set by the Oxfordshire Energy Strategy of achieving a 50% emissions reduction by 2030 (see dotted line).

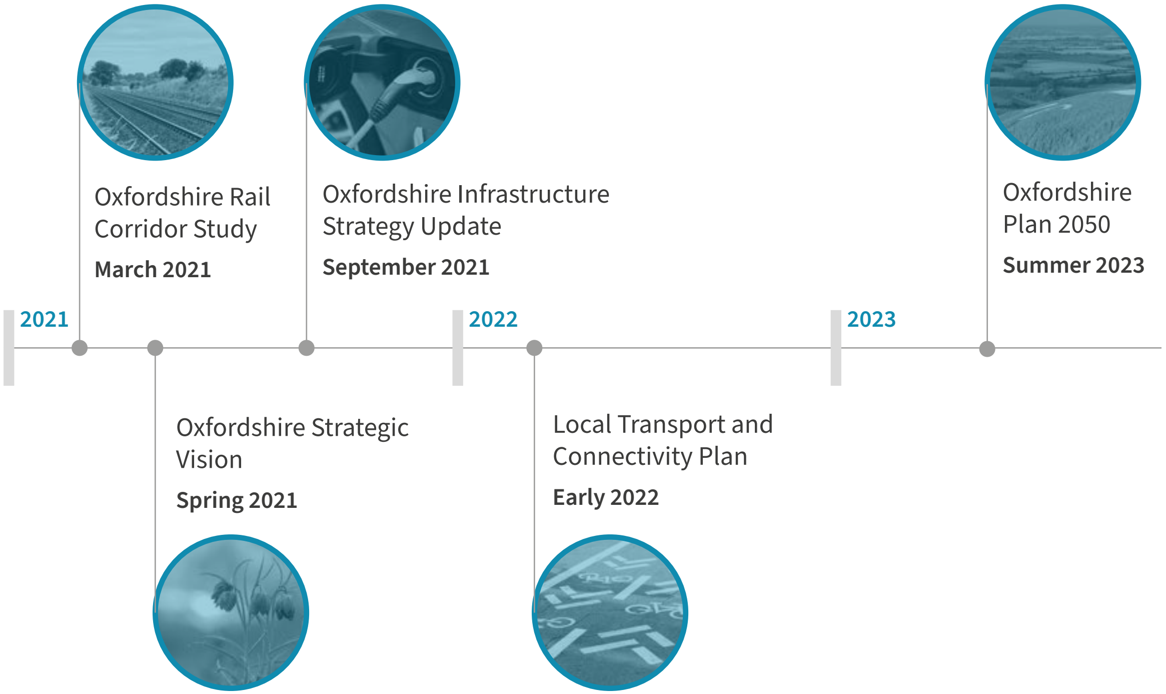
This is a clear success story, demonstrating that significant progress on climate mitigation can be achieved in a short space of time. Much of this progress has been driven by energy efficiency policies at the UK and EU level, and the rapid deployment of offshore wind on the electricity grid. Maintaining the same rate of emissions reduction in Oxfordshire will require relatively greater investment locally, in building retrofit, cleaner heating systems and electric vehicles; and cultural and behavioural changes such as active travel, dietary changes and reduced energy demand.

2.3.2 Local policy to deliver climate goals

Amongst those planning and preparing for significant growth in Oxfordshire, there is increasing recognition of the need for a strategic vision with environmental sustainability and zero-carbon goals at its heart. The Oxfordshire Growth Board, for instance, have called on central government to either reform national building standards in line with zero-carbon ambitions, or to allow local planning authorities to maintain local flexibility to exceed UK standards. In their ‘strategic vision’, the Growth Board sets out an ambition for Oxfordshire to be carbon neutral by 2040. It also proposes definition of ‘good growth’, which in summary, will:

- Enhance the historic and natural environment
- Support a diverse high-value economy
- Be high-quality and resilient to change
- Be sustainable, clean and green
- Embrace innovation and technology
- Be healthy and inclusive

23 Sources: ONS (2019), Regional GDP reference tables; MHCLG (2020), Table 100 Dwelling stock: Number of Dwellings by Tenure and district: England; 2019; BEIS (2020), Sub-national total final energy consumption; BEIS (2020), UK local authority and regional carbon dioxide emissions national statistics: 2005–2018.



There is increasing recognition that infrastructure investment must be compatible with zero-carbon ambitions. With decadal lifespans, investments in infrastructure in the near term have significant implications for achieving climate goals, as carbon emissions become 'locked in' to systems of energy provision, transport networks, waste processing and land use. Rather than using simple cost-benefit calculations, the forthcoming update to the Oxfordshire Infrastructure Strategy[24] adopts a broad set of criteria for evaluating future infrastructure projects, assessing their impact against environmental impact, health, place-shaping, connectivity and productivity. It will also promote the efficient use of existing infrastructure.

24 AECOM (2017), Oxfordshire Infrastructure Strategy.

While these are positive developments, there is a need to consider a broader definition of infrastructure beyond roads, rail and utilities, to highlight the need for investment in upgrading the energy efficiency of the building stock, for instance. as well as green and blue infrastructure such as sustainable drainage systems and urban green spaces.

Timeline of forthcoming Oxfordshire policies and strategic reports:

- Oxfordshire Strategic Vision – Spring 2021
- Oxfordshire Rail Corridor Study (March 2021)
- Oxfordshire Infrastructure Strategy Update – September 2021 (Stage 1 report)
- Oxfordshire Plan 2050 – Summer 2023
- Local Transport and Connectivity Plan – early 2022

In the last 12 months, the Oxfordshire economy has broadly been resilient to the challenges created by COVID-19, due to the region's diverse business base and strong science and technology industries. The most exposed part of the economy has been the sectors which comprise the visitor economy (retail, tourism, hospitality, leisure, arts and culture) which supports 40,000 jobs across the county and contributes over £2.4bn per annum in GVA. The Oxfordshire Economic Recovery Plan (ERP)[25] identifies that the sector was losing over £140m per month during the height of the lockdown, with 85% of businesses reporting at least a 50% drop in revenue and over 70% had closed altogether. Economic projections within the Plan suggest a net overall loss of c6,000 jobs in the economy during the next 5–6 years but a substantial and accelerated recovery from 2021/22 onwards which will return Oxfordshire's growth levels back to pre-COVID-19 levels.

25 OxLEP (2021), Oxfordshire's Economic Recovery Plan.

The ERP and other proposals emphasise the importance of ensuring that the recovery is also able to deliver on environmental and climate change objectives. Measures to create liveable streets and improve air quality, by temporarily pedestrianising city-centre streets during the summer of 2020 and installing additional bike parking spaces were implemented in Oxford City. The County Council has been planning how to spend an additional £3 million on active travel measures in the next year, supported by funding from the DfT Active Travel Fund. This includes a number of Low Traffic Neighbourhoods, traffic filters and point closures in Oxford, as well as pedestrian and cycle infrastructure in Bicester, which will help deliver proposals with the Oxford and Bicester Local Cycling and Walking Infrastructure Plans (LCWIPs) endorsed by the County Council in March 2020. In West Oxfordshire, the Council also included climate as one of the four pillars of its COVID-19 Recovery Plan, implementing a Sustainability Standards Checklist through which all planning applications will be required to meet standards relating to water use, flood risk, biodiversity, net-zero, waste and low-carbon transport.

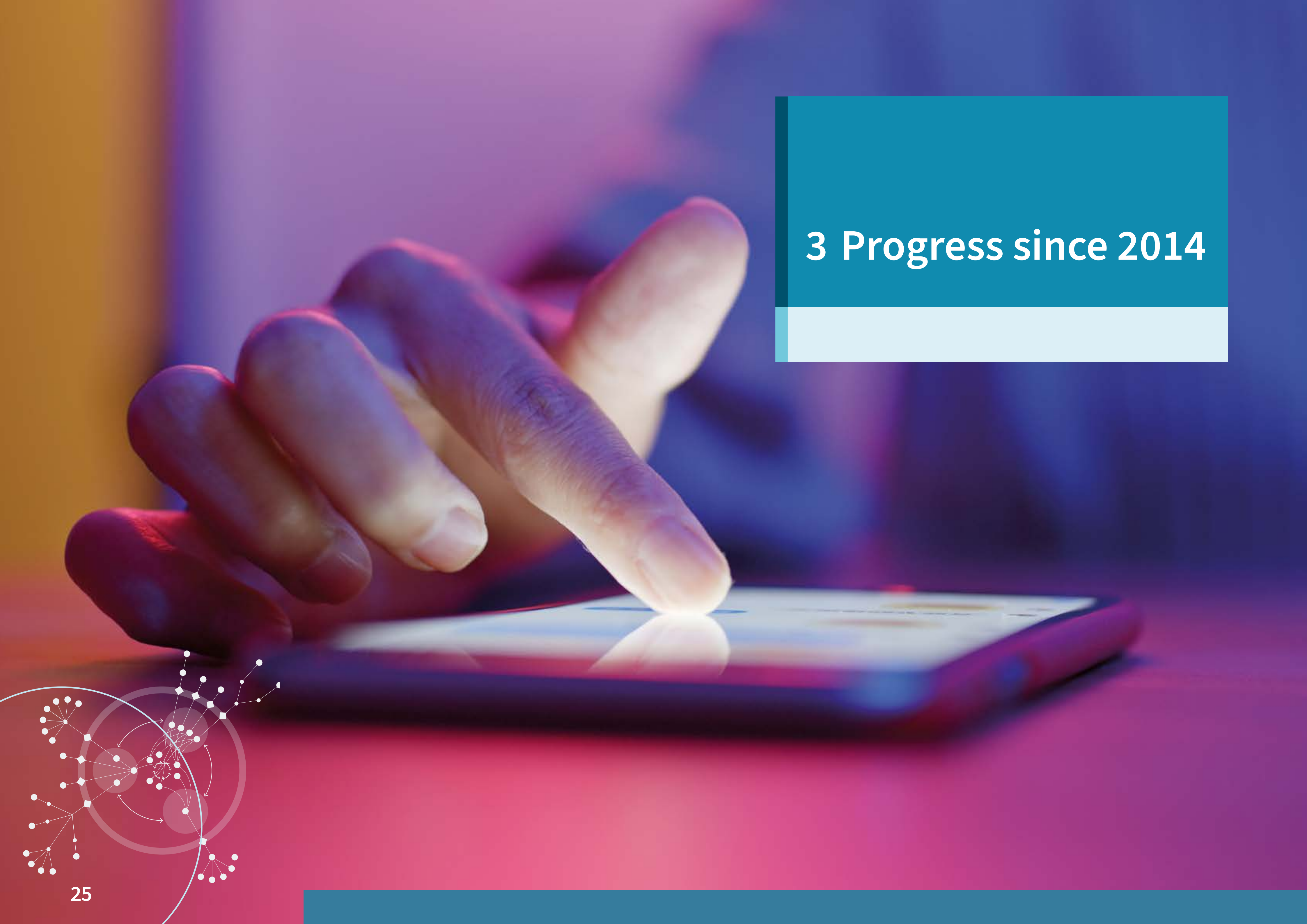
In recent years there has been a significant shift in local policy towards acknowledging the climate emergency, and renewed ambition is evident in the Energy Strategy, the County's Climate Action Framework, the various Local Authority net-zero targets, and forthcoming strategy documents. In order to continue the trend of decoupling growth from CO_2 emissions, there is an urgent need for the principles and concepts articulated in these policy statements to be translated into tangible action. This will include a major programme of building retrofit, deployment of local renewable generation, infrastructure to support active travel, and accelerated ecosystem restoration.

Emissions scope

The Greenhouse Gas (GHG) Protocol categorises emissions into three categories, or 'Scopes'.

When referring to a geographical region, Scope 1 includes direct emissions occurring within the county boundary, including fossil fuels combusted in vehicles or boilers. Scope 2 refers to the emissions associated with energy used locally but generated elsewhere (e.g. electricity), and Scope 3 includes all other indirect emissions from activities including carbon embodied in products purchased, or flights taken by Oxfordshire residents from airports outside the county.

To avoid issues such as double counting, this report focuses on Scope 1 and 2.



3 Progress since 2014

Progress on reducing greenhouse gas (GHG) emissions in Oxfordshire has been more rapid than other areas of the UK, when considering growth in population and GDP. Total CO_2 emissions in 2018 were 4.1Mt (1.2% of the UK total),[26] representing a 27% reduction since 2008, despite an increase in population of 7.6% over the same period.[27] While per capita emissions in Oxfordshire are falling, they remain slightly higher (5.9t) than the national average (5.2t), correlated with higher-than-average household income.[28]

Figure 3.1: Scope 1 and 2 CO_2 emissions in Oxfordshire by sector, 2008 and 2018

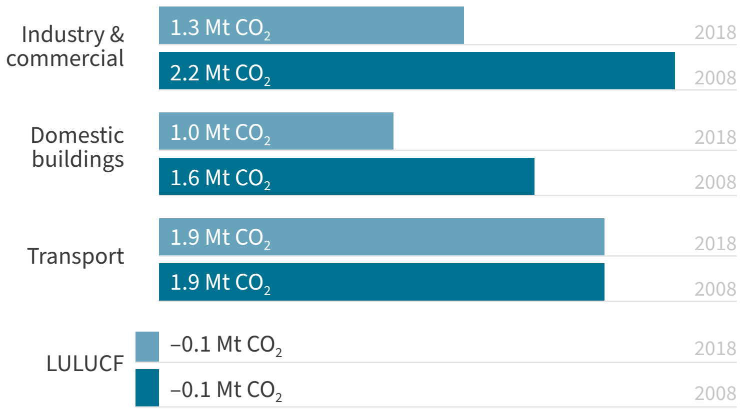


Figure 3.1 shows that the largest share of Oxfordshire's CO_2 emissions come from the transport sector, which has declined by only 1.9% since 2008.[29] The industrial and commercial sector includes all non-domestic buildings emissions, agricultural processes and waste processing, and its contribution to CO_2 emissions has declined by 44% over the same period. Land use, land use change and forestry (LULUCF) are a source of net carbon sequestration, due to forest and grassland cover in rural parts of Oxfordshire.

In 2018, BEIS estimate that this sector absorbed 98 kt CO_2, an increase of 71% on 2008 levels, which is 2.4% of annual net emissions from all sources. However, these estimates are based on a coarse disaggregation of national datasets and the assumption of a continuation of pre-2007 trends in land use change. More detailed estimates presented in chapter 9 suggest that current sequestration rates are around three times this level, i.e. around 7% of total net emissions, but may be declining rather than increasing.

26 County level emissions data is only available for CO_2, not other greenhouse gases (GHGs). UK emissions of CO_2 make up 81% of GHGs, with the remainder from methane (11%), nitrous oxide (5%) and fluorinated gases (3%). Emissions from industrial and commercial sectors are underestimated when compared with transport, because of methane emissions associated with heating and livestock farming, and nitrous oxide derived from agricultural processes. Source: BEIS (2020) 2018 UK Greenhouse Gas Emissions, Final figures.

27 A baseline of 2008 has been used for throughout this report for consistency with the Oxfordshire Energy Strategy, although the focus of this chapter is on progress made since the 2014 Low Carbon Economy report. Between 2014 and 2018, emissions fell by 12%, and population grew by 2.7%.

28 ONS figures. Median gross annual pay in 2018 for UK: £25,780; for Oxon: £28,770. Oxon earnings are 12% above national, while CO_2 emissions are 14% higher than average.

29 Contributions from through-traffic, using highways infrastructure and railways means that estimating transport emissions within administrative boundaries is difficult, and the influence of local policy-makers is limited.

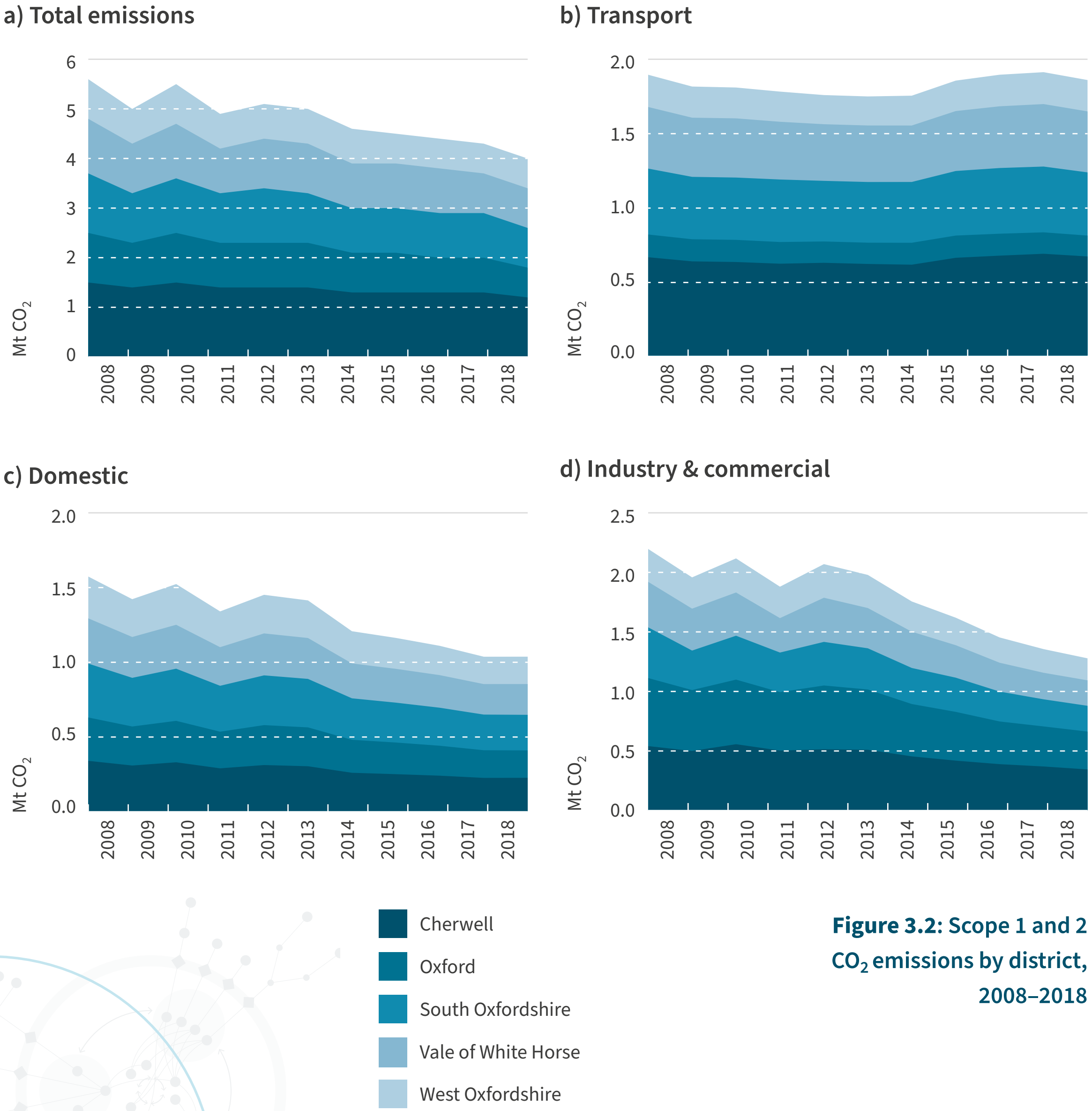


Figure 3.2: Scope 1 and 2 CO_2 emissions by district, 2008–2018

The charts in Figure 3.2 show recent trends in carbon emissions, broken down by sector district in Oxfordshire. Total emissions in all parts of the county have fallen since 2008, but transport emissions remain high. Chart b) includes emissions from motorways, which partly explains relatively high figures from Cherwell and South Oxfordshire.

3.1 Revisiting the scenarios from the 2014 Low Carbon Economy Report

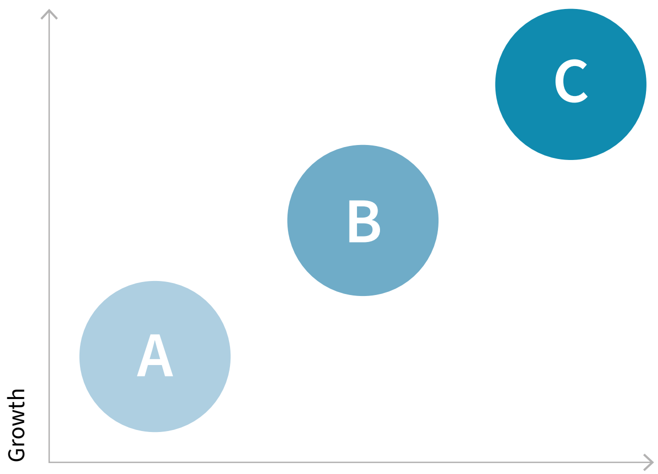
Three scenarios were included in the 2014 report on Oxfordshire's low carbon economy.

Scenario A was a 'business as usual' projection with low ambition for reducing GHG emissions. It extrapolated from historic trends on house building, retrofit, renewables deployment and low-emission vehicle uptake.

Scenario B modelled incremental housing and employment growth with moderate climate ambition, and its figures were based on existing Local Plans. This included 50,000 new homes by 2030, and over 34,000 ultra-low emission vehicles (ULEV) being registered per year. Scenario B assumed 400 homes would undergo deep retrofit per year, and that local renewables generate 23% of electricity and 5% of heat by 2030.

Scenario C combined much higher growth with radical ambition for achieving a low carbon economy. It assumed that 100,000 new homes would be built in the county by 2030, and constructed to meet the highest standards of energy efficiency. Additionally, 4,000 homes would be refurbished per year to achieve best-practice levels of energy efficiency, covering a quarter of all existing domestic buildings by 2030. Scenario C projected that 38,133 new ULEVs would be registered annually by 2030, and local renewables would meet 56% of electricity and 40% of heat demand in the county.

Figure 3.3: A simplified representation of the 2014 scenarios



3.1.1 Observed trends

This section reflects on trends in housing, transport, energy efficiency and renewable generation in Oxfordshire since 2014 by analysing the latest figures available. Table 3.1 lists several key indicators used in the 2014 report. Based on the analysis which follows, the highlighted cells in the table reveal which of the A, B or C scenario figures for 2030 best describe the trajectory Oxfordshire is following.

Table 3.1 – Key indicators from the 2014 scenarios

2030 Scenarios	A	B	C
New Homes	37,000	50,000	**100,000**
No. of homes retrofitted per year	**40**	400	4,000
Share of EVs in new fleets	1%	10%	**25% – underestimate**
Home EV chargepoints	1,000	**10,000**	30,000
Public fast EV chargepoints	10	100	**300 – underestimate**
Renewable electricity supply (GWh)	539	**842**	**2052**
Renewable heat supply, (GWh)	**63**	**258**	2183

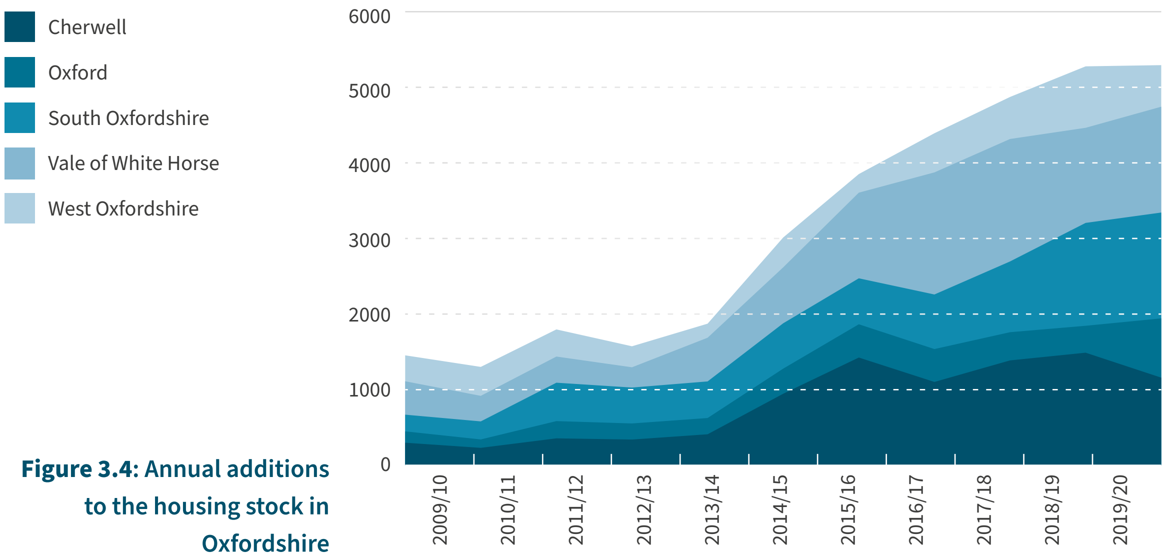


Figure 3.4: Annual additions to the housing stock in Oxfordshire

Housing. The Oxfordshire Strategic Housing Market Assessment (SHMA)[30] forecasted a need for 100,000 new homes in the period 2011 to 2031. A net total of 31,943 new dwellings were added to the housing stock in the nine years from 2011–12 to 2019–20.[31] While this average rate of house building (3,154 pa) is lower than the 5,000 pa needed to meet the stated housing need, Figure 3.4 shows this rate has been accelerating in recent years.[32],[33] Local authorities are due to undertake a comprehensive review of housing need as part of the emerging Oxfordshire Plan 2050.

The energy efficiency standards for new homes within the Oxfordshire Local Plans are predominantly set by national policy, and these are currently incompatible with achieving zero-carbon by 2050. Only 1.5% of all new-builds were awarded an EPC rating of A between 2014 and 2020, while the majority of these were connected to the gas grid for heating.[34]

30 Oxfordshire Strategic Housing Market Assessment (2014).

31 District and City Council Annual Monitoring reports and MHCLG (2019) Table 122: housing supply; net additional dwellings, by local authority district, England 2001–02 to 2018–19. Figures for 2019/20 in South, Vale and West are estimated based on Annual Monitoring report trajectory charts or average delivery in housing supply.

32 Total dwellings in 2019: 295,517, based on MHCLG (2020) Table 100: Number of dwellings by tenure and district.

33 Note that this rate of house building represents a significant increase in population. Between 2011 and 2019 Oxfordshire's population grew by 5.6%. Current ONS projections estimate a further 5.1% increase from 2019 to 2031. However, these estimates do not take account of the population growth associated with planned housing development. This point is made by EEH in a recent report, who project Oxfordshire's population to be as high as 875,000 in 2030 and nearly 1.1m by 2050. Based on recent and planned house building, and assuming a mid-range estimate of 2.35 people per household, our estimates fall between the two. We project Oxfordshire's population to reach 862,000 by 2031, an increase of 25% based on 2019 levels.

34 BEIS sub-national estimates of gas network connections indicate that almost all new homes in Oxfordshire were fitted with gas meters between 2015 and 2019, and that 82% of households in Oxfordshire use gas for heating.

Enhancing the quality of construction, installing heat pumps or even building low carbon district heating networks are measures that may increase the cost of house-building in the short term, but the implication is that without these, expensive retrofit will be needed in future if Oxfordshire is to achieve zero carbon emissions.[35]

The 2014 Low Carbon Economy report highlighted the need for an extensive programme of domestic retrofit in order to reduce energy wastage and associated carbon emissions. While the energy efficiency of Oxfordshire's housing stock is slightly higher than the national average, only 46% of homes achieve an EPC rating of A–C upon completion.[36] Scenario C proposed that 4,000 buildings per year would need to be upgraded to the highest standards of energy efficiency to achieve emissions reductions goals. Unfortunately, no comprehensive dataset on energy efficiency improvements exists, so it is difficult to evaluate progress against this goal. However, government figures relating to the two main retrofit policies, ECO and the Green Deal, indicate that only 0.5% of Oxfordshire households have installed measures through these schemes, which is amongst the lowest rate nationally.[37]

ECO has been running since 2013 and focuses on fuel poor households, of which Oxfordshire has a lower-than-average share. However, estimates indicate that 8.5% of households are living in fuel poverty,[38] which is likely to be higher in the wake of COVID-19 related trends. Uptake of the Green Deal was low across the country.

Transport. Uptake of ultra-low emission vehicles (ULEV) is accelerating rapidly across the UK. In 2019, 3.3% of all new cars registered in the UK were ULEVs, whereas in the first half of 2020, this figure climbed to 8.7%. There is also a rapid shift underway towards the uptake of 100% battery electric vehicles (BEVs), away from plug-in hybrid vehicles (PHEVs). In 2019, new BEV registrations exceeded PHEVs for the first time, and during Q2 of 2020 (a period of national 'lockdown' related to COVID-19), the proportion of new BEVs doubled compared with the previous 3 months, reaching 7.4% of all new car registrations.

Uptake of ULEVs in Oxfordshire exceeds the national average. By the middle of 2020, there were 4,381 ULEVs licenced in Oxfordshire, of which 2,200 were battery electric vehicles (BEVs). This represents less than 1% of licenced vehicles in the county, but the numbers of zero emission vehicles are growing by nearly 50% per year. Although uptake of ULEVs is relatively faster in Oxfordshire than the UK as a whole, it is worth noting that adoption lags behind many European states. Whilst ULEVs represented 23% of all new vehicle registrations in the UK in December 2020, this figure was 72% in the Netherlands, 49% in Sweden, and 27% in Germany.[39] Scenario C had assumed that 25% of new vehicle registrations would be ULEVs by 2030. While considered a stretching target at the time of writing, this figure now looks conservative, and will be overtaken following the decision, in 2020, by the UK government to bring forward its ban on new fossil fuelled vehicles to 2030; meaning that by law, 100% of new registered vehicles will be ULEVs by that date.

35 Currie and Brown (2019), The costs and benefits of tighter standards for new buildings. A report for the Committee on Climate Change.

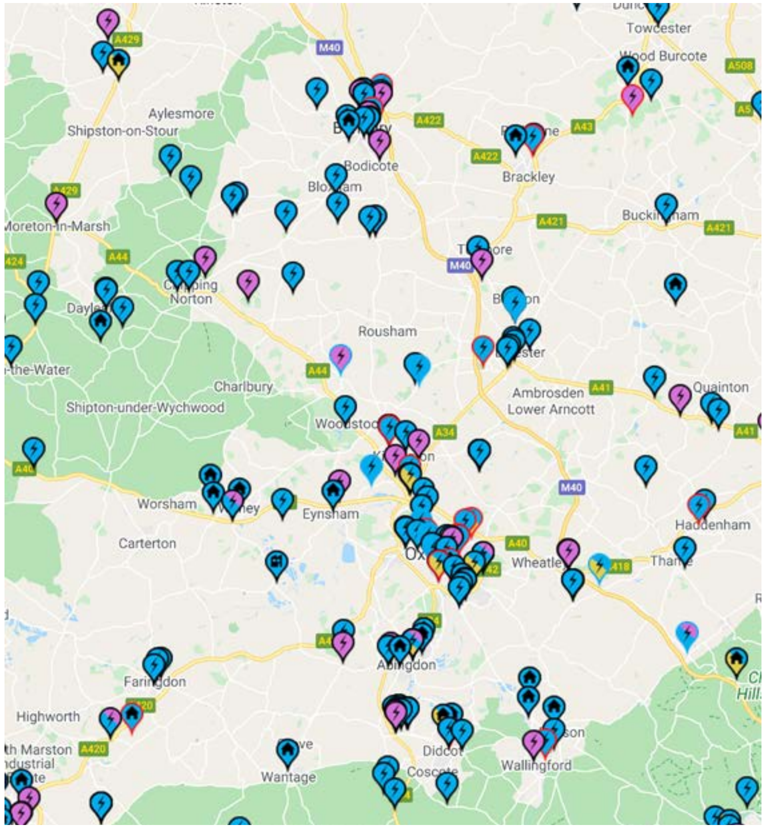
36 www.domesticenergymap.uk

37 BEIS (2020), Household energy efficiency statistics. Efficiency measures installed prior to 2013 are not included in these figures.

38 Affordable Warmth Network (2019), Report on Fuel Poverty and poor Housing Conditions.

39 International Council on Clean Transportation (2021), Market Monitor: European passenger car registrations, January–December 2020.

Figure 3.5: Fast (22 kW, in blue) and Rapid (≥50kW, in purple) public electric vehicle charging points in Oxfordshire. Source: ZapMap



Scenario C included the installation of 30,000 domestic and 300 public electric vehicle charging points by 2030. Unfortunately, there is no comprehensive database of domestic installations, and the Office for Zero Emissions Vehicles (OZEV) do not publish data on the numbers of installations funded through their domestic and workplace grant schemes broken down by local authority area.

However, analysis of data shared by OZEV indicates that roughly 2000 domestic and 120 workplace chargers have been funded in Oxfordshire through their *EV Homecharge Scheme* and *Workplace Charging Scheme* respectively.[40] It is difficult to estimate what proportion of all EV chargers this represents, as some chargers are likely to have been installed without grant support. Tesla, for instance, opted not to participate in the scheme as a manufacturer of chargepoints, and typically provide these to households alongside the purchase of new vehicles. Other EV users may use standard 13A plug sockets.

Data on public charging infrastructure is more readily available, and in 2020, there were a total of 240 devices in Oxfordshire available for public use, of which 44 (18%) were classified as 'rapid'.[41] However, according to the Oxfordshire Electric Vehicle Infrastructure Strategy, the distribution of public chargers is patchy, with most centred in Oxford, and little provision in smaller market towns. An additional challenge is providing access to chargers for the 30%+ of Oxfordshire households without access to off-street parking.[42] Several initiatives are under way to address the challenges of providing fair access to public chargers however. These include the Go Ultra Low Oxford[43] project which is rolling out chargers in Oxford City neighbourhoods with no off-street parking; and Park & Charge,[44] which is installing rapid chargers in public car parks across Oxfordshire. These projects alone expect to deliver an additional 380 chargers, indicating that progress on public charging infrastructure is ahead of even the most ambitious scenario from 2014.

40 Figures provided by OZEV for January 2021.

41 Rapid devices are those rated at 43kW or above.

42 Oxfordshire Electric Vehicle Infrastructure Strategy (2021).

43 Hampton, S, Schwanen, T, Doody, B. (2019) Go Ultra Low Oxford, monitoring and evaluation of Phase One, Final Report.

44 www.parkandchargeoxfordshire.co.uk

The 2014 study called for 200 km of new cycling infrastructure, and the provision of personalised travel plans to every household in Oxfordshire. However, neither initiative has been progressed to date, nor has the proposed 50 km Oxfordshire Busway been commissioned. That said, there has been investment brought forward in other areas including two Local Cycling and Walking Infrastructure Plans (LCWIPs) for Oxford and Bicester, with over £3 million committed to deliver elements of these plans over the next year. Other investments in cycling infrastructure include £16.7m through the 'Access to Headington' scheme, and £5.8m for five routes of the Science Vale Cycle Network, connecting parks at Culham Science Centre, Milton Park and Harwell Campus with the surrounding area. Councils and other stakeholders across Oxfordshire continue to lobby for greater investment from central government, including via the National Infrastructure Commission who called for £150m to be invested in Oxford's cycling network.

The electrification of buses was not included in the 2014 scenarios but has risen up the policy agenda in recent years, driven by several factors including Oxfordshire's thriving automotive sector, and levels of air pollution in some locations in Oxford City which are exceeding legal limits. The national demonstrator pilot, *Energy Superhub Oxford*, is helping to provide the infrastructure needed for rapid bus charging, while in early 2021, the government announced that Oxford and Coventry are set to become the UK's first all-electric bus cities. Our scenarios in Chapter 4 now include figures for the electrification of Oxfordshire's bus fleet.

Energy supply. When it comes to renewable electricity supply, Oxfordshire's most significant potential is in solar photovoltaics. Representing 72% of local generating capacity (see Figure 3.6), its solar fleet represents 3% of the national total: double its share of emissions. Based on land area and population density, Oxfordshire is comparable with other southern counties, such as Cambridgeshire, Hampshire and Wiltshire.

Its technical potential for wind generation is lower than many coastal and mountainous UK counties, and Oxfordshire has already harnessed much of the potential from landfill gas and waste. Total renewable electricity capacity is aligned with its share of the national population, at 1% (453MW). Generation (533GWh in 2019) is 0.6% of the national total.[45]

Despite the decline of subsidies in recent years, renewable generation in Oxfordshire has increased by 64% compared with 2014. Local renewable generation currently represents 15% of total local demand.[46] Several large solar farms are in the development stage, including Ray Valley Solar near Bicester, which will be the largest community-owned solar park in the UK. To meet the ambitious goal set out in Scenario C, local renewable generation would need to increase by between *3 and 4 times* as a proportion of total supply by 2030.

45 BEIS (2020), Renewable electricity by local authority 2014–2019. The different figures for generation vs capacity reflect the lower capacity factor of solar relative to wind power.

46 Based on comparison of datasets: BEIS (2020), renewable electricity by LA 2014–2019, and BEIS (2019) Regional and local authority electricity consumption statistics.

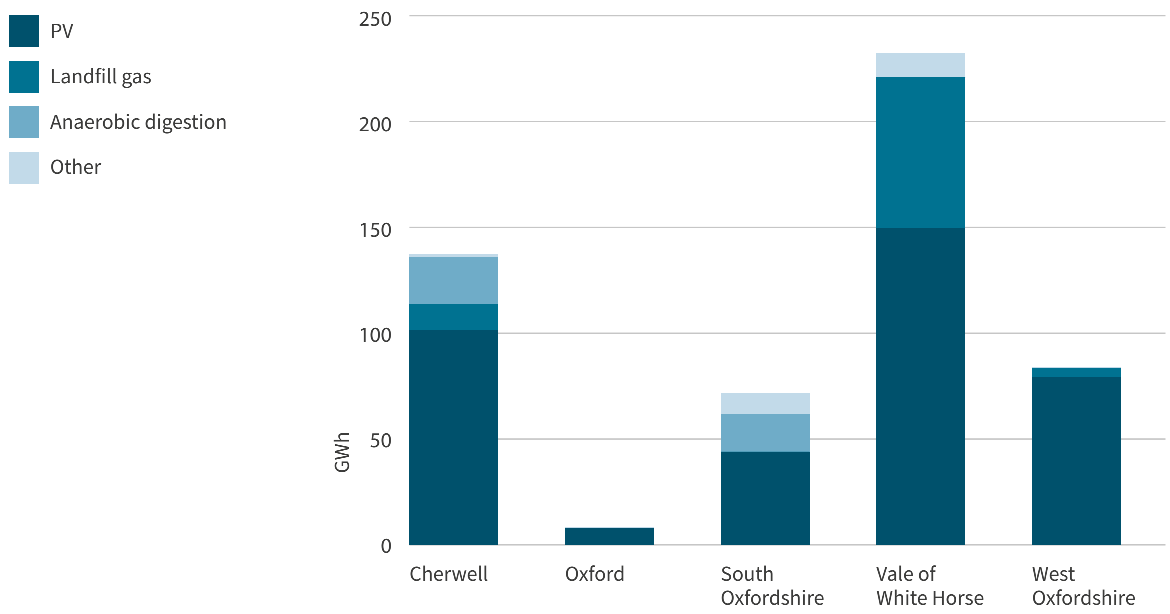


Figure 3.6: Renewable electricity generation (GWh) by source, 2019

However, since 2014, there have been significant developments in the UK's electricity mix. Notably, the cost of offshore wind turbines has fallen sharply, and the UK now has 10GW capacity, with a target of 40GW by 2030 announced as part of the government's '*Build Back Greener*' initiative. Drawing on the analysis behind Scenario C, the Oxfordshire Energy Strategy recommends that the county should aim to generate 56% of its electricity demand from local renewables by 2030. However, based on developments in clean energy supply at the national level, forthcoming interconnector capacity and higher projections for electricity demand, it may be reasonable for Oxfordshire to meet a lower proportion of its electricity demand from local sources than set out in Scenario C, relying on zero carbon supply from elsewhere to achieve net-zero emissions.

In the following chapter, our scenarios provide updated estimates, with the most ambitious equating to 31% of demand by 2030, and 52% by 2050. In any case, if Oxfordshire is to substantially increase the proportion of electricity demand met with local renewables before 2030, there is a need for improved public funding for new solar generation and electricity storage, and additional support for local energy markets.

Evaluating progress on the renewable generation of **heat** is difficult, as data is not collected on the number of biomass boilers, wood-stoves and heat-pump installations, nor their annual generation. However, BEIS do record the total number of domestic installations supported by the Renewable Heat Incentive (RHI), which for Oxfordshire amounts to 1,366, the majority of which are air-source heat pumps (63%) and ground source heat pumps (17%). This represents just 0.5% of all households, indicating that progress on renewable heat has been insufficient. Data is more readily available for the non-domestic sector, which has an installed capacity of 46MW, most of which is biomass.

The most ambitious estimates for decarbonising heat in the 2014 report involved a combination of reduced demand, the widespread roll-out of heat pumps and biomass systems, and utilising heat from anaerobic digestion (AD) plants. As of 2020 however, all heat generated from AD and waste processing plants continues to be unutilised, although the feasibility of using waste heat from the Ardley Energy Recovery Facility has been explored.[47] It is clear that Oxfordshire is not on track to meet 40% of its heat demand from local renewables and that decarbonising heat is one of the most difficult challenges facing the UK in its efforts to reach net-zero. It is hoped that the government's forthcoming Heat and Building Strategy and Future Buildings Standard will provide the policy framework for accelerating progress in this area.

47 BEIS (2019), Heat Networks: 2019 Q2 Pipeline, p70.

Natural environment. Land use in Oxfordshire is changing due to a number of factors. Housing and other development has led to the loss of arable and improved (intensively managed) grassland, but also to the loss of some areas of semi-natural grassland, woodland, scrub, wetland and urban trees and green spaces. In addition, pasture is being converted to arable land in some areas, and vegetation is under stress from climate change. These changes result in loss of the carbon stored in soil and vegetation, as well as loss of the future ability to sequester carbon. For example, from analysis of OS Mastermap we estimate that approximately 2,700 ha of land was sealed due to development between 2014 and 2020. Even if this land was all arable (with relatively low soil carbon), around 180,000 tonnes of carbon stored in the topsoil would have been lost. Although intensively cultivated arable land is a net source of greenhouse gas emissions, its loss will simply displace those emissions as food is produced elsewhere instead, unless demand for farmland is reduced by dietary change or a reduction in food waste.

New developments may plant trees in an effort to partly offset these impacts, but it takes many decades for new trees to reach maturity, thus replacing the lost carbon. However, some land managers are also demonstrating how regenerative agriculture, organic farming, agroforestry and habitat restoration can increase carbon storage and sequestration at the same time as supporting biodiversity and providing other societal benefits (see Chapter 9).

4 Scenarios for a zero-carbon Oxfordshire

There is widespread agreement on the need to drive down emissions and achieve a zero-carbon economy in Oxfordshire by 2050. However, this will not occur without concerted action at multiple scales and by diverse actors. Although Oxfordshire is reliant to a large extent on transformations at the national or even international level to decarbonise its electricity and transport systems, and to eradicate emissions from its building stock, the county also has the option to lead the way towards drastic emissions reductions, going further and faster than other parts of the UK.

This chapter sets out three different pathways to achieving zero-carbon (**Societal Transformation**, **Technological Transformation** and **Oxfordshire Leading the Way**), and contrasts these with a business-as-usual scenario (**Steady progression**). The chapters which follow provide further detailed analysis of the changes needed to achieve net-zero.

4.1 Methodology and approach

Our scenarios build on comprehensive modelling undertaken by the National Grid (NG) in developing their *Future Energy Scenarios* (FES). The four scenarios in this report align with their 2020 FES, which have also been adapted by the electricity Distribution Network Operator covering most of Oxfordshire: Scottish and Southern Electricity Networks (SSEN), to create the Distribution Future Energy Scenarios (DFES). To differentiate between our scenarios and those set out by NG, we have chosen slightly different names for each of the three pathways to zero-carbon.

Where available for Oxfordshire, data on key indicators such as energy demand, renewable generation, and the uptake of electric vehicles have been used as a starting point and combined with modelling by NG to extrapolate figures for 2030 and 2050. However, population growth on a national scale is forecast to be far more modest than in Oxfordshire. We have therefore adjusted the underlying calculations based on expected growth in housing and population, which are consistent across the four scenarios. Further, the NG FES analysis was conducted before the government brought forward the ban on new petrol and diesel vehicles to 2030, so our projections of EV uptake are more rapid.

None of the scenarios should be interpreted as forecasts or predictions, but instead outline different possible pathways to decarbonising the economy, indicating the scale of investment, societal and technological change needed to meet climate goals. The approach in this report differs from that taken in 2014, which included just one scenario with the level of action needed to meet UK climate goals. This time, three of the four scenarios achieve net-zero by 2050, varying in the extent of social and lifestyle change, technology mixes and local action. However, it should be highlighted that each of these pathways require change across all sections of society, driven by strong policy and public support at the national and local levels.

Housing and population growth projections

Oxfordshire's population is growing rapidly. Up to 2031, the figures in this report are based on data compiled by Oxfordshire County Council's Research & Intelligence team, using housing data forecasts provided by City and District Councils. These figures indicate an average of just under 6,000 new homes added to the dwelling stock each year to 2031. Thereafter, no plans have yet been agreed, and for our scenarios we have assumed an additional 4,000 homes are built each year from 2031 to 2050.

All modelling is subject to uncertainty and error. Future energy scenarios have a tendency towards emphasising technological solutions with a focus on supply,[48] underplaying the significance of economic, social and behavioural drivers of energy demand. Models often make broad assumptions about high levels of energy service demand, characterised by thermostat settings and transport preferences. Ecosystem services and consumption emissions are often treated separately. In response, we have adapted our scenarios to include some additional, difficult-to-quantify, features of a zero-carbon future, with a focus on the demand side.[49]

Although the COVID-19 pandemic led to significant reduction in energy demand during 2020, we have not included this in our underlying calculations. There is limited recent data available at the geographical scale needed, and it is difficult to predict the near term rebound in energy consumption, travel behaviour and associated carbon emissions. While this is a limitation of these scenarios, the uncertainties associated with decadal trajectories outweigh near term fluctuations.

A note on local renewable generation

Our 2014 scenarios included metrics relating to the proportion of electricity and heat demand generated by local renewable sources by 2030. The figures of 56% and 40% respectively were incorporated into the Oxfordshire Energy Strategy as recommendations of what might be needed to halve emissions by 2030.

As mentioned in Chapter 3 and discussed further in Chapter 8, recent developments and future projections indicate that this figure for electricity now represents a highly ambitious pathway. Whereas in 2014, Scenario C assumed significant development of onshore wind in the county, in this report we focus primarily on solar photovoltaics for new local electricity generation, for reasons outlined in Chapter 8.

For heat, we are no longer using the indicator: '*renewable heat as a percentage of total heat demand*'. This is partly because it is becoming apparent that, besides improving building insulation, heat pumps will drive the decarbonisation of heating in Oxfordshire, and it is a matter for debate whether these represent local generation or energy efficiency. We have replaced this metric with a simpler indicator which is also used in national policy: the number of heat pumps installed per year. We also include indicators for natural gas and hydrogen demand.

48 Barrett et al (2019). Modelling Demand-side energy policies for climate change mitigation in the UK: A rapid evidence assessment. UKERC Working Paper.

49 It is worth noting that National Grid and other modellers such as the Climate Change Committee have been increasingly including social, cultural and behavioural factors in their scenarios. Our scenarios for Oxfordshire go even further.

4.2 Scenarios

Steady Progression

Steady Progression extrapolates from trends on emissions reductions. It incorporates recent policy announcements such as the ban on sales of new petrol and diesel vehicles, but progress is uneven across sectors, and it does not achieve net-zero by 2050.

In this scenario, Oxfordshire continues to rely on high levels of natural gas for **heating**, with demand for gas falling by only 6% by 2050. The deployment of heat pumps is gradual. Overall energy demand continues to fall but at a more modest rate due to minimal increases in energy efficiency in buildings and industry.

In **transport**, the majority of small private vehicles are electrified, although some plug-in hybrids remain on the roads. The numbers of people working from home on a regular basis continues to gradually increase from the pre-pandemic baseline, but this results in minimal reduction in vehicle mileage as home-workers substitute commutes for other local trips.[50] Demand for train commuting is reduced however. Railway electrification is achieved for the new East West Rail route, but rising costs hamper progress on the main routes through Oxford. There is more progress in electrifying buses, but this fails to attract many new passengers switching from private transport. Rates of walking and cycling remain low as a proportion of total trips, and cycling culture fails to take hold outside of Oxford City as new housing continues to be built at low densities. HGVs become cleaner by switching to gas, but continue to rely on fossil fuels. Hydrogen does not feature significantly as a fuel for either transport, heating, or energy storage.

Electricity demand remains steady to 2030, and then increases by 74% to 2050 (compared with 2018), driven by substantial housebuilding. It is assumed that from 2025 heat pumps are installed in all new homes, and from 2028 their occupants own one electric vehicle, which they charge at home. **Flexibility** is minimal, with limited smart charging practices and vehicle-to-grid (V2G) deployment. The adoption of flexible practices by householders and businesses remains a niche activity in the near term, but time-of-use tariffs become more widely adopted (54%) by 2050. 60% of electricity generation is provided by renewables by 2030, but most of this is provided by technologies deployed outside of Oxfordshire. Nonetheless, falling prices and increased efficiency lead to an increase in **solar generation** of 32% by 2030 (500 GWh), and 131% by 2050 (880 GWh). Installed capacity of solar reflects the current share of 80% ground mounted, 20% rooftop. However, as electricity demand increases, the proportion supplied by local renewables rises only slightly to 16%, and that remains constant as new installations keep track with growing electricity demand.

In this scenario, in line with recent trends, **land use** is largely unchanged except for the continued loss of farmland for housing development. Over 9,000 ha of land (3.5% of the area of Oxfordshire) is allocated for development between 2011 and 2031. Solar farms expand to occupy an additional 670 ha of farmland. Around half of the land in the county continues to be dedicated to livestock farming, with 27% remaining as intensive pasture (improved grassland), and approximately half of the 43% arable land being used to produce livestock feed. Modest habitat restoration efforts are linked to new biodiversity net gain policies, though these are hampered by intense competition for land.

50 Hook, A., Court, V., Sovacool, B.K. & Sorrell, S. (2020). A systematic review of the energy and climate impacts of teleworking. *Environmental Research Letters*, 15: 093003

Societal Transformation

Societal Transformation

This pathway to a zero-carbon economy is driven by significant changes in consumer practices.

Total energy demand falls significantly in this scenario, with a national programme of retrofit leading the way to achieving high levels of efficiency across Oxfordshire's building stock. **Electricity demand** more than doubles by 2050 compared with 2018, driven by the large-scale deployment of heat pumps to replace gas and oil boilers throughout Oxfordshire. Reflecting this, demand for natural gas falls by 31% to 2030, and by 2050 to zero. From 2025, no new homes in Oxfordshire would be connected to the gas grid, but from 2035, some areas of the county's gas grid are repurposed for **hydrogen**.

In this scenario, Oxfordshire maintains its 3% share of UK **solar capacity**. This means more than doubling generation by 2030 (850 GWh) and achieving more than 5 times current levels by 2050 (2,100 GWh). In this scenario, the proportion of rooftop solar grows to 25% of installed capacity. Combined with relatively small contributions from landfill gas, anaerobic digestion and biomass, local renewable generation represents 27% of Oxfordshire's electricity demand in 2050.

Flexibility is a major feature of electricity demand, with Oxfordshire's residents playing a crucial role in balancing the electricity grid to maximise the usage of renewable power. In 2030, 29% of households have adopted time-of-use tariffs which incentivise flexible usage, and by 2050 this rises to 73%. Oxfordshire's increasing number of electric vehicles owners adopt smart charging practices, and V2G technology is deployed across 3% of households by 2030, rising to 26% by 2050. Electricity storage in this scenario is largely decentralised, with building-scale batteries coupled with rooftop solar installations, and a role played by aggregators to harmonise their operation at a neighbourhood scale, such as trialled in Project ERIC.[51] Flexibility is also enabled by a substantial increase in remote working, allowing householders greater opportunity to avoid and shift their demand for travel.

A transformation in mobility takes place, as changing travel habits during the COVID-19 pandemic are incorporated into everyday life. Overall **transport** energy demand is reduced, with significant increases in walking and cycling for shorter trips and widespread home working. Incentives and communications campaigns are needed to drive up the use of public transport following the pandemic. These changes are also driven by bold policies such as the implementation of low traffic neighbourhoods, concentrating new housing in mixed-use development at higher densities, and restrictions on vehicular access to town centres. EV adoption is rapid supported by local, shared public charging facilities, and larger proportions of heavy vehicles including buses and HGVs are electrified than in other scenarios. In this pathway, modal shift drives up train usage and investment. All railway lines in Oxfordshire are fully electrified by 2050.

51 Project ERIC ran from 2015–2017 in Rose Hill, East Oxford.

In **Societal Transformation**, greenhouse gas emissions from **land use** are reduced as the result of the widespread adoption of low-meat diets.[52] This reduces the demand for pasture and arable land for livestock feed, freeing up more space for restoration of native woodland, floodplain meadows and wetlands. In addition, less land is taken for new housing due to strong planning guidance that encourages compact development, together with lower reliance on private cars which reduces the space needed for parking. As a result, the target to double Oxfordshire's woodland is achieved, including through integrating new native woodland planting and regeneration into the Nature Recovery Networks along with restoration of natural grassland, wetland, heathland and shrub. Attractive green travel routes are also integrated into these networks and into new developments, further boosting the number of people choosing to use active travel. Agriculture diversifies, including more horticulture and agroforestry, and a wider variety of food is produced for local consumption. Farmers lead the way in enhancing biodiversity and improving soil quality, including planting and expanding hedgerows, leading to co-benefits for natural flood management, water quality and other ecosystem services.

52 The National Grid Future Energy Scenarios do not provide detail on dietary change, however the Committee on Climate Change's 'Balanced Pathway' involves a 20% shift away from red meat and dairy products by 2030, with a further 15% reduction of meat products by 2050 and their Widespread Engagement pathway has a 50% reduction in meat. Sixth Carbon Budget, p165. Our Societal Transformation scenario sees a 75% reduction for meat but no reduction for dairy, based on a low carbon version of Public Health England's Eatwell Plate.

A note on negative emissions and offsetting

For a single county embedded in a national energy and transport system, it is difficult to define and quantify carbon offsetting. Typically this is defined as carbon mitigation or sequestration measures taking place outside a defined boundary, with a need for evidence to prove that the carbon reductions would not have occurred without additional investment and intervention. If we were to draw a boundary around Oxfordshire, then decarbonisation efforts elsewhere in the UK could be defined as offsetting. New installations of renewable generation such as offshore wind could be classed as offsetting Oxfordshire's emissions, as the county benefits from the zero-carbon electricity produced.

Another way to define offsetting might be to refer to negative emissions technologies and nature-based solutions for sequestering carbon remaining from difficult-to-decarbonise sectors such as aviation and shipping. Options include bioenergy with carbon capture and storage (BECCS), Steam Methane Reforming with CCS (to produce hydrogen), and nature-based solutions including afforestation and ecosystem restoration. Although their scenarios rely on negative emissions to achieve net-zero, the National Grid do not rely on negative emissions from overseas.

For clarity and simplicity, we do not refer to mitigation or negative emissions activities conducted outside Oxfordshire as offsetting. We follow NG in planning for net-zero to be achieved within the UK territory, but acknowledge that Oxfordshire will rely on action taken elsewhere. The extent to which it does varies amongst the three net-zero scenarios, including the deployment of solar photovoltaics, and the quantities of biofuels grown as feedstock for electricity generation in BECCS power plants outside of the county.

Technological Transformation

Technological Transformation

This pathway to zero carbon emissions relies on the widespread deployment of existing technologies and the development of new innovations and infrastructures. Although the means by which Oxfordshire's residents travel and heat their homes are transformed, their practices and behaviours undergo less change, and demand for energy services continues to increase. Of the three net-zero pathways, Oxfordshire is most reliant on technologies developed and deployed outside of the county.

In this scenario, **hydrogen** features prominently as a fuel for heating, energy storage, industrial processes and heavy vehicles. It is deployed rapidly with 110 GWh used in 2030, rising to levels of annual demand in 2050 (5,300 GWh) which roughly equates to current usage of natural gas. Natural gas demand falls less steeply than in the other zero-carbon scenarios, as hybrid boilers are rolled out, ready for sections of the grid to be switched from natural gas to hydrogen. At the national scale, natural gas demand remains high in this scenario, as it becomes the primary means by which hydrogen is generated, accompanied with carbon capture and storage technology. However, it is very unlikely that these conversions take place in Oxfordshire, so natural gas demand falls to zero by 2050.

Although the widespread uptake of electric vehicles drives **electricity demand** up (+84% by 2050), this is substantially lower than in other net-zero pathways, due to less electrification of heat. This is reflected in the lower numbers of **heat pumps** installed in this scenario, although even here the number of homes heated with electricity doubles by 2050. The high costs associated with the shift from natural gas to hydrogen are somewhat offset by efficiency improvements in **buildings**, although ambition on energy efficiency in buildings is lower than in other net-zero scenarios.

Although new homes continue to be connected to the gas grid beyond 2025, policy requires that boilers are hydrogen-ready by this date to facilitate a fuel-switch at a later date.

The proportion of **electricity demand** met by local renewables is slightly lower than in the **Societal Transformation** pathway, as a result of relatively lower uptake of rooftop solar as opposed to ground-mounted. As such, the proportion of rooftop solar falls from 20% to 10%, as large-scale ground mounted installations are preferred. At a national scale, new electricity generation is dominated by wind power, but this is not widely deployed in Oxfordshire. The county retains a 3% share of UK solar capacity, and 23% of electricity demand is met by local sources of generation by 2050.

Flexibility features less prominently in this scenario than other zero-carbon pathways, as consumers are more reluctant to shift the times of day when they travel, charge their EVs or carry out energy intensive activities such as laundry, cooking or electric heating. The proportion of households on time-of-use tariffs is only 10% in 2030, rising to 60% by 2050; while uptake of V2G is negligible in 2030, rising to only 11% of car owners in 2050. Technological solutions, as opposed to changing practices, deliver a larger share of the flexibility needed to balance energy supply and demand, and this scenario includes the development of a new 10MW hydrogen peaking plant in Oxford.[53] Learning from the process of installing of a 50MW hybrid battery on the transmission grid as part of Energy Superhub Oxford, a further 50MW storage capacity is deployed to ease constraints elsewhere in the county.

53 This is included in SSEN's future scenarios.

Transport. In this scenario, the electrification of the private vehicle fleet takes place on roughly the same timescale as in **Societal Transformation**, driven by the ban on sales of new fossil fuelled vehicles by 2030. However, growth in public transport use is slower than in other net-zero scenarios due to lower willingness amongst the public to switch away from private modes. As a result, congestion remains a significant issue in the county, with active modes, public transport and remote working only partially offsetting the growing number of trips taken by private car. With car usage remaining high, this scenario requires the most extensive public charging infrastructure and rapid charging is in high demand, but the uptake of V2G by Oxfordshire's EV owners is modest. Both trends drive the need for investment in electricity grid capacity. Although progress is made to electrify railways in Oxfordshire, some routes switch to hydrogen in this scenario. Hydrogen is the fuel of choice for heavy vehicles.

In this scenario, **agricultural** production is intensified in Oxfordshire, with a larger number of farmers moving to horticulture practices using polytunnels and indoor hydroponics. Intensification is further assisted by technological innovations as automated mechanical weeding, the widespread use of GPS and in some cases, machine learning.[54] As such, levels of food production increase despite some agricultural **land** being allocated for afforestation and solar farms. This scenario features a narrow focus on planting trees, ignoring the value of other habitats and the importance of planting the right trees in the right place. As a result, there are fewer co-benefits for biodiversity or ecosystem services than the other two net-zero pathways, and even some adverse impacts as non-native trees are planted on biodiverse and carbon-rich grassland. Also, without dietary change to free up farmland, and with less compact housing developments, competition for land means that tree planting targets are not achieved.

54 Liakos, K.G., Busato, P., Moshou, D., Pearson, S. & Bochtis, D. (2018). Machine learning in agriculture: A review. *Sensors,* 18: 2674. doi: 10.3390/s18082674

Contributions from the non-domestic sector

As discussed in Chapter 7, the non-domestic sector in Oxfordshire is extremely heterogenous. With more than 32,000 businesses in the county, there is significant variation in the design, fabric and usage of buildings, as well as the business activities taking place within. Whereas for domestic buildings, the number of homes retrofitted to certain standards of energy efficiency is a useful measure of progress, we have used alternative metrics for the non-domestic building stock, focusing instead on the steps taken by businesses to reduce emissions.

There are a wide variety of resources to help organisations develop plans to achieve net-zero. Oxfordshire businesses Seacourt Printers and Anne Veck have developed action packs to support other businesses on their sustainability journeys, while colleagues at Oxford University have helped to launch the SME Climate Hub a repository of advice and resources. Energy Solutions Oxfordshire is a new energy services company launched by the Low Carbon Hub and Oxford Brookes to provide a one-stop shop for businesses to reduce energy wastage.

There are a wide variety of steps that businesses can take to reduce their carbon footprints, and we have selected metrics which will help to indicate that Oxfordshire's business community is taking seriously their responsibility to tackle climate change, by monitoring their impact, developing and publishing net-zero strategies, and taking part in zero carbon networks.

Oxfordshire Leading the Way

Oxfordshire Leading the Way

In this scenario, Oxfordshire goes further and faster than other areas of the UK in achieving zero carbon emissions. This is driven by high levels of public support for local action and strong policy, as well as lifestyle change amongst householders and communities. Oxfordshire builds on its leadership position in the low carbon sector by attracting investment in clean-tech innovation, and expanding community initiatives and the sharing economy.

Oxfordshire Leading the Way balances the need for societal change and technological innovation represented in the two other zero-carbon scenarios. **Heat pumps** are deployed rapidly in Oxfordshire, alongside a transformative retrofit scheme. The retrofit market is assumed to take several years to create, so numbers start small and build up to market maturity in the 2030s. By 2050 it is assumed that 95% of today's housing stock (280,000 properties) have been renovated to a high standard of efficiency. In Oxfordshire no new gas boilers are installed across the building stock from 2025.

Driven by the rapid deployment of heat pumps and electric vehicles, **electricity demand** in this scenario follows the steep trajectory outlined in **Societal Transformation**. Building on the successful trials of markets for flexibility services in Project LEO, businesses and residents actively engage in **flexibility** practices, saving on energy bills and assisting with grid balancing. **Hydrogen** in this scenario is adopted primarily for heavy vehicles and energy storage, with a small amount generated locally using electrolysis.

This scenario involves a moon-shot for the deployment of **solar photovoltaics**. Oxfordshire's share of UK capacity increases to 4% by 2030, and 6% in 2050. This equates to a *three-fold* increase in solar capacity in the county by 2030 compared with 2019 figures, and *ten-times* by 2050. Accelerated rooftop installations play a key role in achieving these increases, and new-build dwellings include an average of 4kW capacity from 2023. In the medium term (2030), the proportion of rooftop solar increases to 40% of installed capacity, but as the availability of suitable rooftops diminishes and large ground-mounted arrays are constructed, this falls back to 30% by 2050. As a proportion of Oxfordshire's electricity demand, renewables provide 31% in 2030, and 52% in 2050.

Energy demand associated with **transport** falls following the COVID-19 pandemic, as Oxfordshire residents incorporate walking and cycling into their daily routines, with more amenities being provided locally, and businesses support remote working. Reduced car-usage is also driven by extensive pedestrianisation measures implemented by Oxford City and the market towns, workplace charging levies, the proliferation of low traffic and higher density neighbourhoods, and the expansion of shared transport options. Vehicle electrification occurs more rapidly than in other net-zero scenarios, and sharing business models, including autonomous fleets, are pioneered in Oxfordshire, driven by a thriving automotive sector. This leads to reduced car ownership. Freight consolidation centres and other localised warehousing and production enable low carbon local delivery of goods throughout urban areas.

Oxfordshire's **land**-based resources play a critical role in supporting decarbonisation efforts at the national scale. This means that a greater proportion of land is allocated for growing bioenergy crops than in other net-zero scenarios, used for power generation, aviation and shipping. The proportion of land currently used for meat and dairy production is reduced as a result of changing diets to make way for bioenergy crops, ecosystem restoration and solar arrays. Solar farms are built throughout the county, but still only occupy less than 1% of land area. Agriculture diversifies and a wider variety of food is produced for local consumption. Permaculture practices are pursued, and the number of allotments in Oxfordshire triples. New local initiatives such as community gardens, farmers markets and land trusts crop up around Oxfordshire. Membership of Good Food Oxford and the Community Action Network quadruples by 2030.

Quality vs quantity

The nature of scenario modelling means that the focus is inevitably on **quantity**: adoption of heat pumps and EVs, numbers of homes retrofitted, businesses conducting energy audits and hectares of trees planted.

Although more difficult to capture in scenario modelling, **quality** is crucial. The 'performance gap' describes the difference between actual and modelled energy usage for buildings, and can be as high as 60% in low energy housing.[55] An integrated approach to quality assurance (such as the systems and standards advocated by the Passive House Institute) is needed to get real-life energy performance down to the levels assumed in the quantitative analysis. Similarly, householders' capacity and willingness to shift their electricity demand matters just as much as the numbers adopting time of use tariffs and V2G technology. Businesses may conduct regular energy audits and monitor their carbon footprint, but acting on this information is what counts. Finally, hectares of trees planted per year is a crude measure, which ignores the importance of selecting species which enhance biodiversity and provide additional ecosystem services besides carbon sequestration, as well as the need to restore a balanced mix of different habitats.

Ultimately, what counts towards climate goals is actual, observed emissions reductions, rather than the number of homes renovated, trees planted, heat pumps installed or EVs registered. The difference between modelled and observed outcomes depends on the quality of design and workmanship, the performance of installed technologies, and user preferences and behaviour.

55 Gupta, R., Howard, A., Kotopouleas, A. & Krishnan, S., 2019. Meta-study of the energy performance gap in UK low energy housing. In: ECEEE Summer Study Proceedings. Presented at the ECEEE, Belambra, Presquile de Giens, France.

Scenarios	Steady Progression		Societal Transformation		Technological Transformation		Oxfordshire Leading the Way		Notes
Indicator	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**	
Buildings									
No. of pre-2020 homes renovated	3,000	30,000	8,900	280,000	3,000	150,000	8,900	280,000	Supply chains and governance arrangements will take 5–10 years, so little change before 2030.[56]
Energy standard for retrofits, kWh/m^2/year (useful energy; domestic space heating only)	100	100	100	60	100	100	100	60	
Average EPC rating for all buildings	D	D	D	B	D	C	D	B	Current average is D; improvement requires support to achieve higher ratings and a regulatory minimum standard to make low-rated buildings unusable (with finance and other support for upgrades).
Percentage of Oxfordshire businesses conducting annual carbon footprints and/or energy audits	3%	6%	15%	80%	10%	40%	20%	80%	Figures refer to businesses with employees (excludes sole traders)
Proportion of large businesses with published net-zero strategies	5%	30%	60%	95%	30%	60%	70%	100%	
Coverage of business networks dedicated to achieving zero-carbon (% of total number of businesses)	3%	10%	20%	40%	5%	15%	25%	50%	Examples include Zero Carbon Oxford Partnership and Oxfordshire Greentech, but more are needed. Figures exclude sole traders.
Heat									
Natural Gas demand (GWh)	4,800	4,900	3,600	0	4,300	0	3,300	0	Demand in 2018 was 5,270 MWh
Hydrogen demand (GWh)	20	160	19	1,600	110	5,300	30	1,800	Currently negligible.
Number of heat pumps (total installations)	41,000	190,000	120,000	390,000	64,000	250,000	130,000	390,000	There are roughly 1,500–2,000 heat pumps in Oxfordshire currently.

56 Construction Leadership Council (2020), Greening our existing homes national retrofit strategy.

Scenarios	Steady Progression		Societal Transformation		Technological Transformation		Oxfordshire Leading the Way		Notes
Indicator	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**	
Transport									
Battery electric vehicles as proportion of all light vehicles on the road	25%	95%	37%	99%	35%	99%	40%	99%	Currently <1%
Number of battery electric vehicles (BEVs)	130,000	600,000	195,000	500,000	185,000	525,000	210,000	450,000	There are roughly 430,000 vehicles in Oxfordshire currently, of which 2,500–3,000 are BEVs.
Domestic and workplace charge points	80,000	200,000	68,000	165,000	74,000	175,000	58,000	150,000	There are roughly 2,000 to 2,500 chargers currently.
Public charge points	7,000	18,000	10,000	25,000	15,000	26,000	16,000	36,000	There are roughly 240 public chargers currently. Includes shared residential charge points (e.g. on street). The European Commission recommends 1 public chargepoint is installed for every 10 EVs on the roads.[57]
% Telecommuting	10%	15%	30%	40%	10%	20%	25%	35%	Defined as percentage of labour force working primarily from home. In 2019, about 5% of those in employment in the UK said they mainly worked from home, although this rose to 47% during the first lockdown in April 2020.
Active travel investment	£10	£15	£20	£40	£15	£30	£25	£40	Per capita, per year, including capital and revenue based on 2021 prices. In 2018/19 active travel investment averaged £6 per person.[58]
Electricity supply									
Solar generation (GWh)	500	880	850	2,100	700	1,400	1,100	3,900	Solar generation was 382 GWh in 2019. In ST and TT, solar capacity remains 3% of UK total. In OLTW, this increases to 4% by 2030 and 6% by 2050.
Total renewable electricity supply (GWh)	660	1,000	1,000	2,200	870	1,500	1,300	4,000	Renewable generation was 533 GWh in 2019.

57 Transport & Environment (2018), Roll-out of public EV charging infrastructure in the EU.

58 Cycling and walking investment strategy Report to Parliament, p24. February 2020.

Scenarios	Steady Progression		Societal Transformation		Technological Transformation		Oxfordshire Leading the Way		Notes
Indicator	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**	
Renewable electricity supply as a percentage of electricity demand	16%	16%	25%	27%	23%	23%	31%	52%	Current renewable electricity generation represents 15% of demand
Flexibility									
Percentage of households with time-of-use (TOU) electricity tariffs	6%	54%	29%	73%	10%	60%	35%	83%	Flexibility figures are taken directly from National Grid's 2020 scenarios. Currently <1%.
Percentage of households utilising vehicle to grid technology	0%	5%	3%	26%	0.2%	11%	5%	45%	Percentage of all households, although not all own vehicles, nor have access to off-street parking.
Land use									
Hectares of trees planted per year	60	60	430	430	210	210	430	430	Tree planting is enabled by dietary change in ST and OLW.
Hectares of agroforestry, hedgerows and garden trees planted per year	0	0	1,400	1,400	0	0	1,400	1,400	Farmer and community participation enables additional tree planting in ST and OLW.
Hectares of natural grassland, heath, scrub and wetland restored per year	5	5	400	400	0	0	200	200	ST aims to double the area of non-woodland semi-natural habitats from 4.5% to 9%. OLW is constrained by heavy demand for land for solar and biofuels.
Percentage of land used for ground-mounted solar generation	0.15%	0.26%	0.23%	0.57%	0.24%	0.45%	0.23%	0.99%	This is calculated based on an area for Oxfordshire of 260,500 ha (2,605 km^2).
Hectares of land used for bioenergy crops	0	0	10,000	10,000	20,000	20,000	25,000	25,000	All scenarios include less than the NG's estimated need for bioenergy, due to land use constraints. The remainder must be grown elsewhere in the UK or imported. ST relies on demand reduction to reduce need for BECCS.
Percentage of food demand met in Oxfordshire	60%	40%	95%	60%	55%	39%	87%	55%	Based on area needed to produce food with an equivalent calorific value. Currently Oxfordshire meets the equivalent of 74% of its food demand. This increases with low meat diets but decreases over time with high population growth and loss of farmland for housing, afforestation, biofuels and solar.

4.3 Investment and economic impact

In a report for the Committee on Climate Change (CCC), Cambridge Econometrics estimated that GDP at a national level would be 2–3% higher between 2020 and 2050, and would generate around 300,000 additional jobs if the UK follows a path to net-zero.[59] Although the investments needed in developing and deploying the solutions for reducing carbon emissions are high, especially in the near term, they predict a net economic benefit.

The economic impacts of the transition are likely to be geographically uneven, and the CCC acknowledges that many jobs will be lost, for instance in the oil and gas sector. Oxfordshire's economy, which is already dominated by the service sector and high-tech manufacturing, stands to benefit substantially from this transition. However, to capitalise on this opportunity, there is a need for unprecedented levels of investment in transport, buildings and the energy system in Oxfordshire.

Based on available evidence and without using econometric modelling techniques, we have provided estimates of the additional investment needed to reach the 2030 goals outlined in **Oxfordshire Leading the Way**.

	Investment 2021–2030	Notes
Transport		
Active travel	£100m	
Vehicle fleet decarbonisation	£240m	Majority of additional investment needed is focused on LGVs, HGVs and buses, as it is expected that the total cost of ownership for battery-electric passenger-cars equals or even undercuts current costs for conventional vehicles before 2030
Electric charging infrastructure	£150m	Includes public and private
Rail electrification	£125m	Based on 50% of the non-electrified[60] multi-track line being electrified at an average cost per km of £1,750,000.[61]

59 Cambridge Econometrics (2020), Economic impact of the Sixth Carbon Budget.

60 The stretch of mainline rail from Reading to Didcot has already been electrified, representing 10% of Oxfordshire's total railway.

61 Railway Industry Association (2019), Electrification cost challenge.

	Investment 2021–2030	Notes
Buildings		
Housing retrofit and heat pumps	£1.5bn	Assumes that costs of (re-)training the workforce are met at national level as part of a strategic re-positioning of the economy to meet decarbonisation targets. Assume £25K per retrofit; £10K per HP. Majority of investment is private.
Business advice and engagement services	£50m	Assume a network of 100 decarbonisation consultants working with local businesses (upscaling OxFutures) @ £50K per consultant per year
Renewable energy		
Solar generation	£630m	Based on CAPEX installation costs of £750/kWp and OPEX of £7000/MW/year.
Grid infrastructure	£450m	Based on £30bn UK CAPEX network investment in CCC's balanced pathway, scaled by Oxfordshire's forecast demand contribution.
Battery Storage (supply side)	£100m	Based on CAPEX installation costs of £500/kWe and OPEX of £25000/MW/year.
Land use & natural ecosystems		
Strong planning policy	Low cost	Strengthen planning policy to protect carbon-rich habitats, encourage green roofs and rooftop solar, and mandate compact, walkable low carbon development. Green roofs expected to reduce building heating and cooling costs and walkable neighbourhoods expected to deliver healthcare savings.
Awareness raising to encourage low meat diets	Low cost	Expected to reduce healthcare costs
Tree planting	£113m	Planting 22,600 ha of tree and agroforestry cover by 2050 at £5000 per ha of cover.59
Plant 8,500 km of hedgerows	£44m	Based on estimate of £526/100m for 8,500 km of species-rich hedge including hedgerow trees.[62]
Habitat restoration	£31m	Estimated £800 per ha for 9000 of meadows and £8000 per ha for 3000 ha of wetlands

62 Warner, E (2020), Opportunities for biodiversity enhancement on the University Estate.

5 Catalysing low carbon innovation

Since the last Oxfordshire Low Carbon Economy report in 2014, much in the political, economic, and social spheres has changed, altering the conditions in which Oxfordshire's low-carbon economy grows.

This chapter starts with an overview of the strategic innovation assets Oxfordshire has and the business, technology and social innovation networks that support and connect those within the county's innovation ecosystem. This is followed by a wide-ranging summary of current activity to foster enterprise and innovation in Oxfordshire's low-carbon economy, looking at existing and planned Living Labs, which are large-scale, placed-based, collaborative and innovative pilot projects, and Oxfordshire's leading low carbon businesses. The chapter concludes with what is needed to ensure the prospering and scaling up of a healthy low-carbon ecosystem.

5.1 Oxfordshire's strategic innovation assets

Oxfordshire has one of the highest concentrations of innovation assets in the world,[63] positioned at the forefront of global innovation in transformative technologies and sectors such as autonomous vehicles, quantum computing, cryogenics, nuclear fusion, space and satellite technology, life sciences, and digital health. The county's business R&D spending is high, at £1,600 per capita (compared to £360 in London) – the seventh highest rate of 42 upper tier authorities.

Driving this innovation are the collection of nationally leading local authorities, research institutions, science, technology and business parks, business tech networks, a strong social enterprise sector, and community action groups. These include the two Oxford universities, Harwell Campus and Culham Science Centre in South Oxfordshire, business network B4, low-carbon business network Oxfordshire Greentech, Oxford Centre for Innovation, Oxfordshire Social Enterprise Partnership (OSEP) which support Oxfordshire's many successful social enterprises, the Community Action Group network's member organisations across the county, and many others.

63 OxLEP (2020), The Investment Plan.

Our universities are at the centre of Oxfordshire's innovation ecosystem. With the technology transfer expertise of Oxford University Innovation (OUI) and the business building expertise of Oxford Sciences Innovation plc, a science business builder devoted to building world-changing businesses and bringing Oxford science to the world faster, the University is by far the UK's most successful university start-up creator having spun out over 200 businesses to date (Figure 5.1). This figure is more than the combined output of University College London (46) and Imperial College (36) in second and third place.[64] Many of the projects & patents managed by OUI have had worldwide impact, such as the development of a new method of producing hydrogen instantly from fossil fuels with minimal oxygenated by-products.[65] Companies spinning out via OUI have attracted over £855m worth of external funding with 4,793 new patents under management.

Oxfordshire has several world leading science, technology and business parks, attracting innovation investment from central government and the private sector. Harwell Campus hosts both The Faraday Institution (in which central government has invested £65m), charged with tackling the global energy and battery storage challenge; and the Satellite Applications Catapult (in which central government has invested £68.3m), which advances innovation solutions in areas like sustainable development, agriculture, intelligent transport, geospatial intelligence and ubiquitous connectivity, through helping organisations make use of, and benefit from, satellite technologies.[66,67]

64 Advanced Oxford (2020), Powering up for the green recovery.

65 Oxford University Innovation

66 OxLEP (2019), Oxfordshire Local Industrial Strategy.

67 Satellite Applications Catapult (2021), About Us: The Satellite Applications Catapult.

Figure 5.1: Oxford University's Spinout Timeline (1959–2020) source: Oxford University Innovation

1958
- Oxford Instruments plc

1973
- Research Machines plc

1977
- Oxford Lasers Ltd

1988
- Oxford GlycoSciences Ltd

1989
- Oxford Molecular

1992
- Oxford Asymmetry Int. plc

1994
- PowderJect Pharmaceuticals plc

1996
- Oxford Biomedica

1997
- Oxagen Ltd
- Oxford Gene Technology

1998
- Celoxica Ltd
- Opsys Ltd
- Prolysis Ltd
- Sense Proteomics Ltd
- Synaptica Ltd
- Synergy Pharmaceuticals

1999
- AuC Sensing Ltd
- Avidex Ltd
- Dash Technologies Ltd
- OMIA Ltd
- Oxonica
- Oxxon Therapeutics Ltd

2000
- MindWeavers
- Mirada Solutions
- OBS Medical (Oxford BioSignals)
- Oxford Biosensors
- PharmaDM NV
- Third Phase Ltd
- TolerRx Inc

2001
- NaturalMotion
- Novarc
- Oxford Ancestors
- Oxford Archdigital
- Oxford Bee Company Ltd
- Oxford Drug Design (Inhibox)
- OxLoc

2002
- BioAnaLab
- Glycoform
- Intrexon (Oxitec)
- Minervation
- Oxford Biomaterials
- Oxford Immunotec
- Oxford Risk
- Oxitec (Intrexon)
- Pharminox
- Zyentia

2003
- Oxford Consultants for Social Inclusion
- ReOx
- Riotech
- Summit plc
- Summit Therapeutics

2004
- Avacta
- EKB Technology
- G-Nostics
- Oxford Medical Diagnostics
- Surface Therapeutics

2005
- Celleron Therapeutics
- Oxbridge Pulsars
- Oxford Nanopore Technologies
- Salunda (Oxford RF Sensors)
- Velocys

2006
- Alcolizer Technology UK (OxTox)
- Aurox
- Cytox
- Deepmatter (Cronin Group – OAS)
- Oxford Advanced Surfaces
- Oxford Medistress
- Particle Therapeutics
- TDeltaS

2007
- Adaptimmune
- Clinox
- Crysalin
- Fuel 3D (Eykona)
- Oxford Biodynamics

2008
- Loop (Nevatas)
- Organox
- Oxford Emergent TB Consortium Ltd
- Semmle

2009
- CN Bio Innovations
- Oxford Financial Computing
- Yasa Motors

2010
- IXO Therapeutics
- Oxems
- Oxepi
- Oxford Photovoltaics
- Tidal – Kepler Energy

2011
- Cella Energy
- First Light Fusion (Oxyntix)
- Oxford Cancer Biomarkers
- Oxford Imaging Detectors
- Oxford Multi Spectral
- Oxtex

2012
- Intelligent Ultrasound
- Oxehealth
- Oxford VacMedix
- Run3D

2013
- MuOx
- Oxford Biotrans
- Oxford Mestar
- Perspectum Diagnostics

2014
- Deontics
- Designer Carbon Materials
- Genomics plc
- NightStar Therapeutics
- Oxbotica
- OxCept
- OxSonics
- OxSyBio

2015
- Animal Dynamics
- Bodle Technologies
- iOx Therapeutics Ltd
- Mixergy
- Navenio
- Orbit Discovery
- Oxford Endovascular
- Oxford Flow
- Sonosine
- Wrapidity (Diadem)
- Xerion Healthcare

2016
- Argonaut
- Circadian Therapeutics
- DiffBlue
- EnzBond
- EvOx Therapeutics
- iota Sciences
- MetaBoards
- Mind Foundry
- OMass
- Osler Diagnostics
- Oxford Nanoimaging
- Oxford VR
- OxSight
- OxStem
- Proxisense
- Vaccitech
- Zegami

2017
- 6D.ai
- BreatheOx
- Brill Power
- Covatic
- InkPath
- MOA Technology Ltd
- Opsydia
- Oxford Quantum Circuits
- Oxford Semantic Technologies
- OxMet
- Oxonomy
- Pro-Mapp
- Quantum Motion Technologies
- Theolytics
- Scenic Biotech BV
- SpyBiotech
- Ultromics

2018
- 1715Labs
- Caristo Diagnostics
- Cocotec
- Cortex Organics
- DeepReason.ai
- Edtopia
- Helio Display Materials
- HEXR (Oxhex)
- Latent Logic
- Macrophox
- Ni20
- ODQA Renewable Energy Technologies
- Oxford HighQ
- Oxford Molecular Biosensors Limited
- Oxford Olefins
- Oxford Sustainable Fuels
- Oxstem Beta
- Oxstem Immuno
- PalaeoPi
- Pepgen
- PQShield
- Refeyn (Arago Biosciences)
- sOPHIa Oxford
- SugaROx

2019
- Akrivia Health
- Asymmetric Suzuki Reactions (EnantiOx)
- Global Malaria Vaccines
- Ground Truth Labs
- GyreOx
- Lime Biosciences
- Machine Discovery
- MiroBio
- Nucleome Therapeutics
- ORCA Computing
- Oxford Brain Diagnostics
- Oxford Ionics
- Rogue Interrobang

2020
- Aistetic
- Base Genomics
- Blue Field Labs
- Dark Blue Therapeutics
- GaitQ
- Global Campus
- Global Health Research Accelerator CIC
- GTT Analytics
- Kleidox
- LitHits
- Living Optics
- Open Clinical
- OXDH
- OxEd
- Oxford Simcell
- OxLOD
- Oxsed
- OxVent
- PhishAR
- Qdot
- Quantum Dice
- Singula Bio
- Skylark Works
- Spintex Engineering

2021
- Aisentia
- Augmented Intelligence Labs
- Curacode
- Hare Analytics
- HydRegen
- Orbit RRI
- Oxford Green Innotech
- OxVax
- Salience Labs

Energy innovation is a strength of the county. Harwell and Culham science parks in the south of the county grew out of the United Kingdom Atomic Energy Authority's (UKAEA) nuclear research dating back to the 1940s. Still a major international centre for nuclear fusion research, Culham is home to CCFE (Culham Centre for Fusion Energy)[68] which operates JET (Joint European Torus) and the MAST Upgrade experiment, supporting the first reactor-scale experiment, ITER, in France and beyond to the first fusion power plants. The EnergyTech Cluster at Harwell Campus facilitates collaboration across 57 organisations comprising over 1100 employees, with strong links to many more across the UK.[69]

Besides expertise long-established at Harwell and Culham, plans are now being developed for The Energy Systems Accelerator (TESA) to be located in Oxford. TESA is a proposed £100m national energy innovation hub, comprising offices, meeting rooms and laboratories, with shared spaces to promote interaction and creativity. The building will house research groups, businesses, spinout companies, public sector innovation teams and community energy groups. Although final decisions have yet to be made, Government has already approved funding for a 'mini-TESA' in Osney Mead.

68 Culham Centre for Fusion Energy.

69 Harwell Campus EnergyTech Cluster.

Local government in Oxfordshire also provides vital resources, support, and leadership in the low-carbon innovation space. Oxfordshire County Council have one of the largest local government innovation teams in the UK, involved in over 60 collaborative projects, and have helped leverage £135m in R&D funding into county projects. Collaborating extensively with businesses and research institutions, their Innovation Hub (iHub) portfolio of projects includes connected and autonomous vehicles, innovative planning, health and care, integrated mobility, electric vehicles, green fuel and smart cycling.

Figure 5.2: Oxfordshire's low-carbon innovation ecosystem

Funding and investment
Better Business Finance
British Business Investment
Green Investment Bank
Innovate UK
Oxford Investment Opportunity Network
OxLEP
Oxfutures
Oxford Science Innovation
Shared Prosperity fund
Venture Capital firms

Low carbon clusters
Abingdon Science Park
Culham Science Centre
Begbroke Science Park
Harwell Science and Innovation Campus
Howberry Park
Milton Science and Business Park
Oxford Centre for Innovation
Oxford Science Park
Oxford Technology Park
Oxford Industrial Park

Networks
Advanced Oxford
Harwell Green Club
Oxford Academic Health Sciences Network
Oxfordshire Greentech
Zero Carbon Oxford

Public sector
Cherwell District Council
Oxford City Council
Oxfordshire County Council Innovation Hub (iHUB)
Oxfordshire Growth Board South Oxfordshire District Council
Smart Oxford
Vale of White Horse District Council
West Oxfordshire District Council

Oxfordshire's low carbon innovation projects
See Figure 5.4

Oxfordshire's leading low carbon business
See Figure 5.5

Oxfordshire's low carbon ecosystem

Community level
Community Action Group (CAG)
Good Food Oxford
Low Carbon Hub CIC
Oxford Community First
Oxfordshire Community & Voluntary Action
Oxfordshire Social Enterprise Partnership

Incubators and accelerator programmes
Centre for Ecology and Hydrology
Centre for Agriculture & Biosciences International
Climate-KIC accelerator
Culham Centre for Fusion Energy
Energy Systems Accelerator
Enterprising Oxford
Harwell Energy Tec cluster
HR Wallingford
Oxford Bio-escalator
Oxford Foundry
Oxford Innovation
Oxford University Innovation
Rutherford Appleton Laboratory (RAL)
Satellite Applications Catapult
Science Technology Facilities Council (STFC)
The Faraday Institution
The Hill
Wood Centre for Innovation

Academia, higher education and skills
Activate Learning
Abingdon & Witney College
Henley College
Oxford Brookes University
- Oxford Institute for Sustainable Development

Oxfordshire Skills Board
University of Oxford
- Environmental Change Institute
- Oxford Martin School
- Smith School of Enterprise and Environment
- Transport Studies Unit

Supporting and professional services
Eco-designers
HVAC engineers and installers
Insulation suppliers and installers
Intellectual Property solicitors
Low carbon business advisors
R&D Tax credit advisors
Renewable energy installers
Sustainability consultants

5.2 Business, technology, and social innovation networks

Oxfordshire has a strong array of networks that connect clusters and individual organisations. They excel at bringing together like-minded people with a common goal and facilitate networking and collaboration. While their impact can be difficult to quantify, the importance of Oxfordshire's networks cannot be understated: they provide the lifeblood for our world-leading innovation ecosystem. Networks provide continuity beyond individual project lifespans, help to signpost, communicate and share learnings amongst a wide range of stakeholders and the broader public. This is particularly true for innovation in environment and sustainability, which has been driven in Oxfordshire by strong networks such as the Community Action Group (CAG) network, Low Carbon Hub CIC, Low Carbon Oxford,[70] Good Food Oxford, and Oxfordshire Greentech.

Low Carbon Hub is a social enterprise with a long history of establishing and running innovative community energy projects and cross-sector collaborations (see case study in this chapter). It was a founding member of Low Carbon Oxford and commissioned the 2014 Low Carbon Economy report. Low Carbon Hub further incubated Good Food Oxford to its launch in 2013, had a lead role in developing the bid for Project LEO, and is the largest investor in the project after SSEN. Low Carbon Hub CIC has a network of 35 community group shareholders, which represents nearly half of the county's low-carbon groups. It also developed the OxFutures I partnership project funded by Intelligent Energy Europe 2012–2016 and supported by the County and City councils, and developed the bid and led the consortium for the OxFutures II ERDF-funded project which led to the formation of Oxfordshire Greentech (see case study in Chapter 7).

Working closely with academic institutions, the public sector and community groups, Low Carbon Hub is at the heart of Oxfordshire's sustainability ecosystem.

Oxfordshire Greentech was launched by Bioregional, Cherwell District Council, and Cambridge Cleantech in 2019, aiming to facilitate the transition to a low-carbon economy by putting on workshops, networking and expert-led knowledge-transfer events and providing funding opportunities. Members, which include businesses in the low carbon sector, as well as those adapting their business models in line with net-zero, benefit from the opportunity to showcase their sustainability credentials for a wide audience. Oxfordshire Greentech have recently partnered with OxLEP to launch a new innovation competition called Energy Pathfinders 2050, aiming to find and showcase Oxfordshire's top 10 most innovative energy projects at a regional, national, and even international level. This will help draw investment for innovative projects into the region and give businesses and projects much needed funding to develop and scale-up.

Several business and technology parks also have their own onsite networks and support systems, such as Harwell Green Club based on the Harwell Campus, which is a forum for people on and off campus who share an interest in a zero-carbon future that hosts speakers with specialist knowledge of an area of interest for the group.

70 This has now been superseded by the Zero Carbon Oxford Partnership.

The strength of Oxfordshire's community action scene is also a crucial component of the county's innovation ecosystem. The Community Action Group (CAG) network comprises over 80 groups from around the county, covering issues such as waste, transport, food, energy, biodiversity and social justice. CAG was established and has been funded by Oxfordshire County Council since 2001, supporting their members with capacity-building, fundraising, training and development. In 2018–2019 the network prevented 82 tonnes of waste from going to landfill, saved 62,323 kWh of energy, and avoided 191 tCO_2.[71] The CAG groups reach 80,000 people and contribute 50,000 volunteer hours to the county per year. It is the largest network of its kind in the UK.

In 2021, Oxford City Council launched the Zero Carbon Oxford Partnership. Building on experiences of running Low Carbon Oxford, 21 leaders from the city's universities, institutions, and large businesses have been invited to sign the Zero Carbon Oxford Charter marking their support for achieving net-zero carbon emissions as a city by 2040. With emphasis on collaborative working, the City Council intend to set up 'sprint groups' focused on transport; energy; creating consortium bids for funding; joint purchasing and procurement; and green-lobbying.

Collaboration underpins the success of Oxfordshire's innovation ecosystem – and this is notable from the reach and achievements of Oxfordshire's networks. Besides these, Oxfordshire boasts a strong informal network of experts, business leaders and community leaders which help to keep sustainability high up on the local agenda and raise awareness amongst the public. Evidence for this can be seen in the membership of the steering group for the Oxfordshire Energy Strategy,[20] and the large numbers of attendees at workshops and events such as One Planet Living Oxfordshire's visioning workshop,[72] and the Oxford Energy Network's Colloquia series.

Photo: Bridge Street Community Garden, Banbury

71 CAG Oxfordshire (2019) Annual Report.

72 One Planet Living Oxfordshire our shared vision workshop.

Photo: Adriano Figueiredo

Case Study: Low Carbon Hub

Spun out of climate change action groups in West Oxford in 2011, the Low Carbon Hub now has a portfolio of 47 renewable energy projects.

Their aim is to prove that we can meet our energy needs in a way that's good for people and good for the planet. They develop community-owned renewable energy installations across Oxfordshire that not only produce clean energy but also generate income to reinvest in further carbon cutting projects. They support energy efficiency projects and provide funding and support to other community energy schemes.

Powering Up – Shifting to renewable energy generation: Managing 47 renewable energy projects generating 4.5 GWh of electricity per year, enough to save 1,343 tonnes of CO_2. They also support community energy projects offering expertise and grant funding.

Powering Down – The Low Carbon Hub want to create incentives making it easy and cost-effective to improve energy efficiency. This includes increasing retrofits for homes and businesses, and they launched Cosy Homes Oxfordshire and Energy Solutions Oxfordshire to help accelerate energy efficiency in these sectors.

Innovation – A partner on Project LEO working closely with the Distribution Network Operator, researchers and digital platform developers, Low Carbon Hub are leading the charge for developing a smart local energy system, empowering communities and delivering energy justice.

£7.3 million has been invested in Low Carbon Hub, from more than 1,300 investors.

5.3 Living Labs

5.3.1 The concept of living labs

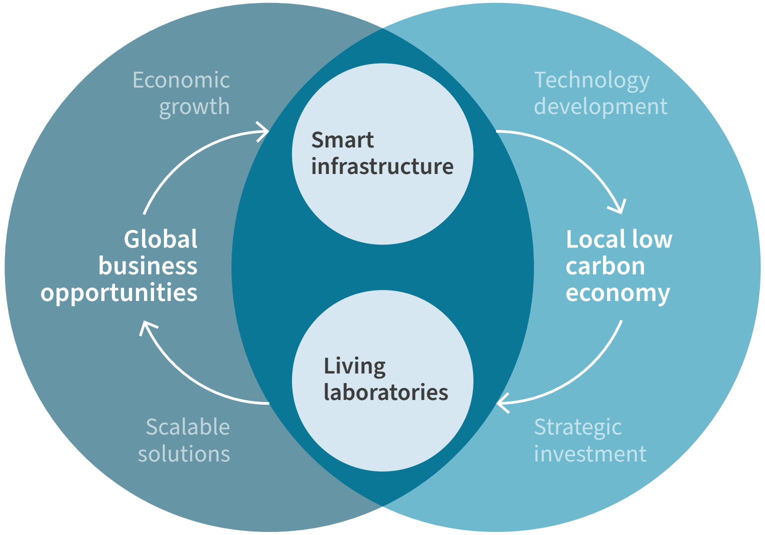
The 2014 Low Carbon Economy report proposed Living Labs as a model for overcoming barriers to innovation and growth, based on collaborative working among and between sectors, and operating at several scales. Living Labs are place-based testbeds, smart living pilots, using emerging technologies to provide proof of concept in order to scale up and scale up and roll out in other locations.[73] In the context of the low-carbon economy, Living Labs are crucial innovation models, going beyond business networks and technology clusters to facilitate large-scale place-based experimentation to trial the systems, partnerships and technologies needed to enable the transition to a low-carbon economy.[74] The European Network of Living Labs (ENoLL) brings together 150+ active Living Labs members worldwide, seeking to create an innovation friendly environment in Europe. Living Oxford (Living Oxfordshire CIC), an umbrella organisation and network for Living Lab activities, projects, and places within Oxfordshire, applied for membership in November 2020.

Since 2014, many other projects in Oxfordshire have built on this Living Lab approach and have progressed, providing useful learning and enabling better understanding of the county's innovation ecosystem. Especially important are the monitoring and evaluation aspects which lead to honest reflections and learning about what does and does not work, as well as engagement with various stakeholders, and avoiding sole reliance on technological solutions.

73 Voytenko, Y., McCormick, K., Evans, J., Schliwa, G., 2015. Exploring urban living labs for sustainability and low carbon cities in Europe. *Journal of Cleaner Production*.

74 Bulkeley, H., Marvin, S., Palgan, Y.V., McCormick, K., Breitfuss-Loidl, M., Mai, L., von Wirth, T., Frantzeskaki, N., 2018. Urban living laboratories: Conducting the experimental city? European Urban and Regional Studies.

Figure 5.3: Living laboratories as a driver of Oxfordshire's economy



Though there are varying definitions of what constitutes a Living Lab,[50] Voytenkoa et al (2016) outline 5 criteria for identifying Living Labs in accordance with the above description:

- **Geographically-embedded** – Living Labs are situated in a geographical area. They may use virtual resources, but they are predominantly focused on real-world application. The geographical area is normally clearly defined and has a manageable scale.
- **Experimentation and learning** – Living Labs test new technologies, ideas, practices, business models and policies in highly visible ways, which can prompt radical social and technical transformation.
- **Participation and user involvement** – Living Labs use participation and co-design with stakeholders, including end-users, accommodating the background and interests of different stakeholder groups. They represent research and innovation processes within a public-private-people partnership.
- **Leadership and ownership** – For Living Labs, skilful leadership is required to find a balance between steering and controlling. Those leading the Living Lab must cultivate openness to new ideas and different stakeholders, as well as having determination to see an idea through to its conclusion.
- **Evaluation and feedback** – Living Labs not only measure actions and outcomes, but use the lessons learned to refine, improve, and design the next round of actions. Openness and honesty about disappointing results is part of the process.49

Due to their scale and aims, Living Labs require different forms of innovation – not merely those that are technological – to excel. What makes them appropriate for the scale of change needed is that they use both:

- '**Science and technology-based innovation**' (STI),[75] which tends to exploit specific knowledge bases (mainly technical and analytical) and is the realm of much research & development (R&D) funding. STI is typically most relevant for earlier technology readiness levels.[76]
- '**Doing, using, interacting**' (DUI) innovation, which makes intensive use of experience and interaction through learning-by-doing, by-using and by-interacting. The knowledge and value created here comes from the combination of people and resources and can usefully be applied for later technology readiness levels.

The importance of technology deployment, real-world testing, and engagement – beyond just research and development – make for an effective collaboration.

75 Parrilli M. D. & Radicic D. (2021), STI and DUI innovation modes in micro-, small-, medium- and large-sized firms: distinctive patterns across Europe and the U.S. European Planning Studies.

76 European Commission (2014), Horizon 2020: Work Programme 2014–2015.

5.3.2 A strategy for Living Labs

Clean growth is a core component of Oxfordshire's Local Industrial Strategy, and OxLEP highlights the potential to build on the Living Labs concept by developing a framework of underpinning principles. These are intended to support the roll out of programmes, data sharing across potential locations and ethical requirements for dealing with real households and businesses.

Supporting these principles is Living Oxford,[77] set up to be an umbrella organisation and network for Living Lab activities, projects, and places within Oxfordshire to enable sharing of experience and learnings, from innovation at a community level across all sectors. Its founding members represent business, research, and public sectors: Oxfordshire County Council, Oxford City Council, West Oxfordshire District Council, SMART Oxford, University of Oxford, Oxford Brookes University, RACE (UKAEA), Harwell Science & Technology, The Hill, MobOx, 42, The Zeta Group, Ocado, EDF and Siemens. Using a Living Lab approach, the consortium leverages and connects people, places, organisations, and projects to deliver better solutions to real world challenges. As an example, it will be delivering The Future of Hydrogen Roadmap for the County Council, a white paper for transformation of energy across local authority-related operations and services to achieve the net-zero targets from the viewpoint of a hydrogen economy.

77 The trading name for Living Oxfordshire CIC.

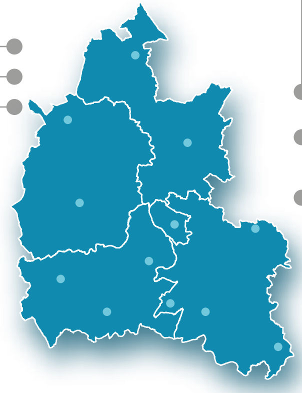
5.3.3 Low Carbon innovation projects

Oxfordshire has an extensive array of low carbon innovation projects, focused on autonomous and low-carbon mobility, renewable energy, and new housing developments. Many of these projects meet the definition of Living Labs described above, involving private, public, and academic institutions, and featuring innovative technology usage in real-world situations with user testing, monitoring and evaluation. Figure 5.4 provides a snapshot of some of the major low carbon innovation projects in Oxfordshire.

The unique value of these projects is their whole-systems approach to low carbon innovation. Not only do they involve developing, trialling and deploying technological solutions, but they combine social and business-model innovation too. This is seen in Park and Charge's aim to connect communities without access to home charging to EV charging facilities with dynamic billing rates; and Energy Superhub Oxford's use of demand side flexibility to deliver renewable heating at a lower cost to Oxford residents. The inclusion of diverse individuals and communities is essential for ensuring a just transition, and several of the projects underway in Oxfordshire are addressing issues of equity and fairness.

Figure 5.4: Oxfordshire's major low carbon innovation projects

Oxfordshire's major low carbon innovation projects



V2go
- Arrival
- CleanCar.io
- EDF Energy
- EO Charging
- Oxfordshire County Council
- Oxford University
- Upside Energy

OxFutures
- Bioregional
- Cherwell District Council
- Low Carbon Hub
- Oxford City Council
- Oxford Brookes University
- University of Oxford

Elmsbrook Bicester
- A2Dominion
- Arcadis
- Barton Wilmore
- Crest Nicholson
- Cherwell District Council
- Farrells
- PRP

Go Ultra Low Oxford
- Centre on Innovation and Energy Demand
- Co-Wheels
- ecomotion
- ENSTO
- eVolt
- Low Carbon Oxford
- Oxford City Council
- Oxfordshire County Council
- Ubitricity
- University of Oxford
- Zeta

Energy Solutions Oxfordshire
- Low Carbon Hub
- Environmental Information Exchange (Oxford Brookes)

Endeavour
- BSI
- DG Cities
- Immense
- Oxbotica
- Oxfordshire County Council
- TRL

Cosy Homes Oxfordshire
- Low Carbon Hub
- National Energy Foundation
- RetrofitWorks

Energy Superhub Oxford
- Habitat Energy
- Invinity
- Kensa Contracting
- Oxford City Council
- Pivot Power
- University of Oxford

Green Ammonia Demonstrator
- Cardiff University
- Oxford University
- Rutherford Appleton Laboratories
- Siemens
- STFC

Garden Village Oxfordshire
- Homes England
- Grosvenor
- Oxfordshire County Council
- West Oxfordshire District Council

Local Energy Oxfordshire
- EDF Energy
- Low Carbon Hub
- Nuuve
- Origami
- Oxford Brookes
- Oxfordshire County Council
- Piclo
- SSEN
- University of Oxford

Omnicav
- Admiral
- Aimsun
- Arcadis
- Arrival
- Latent Logic
- Ordnance Survey
- Oxfordshire County Council
- UK Atomic Energy Authority
- WMG
- XPI Simulation

Connected Autonomous Vehicles
- Air.Car
- DRIVEN
- MaaS:CAV
- MCTEE (Millbrook-Culham Test and Evaluation Environment) project
- MULTICAV
- PAVE (People in Autonomous Vehicles in Urban Environments)

Park & Charge Oxfordshire
- Oxfordshire County Council
- SSE
- University of Oxford
- [ui!]uk
- Zeta Specialist Lighting Ltd

Hosted by:
- Cherwell District Council
- West Oxfordshire District Council
- South Oxfordshire District Council

5.4 Showcasing private sector innovation

Oxfordshire has a strong and innovative private sector, developing products and services aiding Oxfordshire – and the world – to transition to a low-carbon economy. Building on our 2014 report on the low-carbon economy, Professor Douglas Crawford-Brown estimated there were at least 1,200 businesses in Oxfordshire's Low Carbon and Environmental Goods and Services (LCEGS) sector.[78] Growing at a faster rate than other sectors, he estimated an average 4.5% LCEGS growth per year between 2015 to 2018. In this report we do not attempt to update these figures, as quantifying the LCEG sector is becoming increasingly difficult,[79] and our focus is now on transitioning the whole economy to zero carbon activity. Nonetheless, this section highlights those green businesses and initiatives driving clean growth in the county. With so much activity and new companies emerging each month, this is a rapidly evolving landscape. For an up-to-date list of low carbon businesses in Oxfordshire, refer to Greentech's membership[80] and Advanced Oxford's low carbon and environment business directory.[81]

78 Crawford-Brown (2018), Materials for Oxfordshire Greentech.

79 Bishop, P., Brand, S., 2013. Measuring the low carbon economy at the local level: A hybrid approach. Local Economy 28, 416–428.

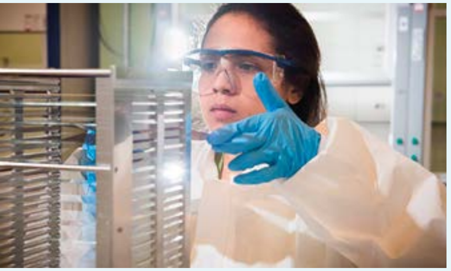
80 Oxfordshire Greentech, current membership, January 2021.

81 Advanced Oxford Low Carbon and Environment Business Directory.

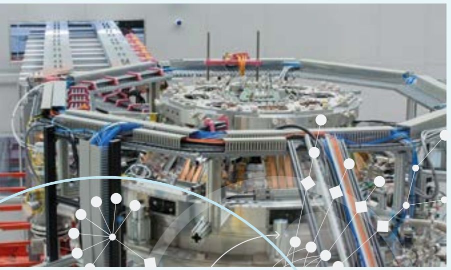
Photo: Brendan Doody

Cutting edge technologies with global impact potential

Oxfordshire is home to several businesses developing cutting-edge technologies with potential for exporting around the world to accelerate the transition to zero carbon. These include:



Oxford PV – The Perovskite CompanyTM, is a world leader in the field of perovskite solar cells. Their solar cell design extends the capabilities of current silicon cells which convert around 20 to 25% of light into energy, by adding an additional layer that absorbs photons from a wider portion of the light spectrum. Oxford PV have increased this efficiency to over 29% already, with further potential in the coming years. The Oxford University spin-out are in the process of scaling up production and are expected to be the first company to sell the next generation solar cells to the public from 2022.



Tokamak Energy grew out of Culham Laboratory, the world's leading centre for magnetic fusion energy research, with aims to advance the development of energy production by the process of fusion, through using devices that combine plasma in a magnetic field along with superconductors. They are now valued at £208m, and in January 2020 raised £67m from new and existing investors to fund the next phase of its strategy to produce grid connected fusion power by 2030

Yasa Motors, a spin out company from Oxford University are the world's leading manufacturers of axial-flux electric motors and controllers for hybrid and pure electric vehicles. In 2019 they secured £18m from Oxford Sciences Innovation and other VC investors for their next stage of rapid growth. This followed YASA's announcement in mid-2019 that a luxury hybrid electric car now in series production is powered by a custom YASA motor.

Social enterprises leading the just transition

The zero-carbon transition cannot be achieved purely through technological innovation, and there is a need for alternative business models to reduce waste and deliver social value.

Oxford-based social enterprise **Waste2Taste** is addressing the fourfold problem of food waste, unsustainable food choices, food poverty, and lack of education in cookery and nutrition, using surplus food from the Oxford Food Bank, Bucksum Farm and elsewhere in their vegetarian/vegan catering service and café. They provide mentoring and training opportunities as well as Cooking for Health and Wellbeing Workshops for the homeless, vulnerably housed, and families experiencing poverty.

Raw Workshop create furniture from used/recycled wood and 75% of their employees come from challenging backgrounds (e.g. mental health, addiction, homelessness, criminality). Raw Workshop have provided 25,000 hours of social impact, have reused 1,500 tonnes of wood, and saved 200,000 kgs of carbon. In 2020, as Oxford City Council decided to introduce temporarily pedestrianised zones to support outdoor eating as part of the COVID-19 recovery, Raw Workshop provided the wooden planters shutting off roadspace to traffic.

Case Study: Eco Business Centre, Elmsbrook

Partners: Cherwell District Council, Architype, Kier, A2Dominion and Town Square Spaces.

The Eco Business Centre is the first workspace in the UK to achieve the highest known building standard: Passivhaus Plus.

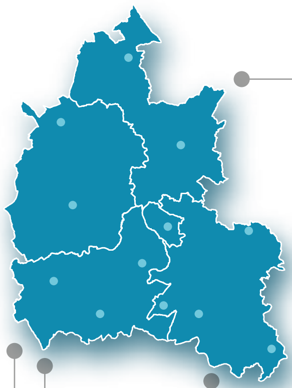
Building Materials include a concrete frame and timber panels, insulated with cellulose fibre insulation. Heat loss is minimised by having a double-door lobby, and external vertical timber fins create solar shading to reduce heat gains during summer.

Natural light and passive thermal regulation: The 3-storey design is fit-out with continuous insulation to minimise thermal bridges. A top-lit atrium with triple glazing reduces electricity use for lighting and provides thermal energy for passive heating.

Energy Generation: Solar Panels on the roof generate renewable electricity (almost as much as it consumes) and the heating source is the eco-village's district heating system.

Figure 5.5: Oxfordshire's leading low carbon businesses (not exhaustive)

Oxfordshire's low carbon ecosystem



Manufacturers and service providers

2Degrees
3Keel
Achilles
Aether
Anthesis
Bodle
Climate Care
Cryptocycle
Earthwatch Institute
Earthworm
Ecoveritas
Elementa Consulting
Ella's Kitchen
Ethex
Fusion Associates
Green TV
Greenteck Global
Mainer
Oxford Advanced Surfaces Ltd
Oxford Product Design
OxWash
QSA Partners
Seacourt
The Oxford Artisan Distillery
WRAP

Natural environment

Agricompas
Agspace
Aston Organics
Blenheim Estate
Bucks, Berks, Oxon Wildlife Trust
Centre for Ecology and Hydrology
Cultivate
Deep Planet AI
Earth Trust
East Hendred Farm
FarmED
Sandy Lane Farm
Sylva Foundation
Tolhurst Organics
Trust for Oxfordshire's Environment

Social impact

Aspire
Bicester Green
Climate Outreach
Common Ground
Legacy Events
Low Carbon Hub
Makespace
Oxford Wood Recycling
RAW Workshop
Restore
SESI Refill
Tap Social
The Old Fire Station
Turl Street Kitchen
Waste2Taste
Yellow Submarine

Energy transition

Adaptix
Aurora Energy
Brill Power
CCM Technologies
Darke & Taylor
Ecosync
Energy Pro
Enistic Energy Management Systems
Exeo Energy
First Light Fusion
Habitat Energy
Halliday Hydro
Joju Solar
Low Carbon Hub
Mixergy
ODQA Renewable Energy Technology
Oxford PV
Oxford Solar PV
Oxford Sustainable Fuels
Oxis Energy
Pivot Power
Poyry
Qdot
SunReign
The Zeta Group
Tokamak Energy
Velocys
Westmill Solar
ZapGo

Transport and mobility

Arrival
BMW Mini
Broken Spoke
Cycleland
EAV Solutions
Electrogenic
EV Car shop
Five AI
Intellicharge
MobOx
Nexeon
OxBotica
Oxford Bus Company
Pedal & Post
ProDrive
Saietta
Street Drone
Williams F1 Advanced Engineering
YASA Motors

Built environment

Beard Construction
Bioregional
Cosy Homes Oxfordshire
Duvas Technologies
Energy Services Oxfordshire
Envirosash
FAB-HAB Project
Green Axis
Green Unit
Greencore Construction
Jessop & Cook
LCMB Ltd
Limetec
Lucy Group
Rationel Windows
Ridge & Partners
Sow Space
Stewart Milne Timber Systems
Transition by Design

5.5 What is next for Oxfordshire?

Previous chapters have explained that in the coming decades Oxfordshire will undergo significant growth in housing, population, and employment. The low-carbon sector is thriving and is well positioned to drive job and wealth creation, while lessening negative impacts on the climate and environment. While Oxford City is at the geographical heart of the innovation ecosystem, low carbon businesses and innovation are proliferating throughout the county, in the existing science hubs in the south, new proposed science parks in the west, and along the Oxford-Cambridge Arc. The Local Industrial Strategy highlights opportunities in Bicester, for instance, proposing an Eco Zone and Hub which builds on the success of the Eco Business Centre and takes advantage of new infrastructure such as East-West Rail and housing developments.

As this chapter has demonstrated, Oxfordshire is at the forefront of low-carbon innovation, pioneering technologies and business models with global rollout potential. Its unique strengths in energy and transport innovation are underpinned not just by its world-class institutions and skilled workforce, but by the thriving networks which drive collaboration and knowledge exchange, maximising the benefit of investment and building momentum for a zero-carbon future. Within this low-carbon innovation ecosystem, low-carbon business leaders are multiplying and finding increasing demand for their products and services. The challenge in the coming decades is for all of Oxfordshire's economy to transition to low, and ultimately zero carbon activity. As Oxfordshire aims to become one of the world's top three innovation ecosystems, the low carbon sector has a crucial role to play.

Case Study: OxWash

OxWash uses electric cargo bikes for their customer laundry collection and delivery service, removing transport related emissions from their operations, with savings of 6,700 kgCO_2 per e-cargo bike/year. The laundry process used by OxWash firstly involves microfibre filtration which captures over 95% of fibres that are shed from clothes during washing, which prevents plastic pollution of water.

Water use is substantially reduced through the reclamation of water used in previous rinse cycled for subsequent washes, leading to a 60% and 70% saving in water consumption compared to conventional commercial and domestic washing machines respectively. There is an average water saving of 32 litres per 8kg wash.

6 Transport

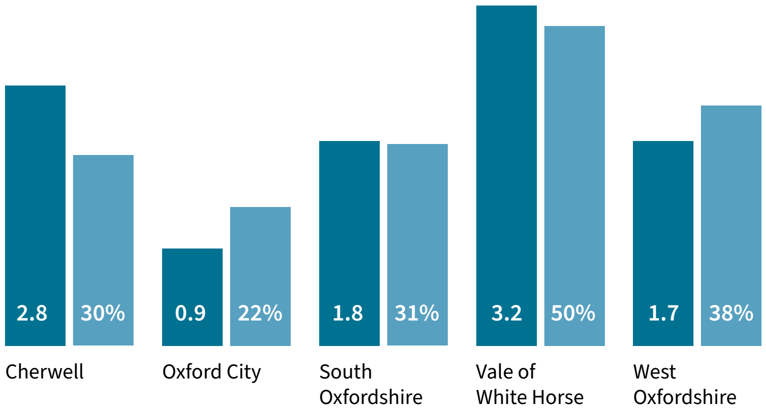
Chapter author: Hannah Budnitz

Photo: Viktor Keri on Unsplash

6.1 Introduction & context

The transport sector is responsible for a large and growing proportion of carbon emissions in the UK and Oxfordshire as other sectors, such as energy and industry, become cleaner. The share of carbon emissions from all road and rail transport increased from 38% to 46% between 2014 and 2018, mirroring the trend in the South East of England.

Figure 6.1: 2018 transport carbon emissions by Oxfordshire Districts, excluding motorway traffic



Oxfordshire, like the UK as a whole, has struggled to reduce emissions from transport, despite successes such as accelerated uptake of electric vehicles in the county and investment in cycling in Oxford City. One factor limiting progress on reducing transport emissions is that new housing has been concentrated outside Oxford City, where transport emissions per capita are higher than the national average, even once motorways are excluded. Whilst some of these extra emissions may be attributed to through-traffic on the strategic A-roads, particularly in Cherwell and the Vale, new housing developments in these areas are also more likely to be less dense and more car dependent than new housing in Oxford City.

This is evidenced by the Royal Town Planning Institute's research on the location of new housing development in Oxfordshire between 2012–2015, and 2015–2017.[82] Although the proportion of planning permission applications granted within built up areas increased from 19% to 77% between the two periods, the proportion within 10 km of an employment cluster decreased from 64% to 38%, driving up the need for longer distance commuting, which may not be possible by bus or bicycle. Less than 10% of permissions granted were located within 2 km of an existing railway station in the first period and less than 20% in the second period, meaning that rail is also not an option for many of those living in new housing developments. The tendency towards car-dependent development may be a result of the national priority to deliver large amounts of viable, new housing, even if at the expense of whether the location of that new housing would enable its future residents to travel sustainably to work and other destinations.

The relevance of planning and local place-making to reducing transport emissions has gained greater attention in the last year, as the global pandemic has forced residents to access essential goods and services close to home. Interactions between urban form and travel behaviour are complex, and assumptions that population and housing growth will lead to traffic growth must be challenged. Drastic emissions reductions cannot be achieved through a transition to electric vehicles alone, as even the most optimistic pathways towards adoption would still require significant demand reduction to meet emissions targets.[83] The key components of pathways to decarbonise transport are often described in terms of 'Avoid, Shift, Improve'. Switching to electric is an example of 'Improve', but it does nothing to reduce congestion, which requires measures that 'Avoid' travel. Nor does it increase footfall on local high streets, as a 'Shift' to local, active travel might encourage.

82 RTPI (2016), Location of New Development.

83 CREDS (2020), Decarbonising Transport: Getting carbon ambition right.

Therefore, Oxfordshire County Council's transport strategy and plans, which are currently being updated and refreshed, recognise the importance of better public transport and active travel connections and infrastructure, controlling and charging for parking, and supporting digital connectivity that reduces the need to travel, as well as encouraging the uptake of low and zero emissions vehicles.[84] Integrated policy measures and bold action on all these fronts will be required to reach zero carbon emissions from transport and achieve the vision of sustainable, resilient, healthy communities and a world-leading, innovative economy.[85]

6.2 Where are we now?

Oxfordshire County Council, its Districts, the Universities, and the private sector in Oxfordshire all have strong track records in promoting and attracting investment in sustainable and low carbon transport and innovation. However, this investment and innovation has not thus far resulted in falling carbon emissions from the transport sector within the County, perhaps because implementation has rarely been at a large enough scale to counteract population and traffic growth. Whilst some emissions will be outside the County's control, such as through-traffic on the trunk road network, many public and private sector stakeholders in the county recognise that a step change in ambition in tackling local emissions is required.

84 Oxfordshire County Council (2019), Connecting Oxfordshire.

85 Oxfordshire County Council (2020), LTCP Vision Document.

6.2.1 Summary statistics

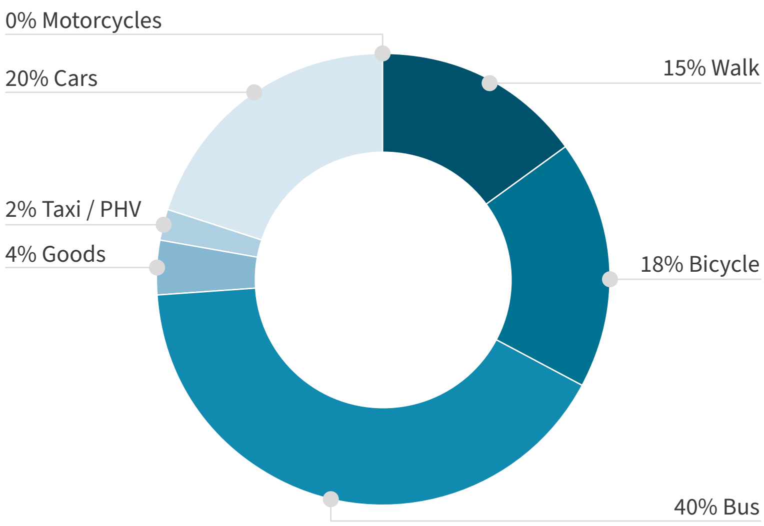
Oxfordshire County Council published its 4th Local Transport Plan in 2016, but they are now developing their 5th Local Transport and Connectivity Plan (LTCP), partially in response to the declaration of a climate emergency and the lack of progress in reducing road traffic emissions. As they began updating their strategy in 2019 by reviewing the situation in Oxford City, they reported that daily traffic flows across the ring road had increased by 5% since 2012, with an average of 45,000 vehicles on the City's roads every morning rush hour.[86] Bus journeys appear to have peaked in Oxfordshire in 2013/14 at 43.2m, with 40.8m recorded in 2019/20, although Oxfordshire residents take more bus journeys per capita than the average for residents of the South East at 59 versus 36.[87] Railway stations in Oxfordshire saw increases in passengers entering and exiting stations in the county year on year, with 21.7m in 2019/20,[88] partially due to the new train line that opened between North Oxford and Bicester. However, there is great uncertainty over the impact of the COVID-19 on rail travel longer term (see section 6.3).

86 Oxfordshire County Council (2019), Connecting Oxfordshire.

87 DfT (2020), Local bus passenger journeys.

88 Office of Rail and Road (2020), Estimates of station usage.

Figure 6.2: Mode split of journey between 07:30 and 09:30 into Oxford City Centre



Cycling across the inner and outer cordons of Oxford City increased by 18% and 15% respectively between 2007/09 and 2016/18, with steeper increases since 2012/14 across the inner cordon.[89] However, whilst cycling is growing in popularity in the City, this trend is not occurring in other towns in Oxfordshire. Whereas almost four thousand people cycle into Oxford city centre in the morning peak, it is estimated that there are no more than three thousand trips per day by bicycle throughout Bicester.[90] And whilst there are an estimated 18,000 pedestrian trips per day in Bicester, this compares to almost 24 thousand pedestrian trips into Oxford's city centre each day. Bicester and the other market towns in Oxfordshire do have the potential to support more active travel, but they are starting from a much lower baseline than Oxford City in terms of infrastructure as well as trips.

Surveys also suggest that 35% of pedestrian trips in Oxford City are walking for a purpose other than leisure, compared to only 15% of pedestrian trips in other Oxfordshire districts. Thus, whilst the modal split from the 2019 inner cordon count shown in Figure 6.2 is encouraging, Oxford City is an outlier. This is not surprising, and the County Council recognises that rural areas may need a different approach. In any case, further progress will be needed even in Oxford City to reach zero by 2050, and reducing carbon emissions from transport in the rest of Oxfordshire, including from travel between towns throughout the outlying districts and Oxford City, will be much more challenging.

89 Oxfordshire County Council (2020), Oxford LCWIP v192001. Approved by Cabinet 190317

90 Oxfordshire County Council (2020), Bicester LCWIP Draft v070920.

6.2.2 Transport and connectivity Investment and Policy

Although carbon emissions from the transport sector have been growing proportionately, there has been substantial policy support and investment in sustainable transport and connectivity in Oxfordshire in the last six years. Concerns have been mounting about dangerous levels of air pollution, and Oxford City introduced the UK's third Low Emission Zone, following London and Norwich. This was aimed at buses, so when bus operators upgraded their fleets, it had an immediate impact on air pollution: in 2017–2018, NO2 emissions fell by 22.7%.[91] However, Oxford City is not the only place to suffer from local air pollution, with Air Quality Management Areas across Oxfordshire. For example, Hennef Way, Banbury recorded the fourth highest levels of NOx in the UK outside London. Furthermore, CO_2 emissions from transport only fell by 1.9% between 2008 and 2018, and were rising between 2014 and 2017, despite the target of a 35% reduction between 2005 and 2020 as set out in the Low Emissions Strategy.

A selection of other sustainable transport and connectivity projects completed during this period include:

- Installed superfast broadband to almost 80,000 premises since 2014.[92]
- £20k to paint three new 5 km routes for pedestrians, joggers and runners, as part of an approximately £1 million pound investment in Bicester Healthy New Town.[93]
- £1.6 million remodelling the Plain Roundabout in Oxford as part of the successful Cycle City Ambition Fund award of £4.2 million,[94] and millions more through other funds invested in cycling schemes as mentioned in chapter 3.
- £2.3 million to upgrade 115 buses with technology to reduce emissions, particularly of nitrogen dioxide, and convert five sightseeing buses to fully electric operation.[95]
- Upgrade of the rail link between Oxford and Bicester via the new Oxford Parkway station offering passenger services to London Marylebone.[96]
- Over £800,000 to trial approximately 30 fast on-street electric vehicle chargers using different technologies, installed as part of Go Ultra Low Oxford.[97]
- Private sector investment in clean, smart, and innovative automotive technology, including Arrival, which is one of the pre-eminent companies manufacturing electric light goods vehicles in the UK, and Oxbotica, who are leading complex trials of autonomous vehicles on the public highway.

91 Oxford Mail (2019), Clean Air Day: Oxford pollution progress stalls.

92 Digital Infrastructure Programme, Progress so far.

93 Cherwell District Council (2019), Bicester Healthy New Town Case Study.

94 Cycle City Ambition Programme: Interim Report, 2018.

95 Oxford City Council (2019), City Council secures further £700,000 to upgrade buses and cut air pollution.

96 Network Rail, How the East West Rail project will make travel across Britain easier.

97 Hampton, S, Schwanen, T, Doody, B. (2019). Go Ultra Low Oxford, monitoring and evaluation of Phase One, Final Report.

EAV fleet for dpd.

Case Study: Automotive innovation

- First local authority in the UK to have a team dedicated to CAV
- YASA technology powers Europe's largest zero-emissions aircraft
- Modular, zero-emissions vehicles assembled by robots alone

Building on its well-established automotive sector with the BMW Mini plant, firms in Oxfordshire are at the cutting edge of innovation in low-carbon mobility.

ARRIVAL

Arrival is revolutionising the electromotive industry, designing and manufacturing vehicles for commercial and public transport use. Their 'Microfactories' are designed so that modular zero-emissions vehicles can be assembled by robots alone, with all materials, components, and software developed in-house. Arrival's proprietary composite materials are 50% lighter than steel, while being durable and resistant to damage.

eav

EAV Transport Solutions are a frontrunner in last-mile transport solutions, having created a pedal and battery-powered hybrid cargo vehicle that they say is 'designed down from a van, not up from a bike.' EAV use natural flax fibre composites so that bodywork is bio-recyclable, and manufacture or locally source materials where possible, with the bodywork and chassis made on site, thereby reducing carbon footprint.

oxbotica

Oxfordshire is also pioneering autonomous vehicle technology, a concept that could lead to improved road safety, greater independence (especially for elderly people and those with disabilities), and reduced congestion and emissions. Tests of six autonomous vehicles in Oxford have now begun as part of a government-backed research scheme named 'Project Endeavour'. Led by Oxbotica, this initiative aims to demonstrate 'level four' vehicle autonomy, which means the car can drive itself without the need for a driver. Vital pioneering schemes such as DRIVEN, MultiCAV, CAVL4R and OmniCAV are also underway and the county council is the first local authority in the UK to have its own team dedicated to Connected Autonomous Vehicles (CAV)

YASA

YASA's revolutionary compact, lightweight and powerful electric motors and controllers enable vehicle hybridization and electrification – especially when there is limited powertrain space. The YASA (Yokeless And Segmented Armature) motor topology also significantly reduces manufacturing complexity, making the motors ideally suited to automated volume production. YASA has gone on to power Europe's largest zero-emissions aircraft, and an YASA electric motor powers Ferrari's first hybrid series production sports car, the SF90 Stradale.

Road improvements have also been progressed over the last six years, as part of new developments planned in Oxfordshire's Housing and Growth Deal and the Oxfordshire Infrastructure Strategy (OxIS) published in 2017. Some of these have included substantial elements for sustainable transport, such as the bus lane along the A40 or the pedestrian and cycle facilities at Culham, but some have been more traditional improvements to road capacity, such as the Lodge Hill Interchange project near Abingdon, and works at Featherbed Lane and Steventon. Road building, particularly to support new developments which may then be more car-dependent, is short-sighted when it has become clear that the transition to zero carbon vehicle technologies is insufficient to reach net-zero within the timescales set by the Paris Agreement or most local governments.[98] Local policy-makers recognise this, and, as climate policy was strengthened over the past two years, the decision was made to revisit the Infrastructure Strategy. In developing the fifth LTCP and revising OXIS, there is consensus around seeking opportunities to accelerate the decarbonisation of transport.

6.3 Challenges and uncertainty around future opportunities

Oxfordshire's 2017 Infrastructure Strategy is under review three years after its publication, offering policy-makers an opportunity to reconsider the challenges of accommodating population and employment growth whilst accelerating plans to reduce carbon emissions, particularly from transport. Its review is also a reminder of the challenges of divided governance structures, where funding sources, statutory responsibilities and policy priorities do not always align.

98 CREDS (2020), Decarbonising transport: The role of land use, localisation and accessibility.

The five district-level local authorities in Oxfordshire are responsible for producing Local Plans with sites allocated for new development and land for future housing, the amount of which is set by a centralised formula, but they have little authority over transport. Meanwhile, the County Council is responsible for transport planning and local transport infrastructure, preparing and updating the LTCP. Quasi-governmental, national bodies such as Highways England and Network Rail have oversight of strategic road and railway infrastructure, and thus major infrastructure projects like new roads or railway electrification. County and District Councils are increasingly able to influence strategic transport network planning as a result of their collaboration on the Oxfordshire Growth Board, but there is a top-down approach to nationally significant infrastructure, with final decisions made by Government Ministers. Collaboration is also the primary tool available to the Districts and County on matters such as cross-border housing provision and Air Quality Management Plans, such that without consensus on an approach, the lack of stable, strategic direction from central government can undermine rather than encourage action.

Oxfordshire also lies at the western end of the area known as England's Economic Heartland (EEH), an area that has developed a strategic partnership between 11 Local Authorities from Swindon to Cambridgeshire. EEH is a Sub-national Transport Body, recognised by the Department for Transport and other public and private sector bodies responsible for delivering transport. As such, it is at the heart of not only one of the largest and growing sub-regional economies in England, but also of the debate around how transport can support growth and simultaneously decarbonise. An east to west railway line and an expressway were proposed as solutions. Phase 1 of the Western section of East West Rail – Oxford to Bicester – is already complete as described in section 6.2.2, and the next section to Bletchley is under construction.

Neither the Transport Strategy published by EEH, nor their submission to government the year before on investment priorities for the Major Road Network in the area include the East West Expressway proposal.[99] One reason for the exclusion is because EEH and many of its constituent authorities are determined to reduce carbon emissions from transport and are aware of the increasing evidence that new roads or increasing the capacity of existing strategic roads will increase carbon emissions from transport. Even assuming a rapid transition to electric cars, capital road investment increases carbon emissions from three main sources, as is clearly described in a recent report evaluating *The carbon impact of the national roads programme* (Highways England's second Road Investment Strategy or RIS2):

- embodied carbon in the raw materials used to build the infrastructure;
- increased speeds as these roads can handle faster traffic flows; and
- induced traffic as longer-distance travel and more car-dependent development is encouraged by the increased road-based accessibility.[100]

The A34 between Newbury and Oxford is included in the approved RIS2 in order to explore "*opportunities to reduce congestion and improve safety*".[101]

99 England's Economic Heartland (2021), Transport strategy and Major road network.

100 Sloman and Hopkinson (2020), The carbon impact of the national roads programme.

101 Highways England, A34 improvements north and south of Oxford.

As some of this route was also part of the East West Expressway proposal, this project suggests that new road investment in Oxfordshire is not completely off the table, although the Transport Secretary officially cancelled plans for the East West Expressway in March 2021 after the Government committed to developing a spatial framework for the sub-region that would include revised transport policy.[102]

Meanwhile, EEH have recently commissioned multi-modal connectivity studies to look at all options, including digital connectivity, to further improve networks across the sub-region. The importance of investment in digital connectivity to support those behaviours which reduce travel and carbon emissions from transport has been highlighted by the COVID-19 pandemic, which has greatly accelerated trends towards online shopping and home working, the latter of which involves online interactions. The Office for National Statistics estimated that 47% of people in employment in the UK worked solely from home in April 2020.[103] Although this fell to about 20% in September when people returned to work in their greatest numbers during the pandemic,[104] this is still much higher than the 5% who worked solely from home in 2019 or even the larger proportion who regularly worked from home multiple days per week over the last decade.[105] Working from home could become permanent for many employees, especially as so many of those who first experienced working from home during the Spring lockdown said they would be interested in continuing to do so at least some of the time.[106] Co-working spaces near home offer a hybrid solution that was also growing in popularity prior to the pandemic.

102 DfT (2021), Oxford to Cambridge expressway project cancelled.

103 ONS (2020), Coronavirus and homeworking in the UK.

104 ONS (2020), Coronavirus and the latest indicators for the UK economy and society.

105 ONS (2019), Home working in the UK.

106 Kelly (2020), The work from home revolution is quickly gaining momentum.

For example, five new, dedicated facilities opened in Bicester in the past three years. Nonetheless, research indicates that working from or near home may not reduce car trips if car travel is required to access other activities and amenities.[107]

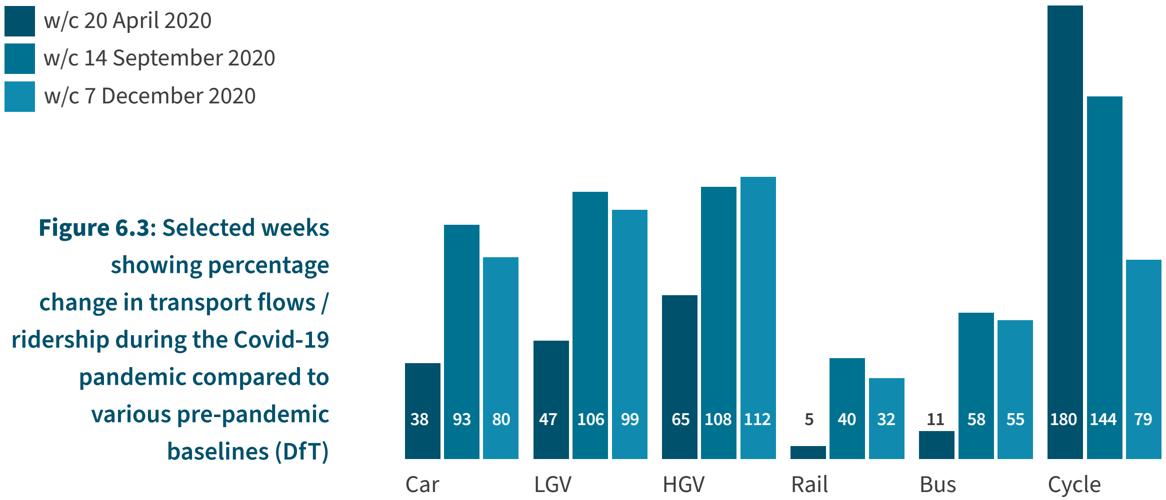


Figure 6.3: Selected weeks showing percentage change in transport flows / ridership during the Covid-19 pandemic compared to various pre-pandemic baselines (DfT)

Furthermore, for those who cannot work from home, the pandemic has undermined trust in public transport, which has regained only a fraction of the ridership it had in 2019, whilst car travel has rebounded much more.[108] With rail particularly affected, in part because many rail commuters have been working from home, this adds uncertainty to the strategic impact of a public transport approach for the sub-region based around the development of East West Rail and its links with existing mainline services.

107 Budnitz, H, Tranos, E, Chapman, L. (2020), A transition to working from home won't slash emissions unless we make car-free lifestyles viable. The Conversation.

108 DfT (2021), Transport use during the coronavirus (COVID-19) pandemic.

Oxfordshire also reported on the first phase of its Rail Corridor Study just before the pandemic, considering options for additional capacity to and through Oxford and the potential of reinstating the Cowley branch line. Although this study is now reaching the stage where an investment programme is being developed, it comes at a time of uncertainty rather than on the back of year on year increases in rail travel, as was the case in 2019. In comparison, bus travel has maintained a stronger customer base during the pandemic than rail services, despite passenger numbers previously having been on a downward trend. In Oxfordshire, buses are particularly important for travel on main routes into Oxford City, where there has been long-term investment in a Park and Ride network and low emission intra-urban buses, complemented by high charges for parking in the city centre. Oxfordshire is also preparing a business case to finalise provisionally agreed funding from central Government to become one of two All Electric Bus Towns in the UK, which will involve Oxford City, and potentially radial routes to other towns in the county.[109]

There is also uncertainty around the future trends for active travel. Walking and cycling became more popular during the first lockdown, with cycling trips almost doubling compared to the first week of March 2020, but this increase has not been sustained during the wet weather of Autumn and Winter, as car travel increased. It is also unclear how much travel over the spring and summer was for leisure or exercise, rather than utility, although the pandemic also highlighted the importance of access to nature for well-being and mental health. Heavy and light goods vehicular traffic have also returned to above pre-pandemic levels, as the popularity of ordering goods online for home delivery has been accelerated, and non-essential shops have increased their delivery services in order to remain open whilst their shopfronts were forced to close.

109 DfT (2021), Coventry and Oxford set to be UK's first all-electric bus cities.

The pandemic has demonstrated the scale of behaviour change that is possible, but also the uncertainty of longer-term shifts and impacts, which could either help or hinder the decarbonisation of transport. Interventions and investment are required to maintain and guide behavioural changes made during the pandemic and further transitions in connectivity and mobility, including electrification, in a way that will meet long-term policy goals. This is recognised in Oxfordshire, where the emergency reallocation of road space and other active travel measures funded during the pandemic, for example, are mostly intended to be permanent. Yet with so many uncertainties about the future and factors beyond local control, the journey to net-zero remains a challenge.

6.4 The journey to zero

The Transport Strategy[110] from EEH clearly sets out pathways towards decarbonising transport by 2050 or even 2040 if possible, whilst supporting the economic success of the region. They recognise that electrification of road and rail transport is only part of the solution, and that it will also be necessary:

- to build on the technological innovation the sub-region is known for to deliver more efficient and connected transport options, including shared, autonomous vehicles; and
- to reduce car trips through demand management and measures that make walking, cycling, shared and public transport the preferred options for local travel, with investment reflecting this road user hierarchy.

110 England's Economic Heartland (2021), Transport Strategy.

As part of the latter, there are proposals to invest in digital connectivity, and there is recognition that electrification and innovation must address emissions from freight transport as much as passenger transport. The emerging LTCP vision also aims to achieve 'a net-zero Oxford transport system... by reducing the need to travel, securing high quality gigabit connectivity, and by discouraging unnecessary individual private vehicle use through making active travel, public and shared transport the natural first choice'.[111] This vision fits well with the 'Avoid, Shift, Improve' framework discussed in the introduction to this chapter. The County and Districts in Oxfordshire are taking steps to set out their agenda for Shift and Improve by collaborating to formally approve documents such as the Electric Vehicle Infrastructure Strategy and the Local Cycling and Walking Infrastructure Plans, which set out policy priorities and commit to certain actions.

Avoid is more about demand management, and proposals are being progressed for a Zero Emissions Zone in Oxford City centre, with charges for all vehicles with tailpipe emissions,[112] and for a Workplace Parking Levy, traffic restrictions and bus priority in the 'Eastern Arc' of Oxford City.[113]

Other examples of committed plans to invest in infrastructure to support pathways towards decarbonising transport include:

- Almost £3million to improve and segregate cycle paths and widen pavements in Bicester and Witney, and install Low Traffic Neighbourhoods in Oxford City as part of the Department for Transport's Active Travel Emergency Fund.[114]

111 Oxfordshire County Council (2020), LTCP Vision Document.

112 Oxford City Council (2021), Zero Emissions Zone.

113 Oxfordshire County Council (2019), Connecting Oxfordshire.

114 Oxfordshire County Council (2021), Emergency Active Travel Fund, Phase 2.

- Bus priority and new park and ride services on the A40 between Eynsham and Oxford City.
- Private sector investment in micromobility schemes, including bicycles, e-bikes, e-scooters, and e-cargo bikes.[115]
- Over £5million to install fast electric vehicle charging hubs in two dozen public car parks throughout Oxfordshire in 2021 as part of the Park and Charge project funded by Innovate UK.[116]
- Continued roll out of Controlled Parking Zones to manage demand for parking throughout Oxfordshire and complement the Workplace Parking Levy.

The success of any decarbonisation pathway is dependent upon policies and regulations that are consistent with the climate emergency and net-zero declarations of the local authorities and other stakeholders in Oxfordshire, as well as active engagement with residents and businesses. For example, the consultation draft of the LTCP vision makes it clear that they recognise that different approaches may be required for more rural areas compared to the urban parts of the County, and that freight may need to be managed differently from passenger transport. Indeed, proposals for reducing emissions from freight range from alternative fuels, both electric and hydrogen, to alternative technologies, such as driverless convoys, to alternative business models, such as freight consolidation centres. Engagement will also be essential to overcome concerns around the safety of public transport and to take advantage of changes in commuting patterns to minimise operational costs on public transport.

However, demand for goods and travel is generated to enable people to participate in work and other activities, access amenities and services, as well as green space and nature, and interact with others. Thus, the ability to Avoid or Shift trips and mileage remains a function of land use planning, spatial strategy, and the density of housing and activity. To achieve a zero-carbon future, especially in light of the expected job, housing and population growth in Oxfordshire, planning for every new development, regeneration or change of use must aim for carbon neutrality in its transport impacts through careful location and design.[117] As discussed in Chapter 2, there has been some decoupling of growth and carbon emissions in Oxfordshire, but this has not yet resulted in falling emissions from transport.

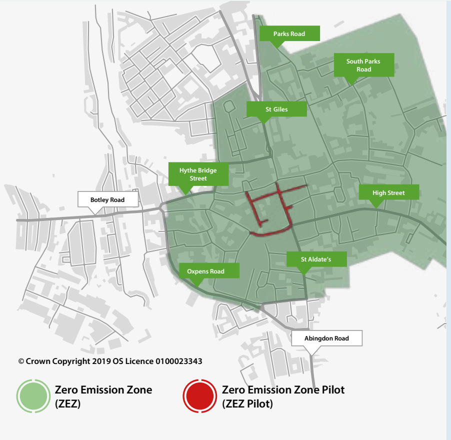
Ports and airports

Plans for decarbonising transport across the EEH sub-region also consider reducing emissions from travel between the sub-region and ports and airports, but do not directly include the emissions from aviation or shipping, nor how the demand from the sub-region's population for flying or for goods utilising the global supply chains might be reduced and mitigated. Emissions from these sources are often excluded from local net-zero pathways due to a lack of both data at a sub-national level, and limited local control over measures such as airport expansion. Therefore, they are also not included in our scenarios, but it is important to recognise that local people and businesses have a role in the emissions from these sub-sectors as well as from road and rail transport.

115 Pony.

116 www.parkandchargeoxfordshire.co.uk.

117 RTPI (2021), Net-zero Transport: the role of spatial planning and place-based solutions.



Case Study: Zero Emissions Zone (ZEZ), Oxford

Partners: Oxford City Council, Oxfordshire County Council

Oxford's Zero Emissions Zone (ZEZ) is set to be the first of its kind, acting as a regulatory driver to encourage the transition towards zero emissions transport and helping the city to tackle its air pollution, congestion, and improve quality of life for residents.

Vehicles entering the ZEZ will need to be 100% zero emission vehicles in order to avoid charges, with all other vehicles being charged between 7am and 7pm an initial £2–£10 per day, which will increase to £4–£20 per day by August 2025. Exemptions and discounts will be given to certain road users, and the councils are providing support to residents and businesses to adapt. Traders in the Covered Market are being supported by the City Council to receive deliveries through sustainable modes, including through EV charging points, purchasing several electric vans and cargo bikes, and installing additional storage space for goods. Pedestrianisation of the city centre will increase the city's vitality and air quality.

The rollout of the ZEZ will initially cover 8 main roads and will be expanded to cover the rest of the city centre in Spring 2022.

> **"2021 will be a landmark year in Oxford's journey to improve air quality and tackle the climate emergency... We know the impact that air pollution can have on people's health, and the ZEZ will help us make a difference both in Oxford and beyond." Councillor Tom Hayes, Oxford City Council**

In our scenarios we identify pathways to zero-carbon transport within Oxfordshire that all require a mixture of Avoid, Shift, and Improve, but the amount occurring in each varies depending upon whether the focus is on societal transformation, technological change or local leadership. For example, a societal transformation might expect more extensive avoidance of travel than other pathways, as the acceleration of telecommuting and online shopping and services is maintained post-pandemic. In contrast, a technological transformation would see more effort to improve the performance of road vehicles, including hydrogen fuel as well as electrification, and autonomous vehicles concentrated in the freight sector. Finally, Oxfordshire could apply its local innovative industries to encourage a shift away from private car ownership to fewer shared, electric, and even autonomous vehicles. Since all scenarios will require a minimum reduction in private car travel of around 15% through avoid and shift measures by 2050 to achieve net-zero,[118] any success in reducing car travel should also reduce the fleet of cars in the county relative to population, as is shown in the scenarios. The foundations and knowledge for the switch to less vehicle mileage per head, more efficient use of fewer vehicles, and the spread of zero-carbon technologies are all available in Oxfordshire. The next steps in setting out ambitious policy are underway, and ambitious action must follow.

118 Committee on Climate Change (2020), Sixth Carbon Budget: Sector Summary Surface Transport.

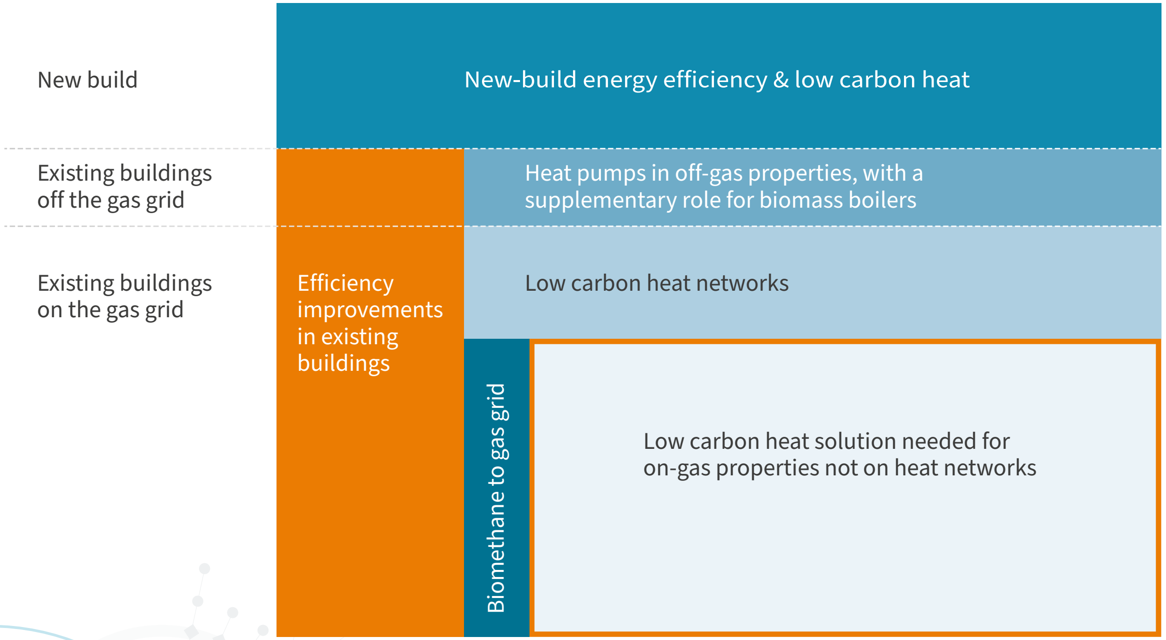
7 Energy efficiency and heating demand in buildings

Photo: Erik Mclean on Unsplash

7.1 Introduction

The decarbonisation of heat is a current ‘grand challenge’ in UK research and policy, reflecting the complexity of the topic and the fact there are many contingent questions and no clear right answers. The Committee on Climate Change summarised the challenge of heat decarbonisation graphically[104], highlighting several technical options that could contribute towards the overall goal, but with a large remaining unknown for heat in buildings that are currently on the gas grid (Figure 7.1).[119]

Figure 7.1: The buildings heating challenge and some partial solutions. The size of each block is roughly proportional to the scale of emissions reduction



119 Committee on Climate Change (2016), Next steps for UK heat policy.

The Committee on Climate Change has called for no new conventional gas boilers to be installed in buildings ahead of 2035 (phase-out dates range from 2025–2033 for different sub-sectors of the building stock).[120]

The challenge of decarbonising heat can be understood in terms of three interdependent elements: energy sources; system impacts, especially peak demand; and changes within buildings (reducing heat loss and installing new conversion technologies). These all have an impact on heat in buildings. The switch away from fossil fuels (gas, oil, LPG) will require new end-use conversion technologies within buildings, but also changes to buildings themselves to reduce heat loss and overall energy demand. There are several reasons for this. Firstly, peak demand for heat and electricity in the UK are both closely associated with residential demand. If residential heat demand is to be electrified, then the peak will increase, leading to greater cost and complexity in providing secure energy supply. Energy efficiency can significantly reduce the demand for heat, making the peak lower and the whole system more resilient. Secondly, the vast majority of residential heating systems will need different end-use technologies and changes in household practices around heating. Old, inefficient homes will in many cases need to be upgraded to be compatible with heat pumps by reducing heat loss and increasing the size of radiators. Thirdly, in addition to all the technical reasons, energy efficiency of homes has an important role to play in improving health and well-being (especially for the vulnerable and fuel poor). Finally, capital investment in energy efficiency can reduce costs – not just running costs for consumers, but also avoided infrastructure costs elsewhere in the energy system as a whole.

120 Committee on Climate Change (2020), The Sixth Carbon Budget: the UK’s path to net-zero.

Compared with housing, non-residential buildings are very varied in their functions, size and energy consumption patterns. Investments are needed in technology in non-residential buildings, and changes are also needed in building management and operation. Capital investments and management are both allied to decision-making in organisations, so it makes sense to focus on decision-making processes as the means of achieving changes in the non-residential sector that are in line with the zero-carbon transition.

Different approaches are needed for larger and smaller organisations, reflecting the relative formality of management structures and the available resources for decision-making. In all cases, decisions that align with net-zero carbon need to also reflect the strategic priorities of the firms themselves, which are typically nothing to do with energy or emissions. Expert and skilful advice services are needed to accompany organisations on the journey to zero-carbon, a process of engagement that can take several years. Finance will need to be part of the support package, but funding on its own is insufficient.

Achieving zero-carbon heating in the built environment will require coordination of policy-making and market transformation on a scale that has not yet been attempted.

A strong focus of recent debates has been on increased use of electricity or hydrogen (presumed to come from renewable sources) to replace the direct burning of fossil fuels (mostly gas, but also liquid and solid fuels).

There are many synergies and difficult trade-offs between the different blocks in Figure 7.1, so it makes sense to think of the heating challenge as a complex system in its own right. This can be shown by two brief examples. Firstly, the successful installation of heat pumps in existing homes will in many cases require upgrades to the home to make it compatible with the heat pump. The lower operating temperatures of a heat pump (when compared with a conventional boiler) mean that the system may need larger radiators (or under-floor heating) and insulation added to the building envelope. Heat pumps and building upgrades need to go hand in hand, otherwise there is a risk of poorly functioning technology getting a bad reputation, with poor energy performance accompanied by low customer satisfaction and loss of consumer confidence. Secondly, while heat networks can in theory provide efficiencies and economies of scale, it only makes sense to invest in the infrastructure of a heat network if demands for heat can be maintained or increased over several years. For large organisations (with multiple buildings in close proximity) or in large-scale new developments, it may be feasible to get a heat network up and running, provided there is a contract negotiated in advance covering energy (or energy services) over several years of operation. But in existing neighbourhoods, where property ownership is highly fragmented and consumers are able to switch energy supplier freely at short notice, setting up heat networks is normally too risky, messy and complex. Countries where heat networks are widespread in existing towns and cities often have governance arrangements in place where local authorities have stakes in effective local monopolies for providing heat (or heat as service). Consumers cannot switch to alternative heat systems where the municipal heat network is in operation.

The switch to electrification of heat (eg using heat pumps) would have implications for the energy system, not only in terms of peak energy demand, but also for energy storage and the effects on the gas industry of having stranded assets in the shape of under-used or obsolete pipes. An alternative to heat electrification is hydrogen in the existing gas grid, although there are still technical challenges around compatibility and safety. Hydrogen can be generated by two principal means: steam methane reformation (SMR), which uses natural gas (methane); or electrolysis of water. Hydrogen generation requires inputs of both electricity and a feedstock (methane or water), which means that hydrogen is relatively costly and inefficient to produce. However, hydrogen has the potential to make use of the existing gas grid, and would also be compatible with heating systems based on boilers. In our pathways to net-zero the uptake of hydrogen for heating is highest in Technology Transformation, because it is less disruptive to household practices and domestic heating supply chains than the heat pump alternative. Other uses of hydrogen are considered in chapter 8.

7.1.1 Demand for heat in Oxfordshire's buildings

Gas consumption for Oxfordshire in 2019 was a total of 5.3 TWh (not weather-corrected), the majority of which is demand for space and water heating in buildings.[121] Other end-use applications for gas are also included in the total figure (for example in industrial processes and for cooking). This total consumption came from gas sales related to 238,00 domestic and 3,000 non-domestic meters.

Biomass (e.g. wood burners) is now assumed to be a relatively small part of the future energy mix compared with earlier studies. This is partly because of concerns about indoor and outdoor air quality (ref), but also because it competes with land needed for other uses, and there will be other priorities than heating for the use of what limited biomass resource there is.[122]

Neighbourhood-scale approaches (e.g. heat networks) have the potential to make use of heat that would otherwise be wasted. For example, the Energy from Waste plant at Ardley could provide useful heat to nearby buildings in Bicester, although this idea has not yet been put into practice.

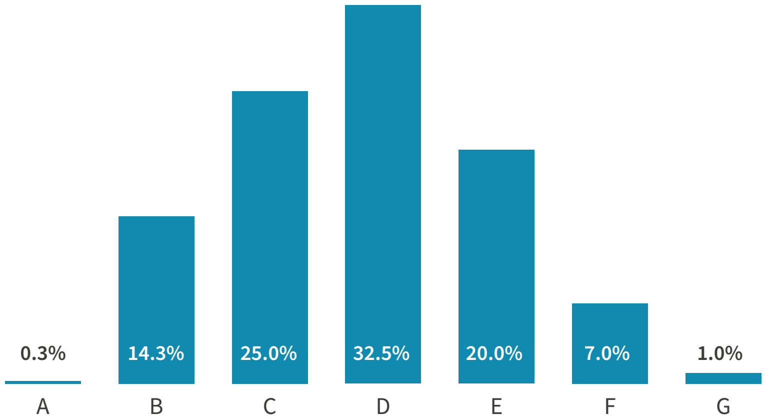
121 BEIS (2020), Regional and local authority gas consumption statistics.

122 CCC (2019), Net Zero: The UK's contribution to stopping global warming.

7.2 The residential sector

Housing growth figures are central to many debates about Oxfordshire's future. From an energy perspective, every new home that is not zero-carbon represents an additional burden to be mitigated by other means, for example through retrofit. New homes are not zero-carbon, so new house-building adds new sources of emissions; and even if new homes become zero-carbon in future, the impacts of existing housing remain to be addressed.

Figure 7.2: Distribution of domestic EPC ratings in Oxfordshire



Percentage of total by EPC band

Energy Performance Certificates (EPCs) are required for dwellings at the point of sale or rental, giving an indication of the relative efficiency of the building fabric, heating systems and fixed lighting (but excluding plug-in appliances). The ratings are shown on the familiar A–G scale (A is most efficient; G is least efficient). Although EPCs have been criticised for sometimes being inaccurate and incomplete at the level of an individual dwelling, the distribution of EPC ratings gives an overview of energy efficiency across a stock of buildings. Oxfordshire, like other areas of the UK, has a housing stock grouped around the middle ratings of C–E, which account for over 75% of the total in Oxfordshire (Figure 7.2).

7.2.1 New homes

The design energy standard for new homes in England is prescribed in two Approved Documents of the Building Regulations: Part L1A (conservation of fuel and power) and Part F (ventilation). A proposed Future Homes Standard was put out for consultation by the Ministry for Housing, Communities and Local Government in 2019, to which the government response was published in January 2021. It promises to put regulations in place in 2025 for new homes to emit 75–80% less emissions than homes built to the 2013 standard, and for those homes to be 'zero carbon ready' by having electric heat pumps instead of gas boilers. This means, in effect, that the homes will become 'zero carbon' once the grid electricity supply is completely decarbonised. Details of the policy are expected to be published in 2023 ahead of legislation in 2024, coming into force in 2025. In the meantime an interim revision to Part L is promised for 2021, which would lead to new homes emitting 31% fewer emissions compared with the 2013 standard. A 'heat and buildings strategy' is also promised.[123]

Two relevant policies for new housing were scrapped in 2015: the Code for Sustainable Homes and the target for having 'zero carbon homes' from 2016. With Part L of the Building Regulations last revised in 2013, it can be seen that relevant policy for new housing has not only stagnated, but actually gone backwards, in the last eight years.

123 MHCLG (2021), The Future Homes Standard: 2019 Consultation on changes to Part L (conservation of fuel and power) and Part F (ventilation) of the Building Regulations for new dwellings.

Another key challenge for zero-carbon is the so-called 'design-performance gap' between design intent and real-life performance of buildings. Energy consumption in new homes can be 50–100% higher than specified in the design standard, although homes built to the world-leading Passive House standard seem to have a much smaller design-performance gap than conventional homes, as well as being designed to a significantly higher standard.[124]

It is worth noting that the Passive House standard is associated with a whole suite of supporting design tools, training, accreditation, building certification, networks and events.[125] The Passive House approach enshrines a commitment to quality as well as high environmental performance, and this integrated and rigorous approach does indeed seem to lead to high quality outcomes. In contrast, a review of over 100 studies into the design-performance gap in mainstream housing development found three broad causes of the problem, all related to the culture and organisation of project teams:

- Lack of relevant technical knowledge
- Poor communication
- Unclear roles and responsibilities[126]

The implications of the design-performance gap are profound and far-reaching for the construction industry, its supply chains, labour markets and training institutions – requiring significant new national policy to fix.[127] If the design-performance gap is not substantially reduced by changes to construction practices, then the quantity of zero-carbon energy supply will have to be significantly increased for the overall zero-carbon target to be met. Peak demand will also be higher than energy system operators might expect if they do not take account of the design-performance gap in buildings.

There are provisions in the Planning and Energy Act (2008) for Planning authorities to stipulate increased on-site renewable energy and tighter building efficiency standards locally. In addition to using Planning powers, one other possibility for local authorities to accelerate the building of high-performance housing developments is to take a 'public procurement' approach, working with stakeholders to create good quality, new housing to zero-carbon standards ahead of the nationally laid-out timescales. This may provide exemplars to learn from, but it is likely to be time-consuming and require additional funding – a slow and incremental alternative to more ambitious and better coordinated national policy.

124 Johnston, D., Farmer, D., Brooke-Peat, M. & Miles-Shenton, D. (2016). Bridging the domestic building fabric performance gap. *Building Research & Information*, 44(2): 147–159.

125 See Passivehouse.com

126 ZCH (2014), Closing the gap between design and as-built performance: end of term report. London: Zero Carbon Hub.

127 Killip, G. (2020). A reform agenda for UK construction education and practice. *Buildings and Cities*, 1(1): 525–537. doi: 10.5334/bc.43

7.2.2 The existing housing stock

In 2019 Oxfordshire had some 295,500 dwellings, of which 253,000 (86%) were privately owned – either owner-occupied or privately rented. Approximately 6,000 (2%) were vacant. Statistics for the private rented sector are no longer reported separately in government statistics, but in 2017 the private rented sector accounted for 23.5% of the total privately owned stock (and 19.5% of total housing) in GB. Scaling these national figures it can be estimated that nearly 60,000 of Oxfordshire's homes were privately rented in 2019.

Figure 7.3: Oxfordshire's housing stock by tenure and local authority area, 2019

Case Study: Elmsbrook

- A zero-carbon development
- 40% green space to achieve a net biodiversity gain
- One of 11 One Planet Living schemes worldwide

Elmsbrook is a 393 home development, the first phase of NW Bicester eco-town that could eventually provide 6,000 homes and associated infrastructure for Bicester. It is the only UK development to meet the original principles of PPS1 for eco towns and is the largest zero-carbon development in UK. When complete the development will include a primary school, community centre, an eco-business centre and local neighbourhood shops. With cycle and pedestrian routes, a bus stop within 400 metres of every home, live timetable updates in each home, charging points for electric vehicles and an electric car club, residents are being encouraged to adopt sustainable modes of travel. Key features:

- All homes are built to Code for Sustainable Homes Level 5 incorporating high insulation levels, triple glazing, rainwater harvesting and water recycling.
- Timber-frames used instead of brick and block construction.
- PV solar panels installed on every home (34 m^2/house) – due to be the UK's largest residential array.
- Heat and hot water come from the community's own combined heat and power plant.

7.2.3 Residential heating policy context

Over several decades policy for domestic energy efficiency has been based on single measures (e.g. boiler upgrades; loft or cavity wall insulation), but full decarbonisation will require high-quality and integrated solutions across entire buildings stocks and districts. This will entail better integration of services within the construction sector and new coordination approaches between demand reduction and the energy supply system.

The term 'retrofit' is used to describe an integrated service using a 'whole home' approach, rather than the earlier policy approach based on individual measures. Installation may take place all at once or in a phased 'over time' approach, but in any event it requires high levels of competence in project teams.

The need for integration and quality assurance was highlighted in the 2016 'Each Home Counts' report (also known as the Bonfield Review), which was commissioned in the wake of the failure of the Green Deal policy. New occupational standards have been developed specifically for retrofit: a standard for the new role of 'retrofit coordinator' (PAS 2035 standard); and a standard for installers (PAS 2030). While being broadly welcomed by the construction industry, the Construction Leadership Council has argued that these new standards need to be integrated into an overarching National Retrofit Strategy, covering eight interlocking components:

- Leadership and communications
- Support for research and innovation
- Energy performance standards
- Finance
- Training and accreditation
- Supply chain investment
- Creating consumer demand
- Compliance and quality regime[128]

BEIS commissioned six supply chain 'demonstrator' projects from 2018–2021 (including Cosy Homes Oxfordshire) in order to test different approaches for increasing the rates of energy efficiency improvements amongst 'able to pay' owner occupiers, which represent over two-thirds of households. The evaluation of the 'demonstrators' programme reveals a very immature market struggling in the face of stop-start government policy, and hampered in its final year by the COVID-19 pandemic. Firms in the supply chain do not come forward to take on retrofit without assessing their own possible risks and rewards. Understanding how the sector operates, and de-risking the retrofit task for them, will be important features of any more successful future policy. Without a concerted effort to develop a national retrofit strategy the opportunities for carrying out retrofit work when repair and maintenance work is being planned will continue to be missed, rather than seized. In the current state of the market there is neither sufficient consumer demand nor industry capacity to deliver the type and quality of service needed.

128 CLC (2020), Greening our homes: a national retrofit strategy - a consultative document.

In the private rented housing sector, a Minimum Energy Efficiency Standard (MEES) was introduced in April 2020. To be legally rentable, a property had to have a minimum EPC rating of E, or else an exemption can be filed on a private rented sector 'exemptions register'. The register relies on self-certification from landlords. Local authorities can view the exemption register, providing data on properties and landlords claiming exemptions. This information could be used by local authorities to encourage greater participation in the scheme, although there is no resource to support this work, nor any obligation on landlords to do more than register their exemption.

The most significant energy efficiency programme for vulnerable households in recent years has been the Energy Company Obligation (ECO), run in three phases from 2013–2020. Through ECO over 3 million measures were installed in 2.2m households – most homes had one measure installed.[129] The installation of new boilers, heating controls, cavity and loft insulation all contribute to energy efficiency and improved comfort and well-being for householders. The programme is designed to deliver the relatively quick and cheap measures with the highest ratio of CO_2 savings per pound spent; it is not designed to deliver an integrated retrofit consistent with zero-carbon.

129 BEIS (2021), Household Energy Efficiency Statistics, headline release (March 2021).

Case Study: Cosy Homes Oxfordshire

Partners: Low Carbon Hub, National Energy Foundation, Retrofit Works. Pilot funder: BEIS

The Cosy Homes Oxfordshire initiative (managed by Low Carbon Hub) was one of six national Local Supply Chain Demonstrators run by the Department for Business, Energy and Industrial Strategy (BEIS) between 2018–2021.

CHO is based on a business model of quality installation and customer service, intended to take the customer (and their property) on a 'retrofit journey'. Not everything has to be done at once, but there is a 'whole home plan' developed as part of the service, which sets out how each individual property can be upgraded to be compatible with zero-carbon over time, potentially doing the work in stages and fitting in with each household's changing circumstances. As with all of the Demonstrators, CHO has not been able to achieve its targets in the 3 years of BEIS funding, which is due to end in April 2021. The intention is to continue to operate CHO without BEIS support, but the future of the scheme remains very uncertain.

Case Study: Springfield Meadows

Partners: Ssassy Property and Greencore Construction

- Net-zero embodied carbon from construction. Saving an estimated 1,250 tCO_2
- Rooftop photovoltaics are installed on all homes

Springfield Meadows is a small residential development in Oxfordshire that delivers net-zero carbon for both embodied and operational energy. The construction utilises the Biond hemp-lime system to achieve net-zero carbon emissions, while shared outdoor spaces, a wildflower meadow, orchard and pond enhance local biodiversity.

The project has followed Bioregional's One Planet Living® framework throughout the design, planning and construction stages, which not only helps to minimise impact from the construction, but helps create a strong low-carbon community. Ssassy Property plans to establish a management company to deliver a One Planet Action Plan, which will be handed over to residents.

There is no certainty or consensus about how much could or should realistically be done with energy efficiency. Some pioneering retrofit projects have shown that 80–90% emissions reductions are possible at the scale of an individual dwelling, but the technical and practical challenges of such deep retrofits grow exponentially as the performance target rises, as does the capital cost. It may be more realistic to aim for something like 50–60% reductions through energy efficiency, and meet the reduced demand from renewable sources of heat supply. Exploring the technical and cost dimensions of housing decarbonisation could be the focus of a neighbourhood-scale living lab, and would provide useful evidence for future policy locally and nationally. However, widespread adoption of retrofit relies heavily on the national policy context, without which any county-scale actions will be limited to pilots and research projects.

Case Study: Mixergy

Mixergy®

- Domestic hot water tanks that allow you to heat what you need, saving energy and money and reducing carbon emissions.
- 'Internet of Tanks' – provides flexibility to the grid and enables greater adoption of renewable energy technology
- Up to 20% savings on hot water energy bills

Mixergy is a spin-out company from the Energy and Power Group (EPG) at the University of Oxford, based in Cassington, West Oxfordshire. The company develops and delivers intelligent, cost-effective, and energy-efficient domestic water heating solutions which enable households to live better, save money and reduce their impact on the environment.

Supported by Oxford Sciences Innovation, Mixergy are also the first to intelligently connect a decentralised, digital network of tanks that can provide flexibility to the grid and support the clean energy transition. Already their 'Internet of Tanks' (connected to Internet Of Things (IOT) network) is delivering more than a megawatt of Demand Side Response (DSR) service to the National Grid, using excess electricity from the grid at times of day when there is a greater supply than demand of renewable electricity.

7.3 The non-domestic sector

Available statistics on end-use demand in the non-domestic sector are reported nationally, not at county level. In 2019, the national split of end-uses fuels for heat (Figure 7.5) was dominated by gas (40% of total service-sector heat demand) and electricity (38%). The top three sub-sectors nationally for heat demand were offices, retail and hospitality (Figure 7.6). In Oxfordshire the proportions are likely to be different, with health and education probably being higher than the national average.

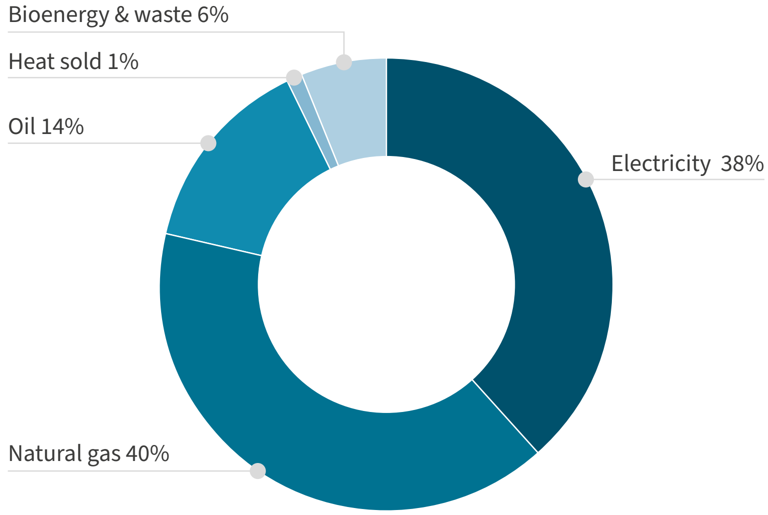
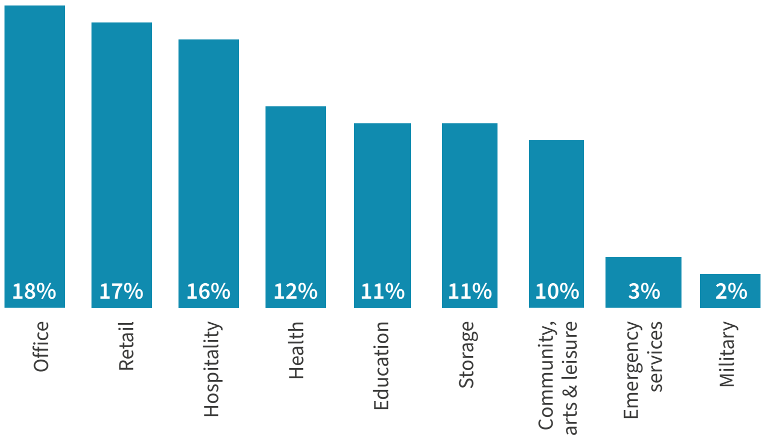


Figure 7.4: Breakdown of fuels for heating loads in the UK services sector, 2019

Figure 7.5: Sub-sectors of heat demand in the UK services sector, 2019



7.3.1 Oxfordshire's non-domestic building stock

In contrast to the data on domestic buildings, the non-domestic building stock is less well documented and understood. According to the Non-Domestic National Energy Efficiency Data-Framework (ND-NEED), there were estimated to be 1,656,000 non-domestic buildings in England and Wales in March 2020. This number is not disaggregated by local authority area in published figures. In very rough terms, the size of Oxfordshire's economy, population and housing stock is approximately 1/100th of national UK data and 1/90th of England and Wales (ie excluding Scotland and Northern Ireland). Applying the 1/90th estimate to ND-NEED data, Oxfordshire's non-domestic building stock in 2020 can be estimated at 18,400 buildings.

7.3.2 Energy Performance Certificates (EPCs) and display energy certificates (decs)

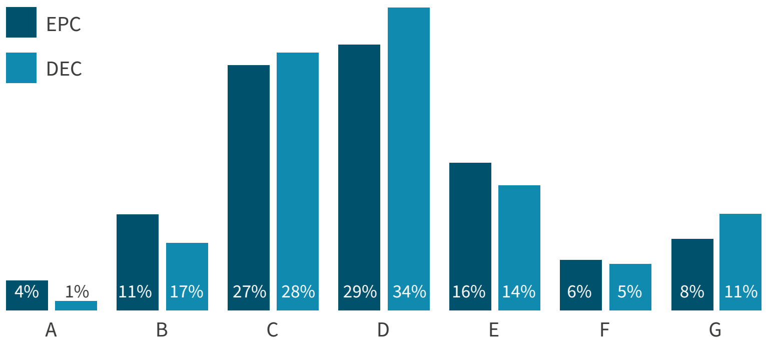
An Energy Performance Certificate (EPC) is required when a property is constructed, sold or rented. Non-domestic EPCs take account of air-conditioning/cooling. In September 2020 a total of 11,800 non-domestic EPCs were lodged for Oxfordshire buildings.

Display Energy Certificates (DECs) are required for larger public buildings over 250 m^2 that are frequently visited.[130] Where EPCs record only an 'asset rating' (based on technical parameters of the construction and energy services), DECs additionally record 'operational ratings', which use actual energy consumption to assess operation and management.

Between 2014–2019 there were 3,875 DECs lodged for Oxfordshire buildings. The City of Oxford has higher numbers of DEC lodgements than any of the District Councils. In the same period the City's share of Oxfordshire's DEC lodgements was 45% (by number of DECs) or 60% (by total floor area). This reflects the fact that there are more large public buildings in Oxford city than in other parts of the county.

EPCs and DECs can, in theory, be a useful source of information for improving stock energy performance. However, the coverage and accuracy of building energy labels can be variable, so they need to be used with caution. The distribution of EPC and DEC bands (Figure 7.6)[131] could inform a programme of engagement with building owners with the aim of improving building energy performance through sharing resources and good practice.

Figure 7.6: Distribution of EPC and DEC bands in Oxfordshire



130 For a detailed definition and exemption criteria see DECC (2015), Improving the energy efficiency of our buildings.

131 DEC bands are totalled for 2014–2019; EPC bands are upto September 2020; EPC band A includes A+.

Case Study: OxFutures

Partners: Low Carbon Hub, Oxford City Council, the University of Oxford, Oxford Brookes University, Cherwell District Council and Bioregional. Funder: MHCLG / ERDF

- 146 energy audits across Oxfordshire for SMEs
- Delivered 4393 hours of support
- Supported the creation of 4 new low-carbon start ups

OxFutures is a £4.2m project to boost low carbon economic development in Oxfordshire. It is supported by the European Regional Development Fund and run through a collaborative partnership between the Low Carbon Hub, Oxford City Council, the University of Oxford, Oxford Brookes University, Cherwell District Council and Bioregional.

The programme offers free energy audits and grant funding to SMEs in Oxfordshire to identify energy saving opportunities, to reduce energy bills and cut carbon emissions. The project also supports SMEs to develop and bring to market new environmentally sustainable products and services. Support includes knowledge sharing between academics, local authorities and SMEs and providing grant support for new low-carbon start-ups, and those developing new low-carbon products and technologies.

A recently-approved extension of the programme means that it will be able to offer sustainability support to businesses until 2023.

By the end of 2020, the project had:

- Delivered energy audits to 146 businesses with 966 recommendations, of which a third have been implemented
- Supported 28 SMEs with funding to install energy efficiency measures, reducing their energy bills and CO_2 emissions
- Awarded grants to a further 14 SMEs to develop new sustainable products and services
- Launched a new business network, Oxfordshire Greentech, which was set up to strengthen knowledge-sharing and trade in the low-carbon sector and deliver a long-lasting legacy from the project

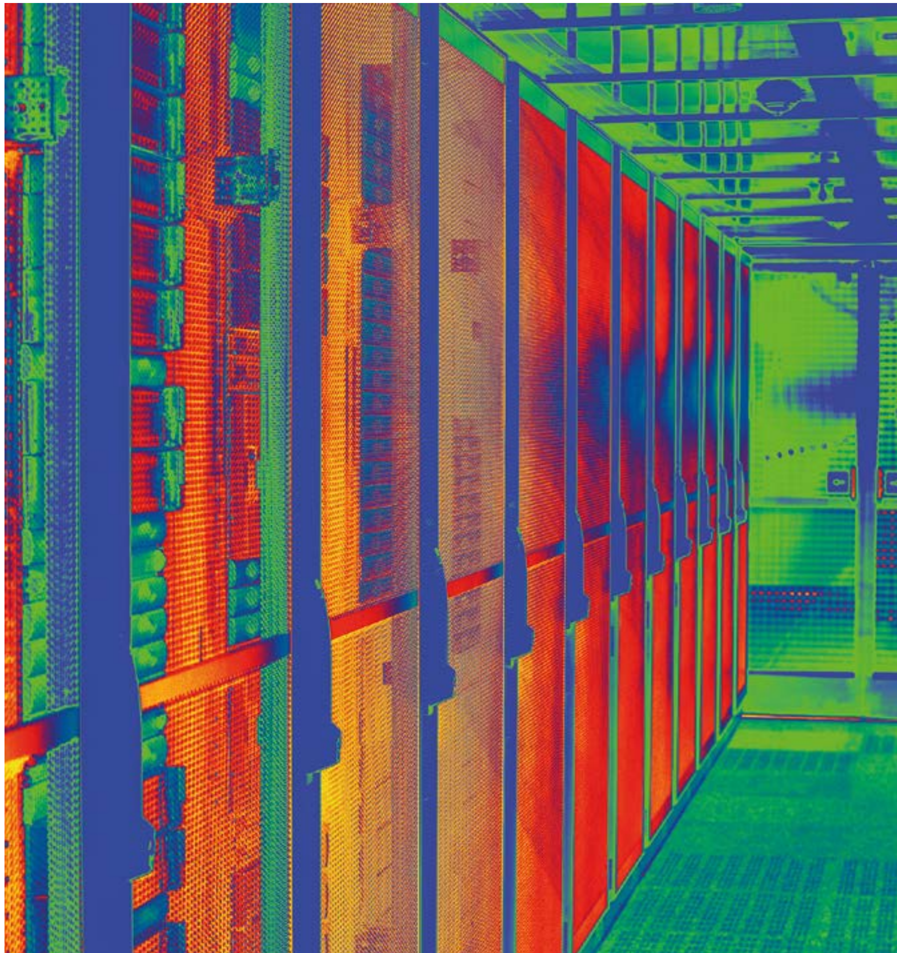
> “The early cash flow from the OxFutures GreenFund Grant allowed us to take the time to foster relationships that helped bring [our] vision to reality, extending the impact of the financial support from our incredible early stage investors and allowing us to develop and test unique new in-house products and services bespoke to the needs of the EV driver.” Holly Peters, EV Carshop

7.3.3 Organisations and non-domestic buildings

The non-domestic building sector encompasses a very wide variety of building types, sizes, functions and energy demands. It is therefore not possible to make meaningful recommendations for technologies and building improvements across the whole sector, because what may be appropriate in one case will not be appropriate elsewhere. For non-domestic buildings, a different approach is needed. Instead of focusing on technical interventions, energy performance of buildings can be improved by focusing on the processes of organisational decision-making. One-off investment decisions and ongoing facilities management both have an important role in achieving net-zero. Several elements of good practice can be identified in these processes, for example:

- Energy audits – gathering and analysing consumption data is an important first step in decision-making
- Networks and knowledge-sharing – to disseminate knowledge and promote collaboration
- Senior management commitment
- Effective communication

Some premises occupied by SMEs share characteristics with domestic properties in terms of their physical make up and their potential for improvement (e.g. offices of small professional services companies in converted housing or premises over shops). However, other SMEs are very different (e.g. technology start-up companies with specialist equipment in dedicated facilities). With SMEs, as with other commercial organisations, it is important to understand each firm, its premises and decision-making processes. Improving energy performance requires a process of engagement, not a blanket prescription of technical changes.



Case Study: University of Oxford Environmental Sustainability Strategy

Oxford University[132] has set a target to achieve net-zero carbon and biodiversity net gain by 2035, focused on ten priorities:

1. **Research** – Increase research and engagement in environmental sustainability.
2. **Curriculum** – Offer all students the opportunity to study environmental sustainability.
3. **Carbon emissions from buildings** – Minimise carbon emissions from energy consumption.
4. **Biodiversity** – Reduce impacts from operations and enhance biodiversity on the University's estate.
5. **Sustainable food** – Reduce carbon emissions and biodiversity impact of the University's food.
6. **Sustainable resource use** – Reduce environmental impacts from consumption and supply chain.
7. **International travel** – Reduce aviation emissions from University staff and student travel, and offset the balance of emissions.
8. **Local travel** – Reduce the need to travel; encourage walking, cycling and public transport; manage car travel demand.
9. **Investments** – Ensure that the University, as an investor, is part of the solution to climate change and biodiversity loss.
10. **Learning from the pandemic** – Build on the potential shift to more environmentally sustainable working practices.

The University will reduce its own emissions (scopes 1–3) as much as possible and use offsetting for the residual emissions in order to reach net-zero carbon by 2035 (taking 2009/10 as the carbon baseline).

The University will account for the biodiversity impacts from developments on its estate, management and operations, and the supply chain. The strategy is to avoid and reduce impacts as much as possible; remediate impacts and use biodiversity offsetting to compensate for any residual impacts. Biodiversity will be overall demonstrably enhanced by 2035 (taking 2018/19 as the biodiversity baseline).

132 Here 'Oxford University' includes the buildings and activities of departments, central administration, Kellogg College and St Cross College. It excludes Oxford University Press and the other 43 Colleges and Halls, which are independent and self-governing.

7.4 Neighbourhood-scale heat systems

Neighbourhood-scale approaches to heat have the potential to reduce waste and emissions by making use of heat between and among multiple buildings. Waste heat (e.g. from high-temperature industrial processes) might be reutilised in lower-temperature settings nearby, including space and water heating in buildings, thereby making the energy 'work twice'.

District heating schemes typically involve some form of centralised and relatively large-scale heat plant, connected to local demand sources through insulated underground pipework. Centralised plant has the advantage of being readily accessible for maintenance and, ultimately, replacement. The options of Combined Heat and Power (CHP) or Combined Cooling, Heat and Power (CCHP) can bring significant additional benefits, by satisfying thermal loads (cooling or heating) as well as generating electricity on-site.

Case study: The Hospital Energy Project

Oxford University Hospitals NHS Foundation Trust

Partners: OUH NHS Foundation Trust; Vital Energi; The Carbon & Energy Fund, Department of Health

The Oxford University Hospitals NHS Trust is the main provider of acute clinical care for Oxfordshire and surrounding areas. It delivers care across 4 hospital sites, has an annual turnover of over £1bn, employs over 11,000 staff, and has 1.4million patient contacts per year. In 2015 it consumed roughly as much energy as a town the size of Witney (12,000 homes).

The energy system had been in service for over 35 years. It was worn out and unreliable, and it had not kept pace with changes in clinical practice and care services. Some lighting inside the hospitals had not changed since the 1970s and badly needed an upgrade to meet modern needs.

The Hospital Energy Project removed old heating infrastructure at the John Radcliffe and Churchill Hospitals, and replaced it with a more efficient, cheaper system. Work took place between 2015–2017 to install the new infrastructure, and an energy performance contract with Vital Energi guarantees smooth operation and energy costs for the Trust until 2042. A new underground energy link between the John Radcliffe and Churchill Hospital sites allows both to share their energy resources, and to make maximum use of the combined heat and power (CHP) from the new energy centre at the JR.

Technology installed for the Hospital Energy Project included energy efficiency and new energy supply:

- New boilers and chillers
- Combined Heat & Power (CHP) plant (4.5MWe)
- 6,400 new light fittings
- 2.2 km underground energy link distributing heat and power between John Radcliffe and Churchill Hospital sites in Headington
- Improvements to building management system

The project delivered multiple benefits in terms of improved services and savings:

- £11m saved on backlog maintenance over 3 years
- Improved lighting in public and clinical areas
- Virtually no procedures cancelled due to lack of heating or cooling
- Energy link makes best use of energy across 2 sites
- Annual savings of £460,000 and
- >10,000 tonnes CO_2 (about one third lower than previous), based on 2015 emissions factors

CO_2 emissions savings from CHP are calculated in comparison with the emissions from the input fuel (in this case, natural gas and Heavy Fuel Oil at Churchill Hospital) and also the grid electricity that would have been needed had the CHP not been built. As more renewable generation comes on line, the emissions factor of national grid electricity falls, and the calculated savings from CHP need to be adjusted downwards.

7.5 Outlook

All pathways to net-zero require profound and widespread changes to the built environment. Achieving these changes requires a much bolder and more joined-up approach to national policy-making than has been seen in England in recent years. Without a better national policy framework, individual counties (including Oxfordshire) are very limited in what they can achieve for the effective decarbonisation of heat in buildings. For local strategies to prosper, responsibilities and resources need to be devolved to the most appropriate local level. For example, the Association for Decentralised Energy (ADE) argues for a new 'zoning framework' to re-shape the way in which heat decarbonisation in the UK is tackled[107]. Such a framework would assign the resources and powers to local authorities to plan for the future of heating locally, integrating energy efficiency and energy supply (including neighbourhood-scale heat networks) into a coherent strategy for new infrastructure, market development, institutions and governance. Zoning would allow different local areas to develop their own strategic plans for heat, set in the context of clear and consistent national policy. A version of this approach has been trialled through Local Heat and Energy Efficiency Strategies (LHEES) in Scotland. The LHEES pilots carried out in 2018 showed some positive results but also revealed that the voluntary/optional status of the initiative made it a low priority for some stakeholders.[133] For such ideas to have traction, they need some regulatory force behind them.

The markets for goods and services to create and maintain low-carbon buildings are small and immature. A much stronger focus on market creation and development is needed if existing technologies are to be deployed at the scale and quality required. New technologies (e.g. digital) may help, but they need to be integrated into viable market offers if they are to succeed at scale. Both the demand and supply for low-carbon heating services need to be stimulated at the same time. The kinds of market signal that are required include regulation to minimum standards, comprehensive financing packages, and consumer-facing information. There needs to be a new focus on the construction and building management industries as essential providers of zero-carbon services. New quality assurance systems need to be built around training, accreditation and robust compliance-checking. To have the required market impact and regulatory force, these changes need to be made at national level. National policy changes that would help include:

- An end to the short-term, stop-start approach to policies and programmes, which has undermined stakeholder confidence and halted progress in recent years
- A return to regular revisions of the Building Regulations with a clear 'roadmap' to zero carbon in line with national carbon budgets and local infrastructure planning
- A new focus on driving out poor quality in the construction sector using a combination of mandatory training and accreditation, backed by independent and properly resourced compliance-checking (e.g. through Local Authority Building Control)
- Regulation of property transactions (sales, leases) to mandate minimum building energy standards, backed by finance packages to provide capital and information campaigns through networks and local agencies

133 Scottish Government (2019), Local Heat and Energy Efficiency Strategies (LHEES): phase 1 pilots – social evaluation.

- Building energy ratings and installer accreditation systems that are robust enough to de-risk zero-carbon building energy services for private-sector investors
- Devolution of powers to regional and local authorities, backed by adequate funding for capacity-building and delivery, with the aim of developing strategic neighbourhood-scale approaches to zero-carbon heat

In the absence of stronger national policy, the opportunities for Oxfordshire to make progress on renewable heat in buildings are limited. A contribution could be made by continuing to initiate research projects and taking part in national demonstrators. These are unlikely to achieve scalable results on their own, but they can provide useful evidence on different aspects of the 'grand challenge' of heat decarbonisation. There is a need for local, context-specific work to help develop markets for construction, management and heating services that are compatible with net-zero carbon emissions. The focus needs to be on governance arrangements and new business models, not just on technology.

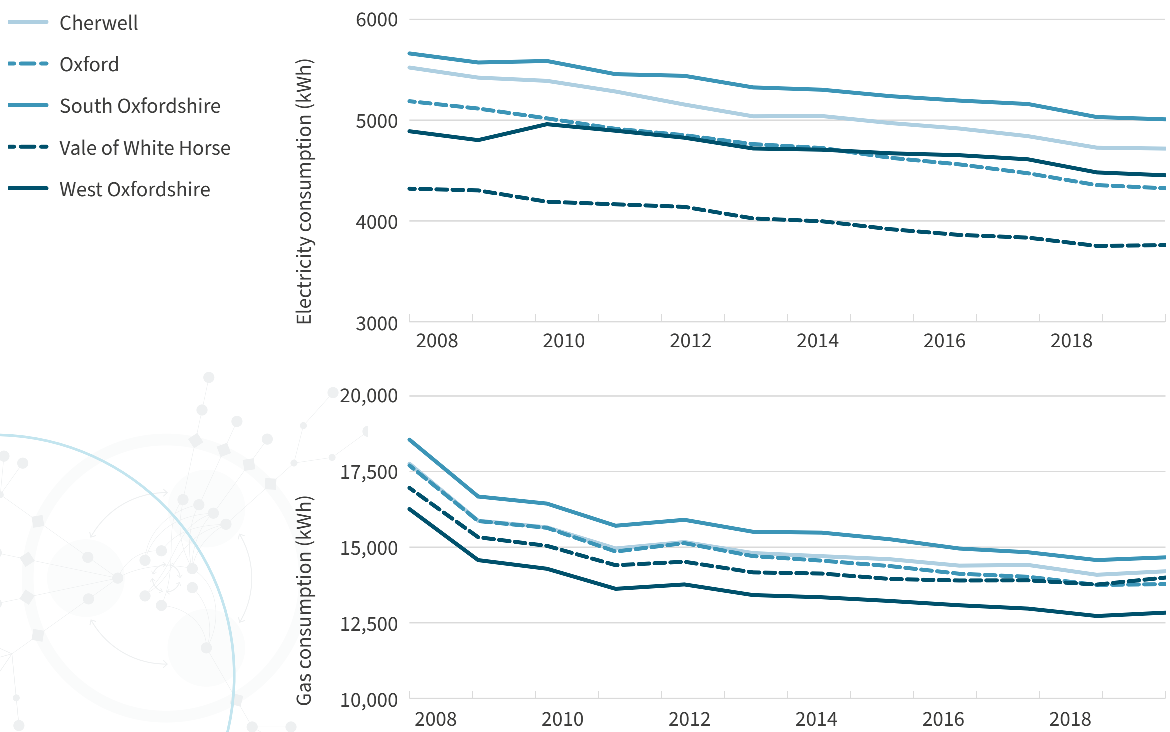
8 Zero-carbon energy

Chapter authors: Scot Wheeler & Nick Eyre

8.1 Local progress within a national context

If the UK is to achieve net-zero emissions by 2050, a transformation of the energy system is required. This chapter supports the vision set out in the Oxfordshire Energy Strategy by updating on current progress and analysing how the objectives fit within the national energy context which has moved on significantly from 2014. Section 8.2 discusses recent progress towards energy decarbonisation and section 8.3 presents how energy demand is likely to change between now and 2050. Section 8.4 then explores the resource potential which can be exploited within Oxfordshire. Finally, 8.5 highlights the importance of networks – both technological and social – in enabling the transition. As in our scenarios, we draw on National Grid's Future Energy Scenarios to provide context to Oxfordshire's current and future energy transition.

Figure 8.1: average annual domestic energy consumption per household within each Oxfordshire Local Authority District for (a) electricity and (b) gas between 2008 and 2019



8.1.1 Demand today

Between 2005 and 2014, energy demand in Oxfordshire declined steadily, but has recently stabilised, reaching 17,660 GWh in 2017.[134] Of this total, petroleum products accounted for 45% (7,919 GWh), gas 30% (5,342 GWh) and electricity 20% (3,601 GWh). Figure 8.1 compares the annual domestic electricity and gas consumption per household across all district council areas, all of which show a negative trend. Electricity savings can be attributed for the most part to more efficient appliances and LED lighting, while falling gas consumption is driven by efficiency improvements of existing housing stock, and the building of new homes with relatively higher energy efficiency.

8.1.2 Low carbon generation today

Oxfordshire's strengths within the energy sector are led by its advanced research and innovation capability. However, this has not necessarily translated to accelerated mass adoption of low carbon energy technologies when compared to other southern regions of England. While this is partly due to Oxfordshire's position as a central, low lying, landlocked county, limiting natural renewable potential (specifically hydro and wind) relative to other regions in UK, a significant solar resource exists which must be further exploited as part of any net-zero transition.

134 BEIS, Sub-national Total Final Energy Consumption Statistics 2005–2017.

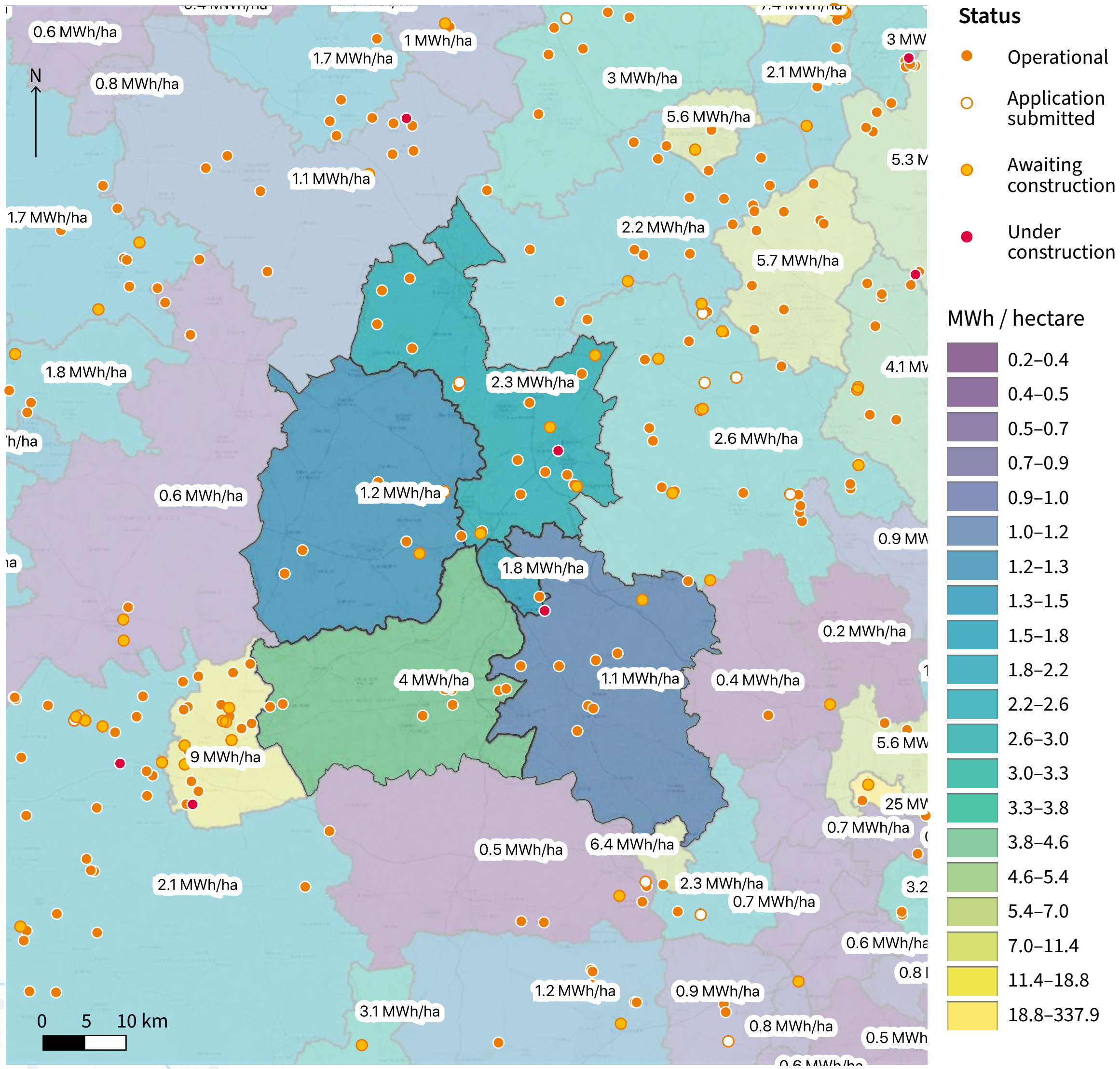


Figure 8.2: Low Carbon Energy Oxfordshire Map: the shading (and associated numbers) displays the low carbon renewable electricity energy generation per hectare (MWh/ha) of each Oxfordshire Local Authority District and surrounding area[39]. The orange circles indicate the position and development status of major renewable energy installations

According to government renewable energy statistics39, Oxfordshire's total annual renewable energy generation for 2019 was 533 GWh (with an installed capacity of 453 MW). The map in Figure 8.2 shows how this is broken down by district, normalised per hectare.[135] Vale of White Horse, a rural district, accounts for 44% of energy generation and Oxford City 2% reflecting the relative urbanisation of the different regions. Within the context of Great Britain (excluding NI), Oxfordshire contributes just 0.6% of a total 116.6 TWh, half that of its population share and contribution to CO_2 emissions. Despite having a share of 1% of national generation capacity, the share of energy generated is lower as the main source is solar PV, with a lower capacity factor (~11% cf. 40% for offshore wind).[136] This places Oxfordshire 41st out of 150 counties and Unitary Authorities in Great Britain for absolute renewable energy generation, 68th on a per household basis, and 100th on a per hectare basis. Within the context of Oxfordshire itself, local renewable electricity generation contributes 3% towards total energy demand and 14.8% of total electricity demand.

Solar PV currently accounts for 72% of Oxfordshire's renewable mix (85% of capacity), generating 382 GWh of energy in 2019. This represents 3% of national solar generation meaning Oxfordshire contributes roughly three times the solar generation compared to its population share. To put this in context, Oxfordshire ranks 9th out of 150 GB Counties and Unitary Authorities for absolute solar energy generation, a great achievement but behind comparable counties in terms of area, solar resource and social demographic, including the likes of Wiltshire, Cambridgeshire, Hampshire and Kent. Normalising on a per hectare basis to account for region size, Oxfordshire ranks 32nd, while accounting for population, on a per household basis, Oxfordshire is 15th.

135 BEIS Renewable Energy Planning Database, September 2020.

136 DUKES 2020, Chapter 6: statistics on energy from renewable sources.

These standings for solar have remained constant over the last five years, indicating that progress has been in line with peers. There are more than 10,000 registered installations, ranging in size from <10 kW domestic rooftop solar to large 35 MW ground mount installations.[137]

Landfill Gas (16.5%) is the second highest contribution to Oxfordshire's renewable generation with 15 MW of installed capacity registered through the Renewables Obligation (RO) scheme located at Ardley and Sutton Courtney. Generation from landfill gas is expected to decline as waste sent to landfill is reduced. The government's renewable energy statistics does not include energy generated from the 27 MWe Ardley Energy Recovery Facility (ERF) located near Bicester, which generates 218 GWh of electricity per year from over 95% of Oxfordshire's residual municipal waste which would otherwise go to landfill. Oxfordshire County Council estimate at least 30% of this waste is biodegradable and could be classed as renewable. However, incineration alongside non-biodegradable waste produces high carbon emissions (0.44 tCO_2/MWh) per unit of energy,[138] double that of the current UK electricity grid, and is unlikely to be significant in a future zero carbon electricity system.

There are six **Anaerobic Digestion** (AD) facilities across the county generating 7.5% of Oxfordshire's renewable generation. The largest of these, Cassington AD and Wallingford AD are owned by Severn Trent Green Power and between them, they accept all domestic food waste and some commercial food waste (depending on specific District Council arrangements) from Vale of White Horse, South Oxfordshire, West Oxfordshire and Oxford City; this only accounts for part of the total feedstock, with other commercial contracts and local authority imports making up the rest.

137 OFGEM, FiT Database 2018.

138 Birmingham Energy Institute (2020), Energy from Waste and the Circular Economy.

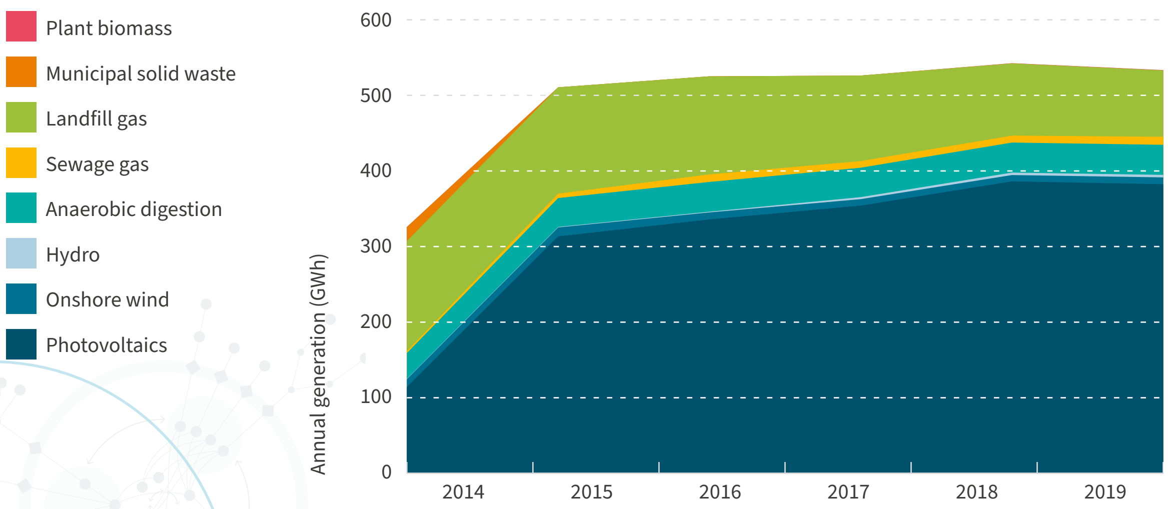
The methane generated is used onsite for electricity generation, providing 2.4 MWe and 2.1 MWe capacity from Cassington and Wallingford respectively, enough energy to power 5,000 homes annually. Cherwell's food waste is currently processed at an In-Vessel Composting (IVC) facility at Ashgrove Farm, Ardley, and not used for electricity generation. There are two Sewage Gas plants within Cherwell and South Oxfordshire, the largest of these being the 2.4 MW facility in Didcot, notable in 2010 as being the first demonstration of biomethane from sewage being injected into the national grid.

The main **onshore wind** resource within the county is the community owned 6.5 MW Westmill Wind Farm in the far south west of the county which was erected in 2008 generating around 11 GWh per year since then; it sits alongside the 5 MW Westmill Solar Farm which was developed in 2012. Since then, no further significant onshore wind development has happened, hampered by unfavourable national policy for onshore wind and local planning challenges.

Finally, for electricity generation, **hydro** contributes 3.3 GWh per year and has seen a notable expansion in capacity over the last 5 years with the completion of the community owned 49 kW Osney Lock Hydro, a 400 kW privately owned plant at Culham Weir in 2016, and the community owned 400 kW Sandpford Lock Hydro completed in 2017. Sandford Lock Hydro was developed and is operated by the Low Carbon Hub on behalf of local community members who instigated the project via a community share offer run by the Low Carbon Hub, raising £1.4m of investment.

Figure 8.3 shows how renewable electricity generation has changed through the period 2014–2019; strikingly, installations have plateaued with generated energy increasing by less than 5% in 4 years. Between 2014 and 2015, capacity was still increasing sharply thanks to a favourable Feed-in-Tariff (FiT) rate of around 16 p/kWh for solar PV; that year Oxfordshire saw an increase of 126 MWp in solar PV alone. From April 2016, the FiT rate dropped just under 5 p/kWh and was abolished from April 2019, with the effect on new installed capacity dropping to an average of 10 MW per year since 2016 (just 1.4 MW in 2019). According to the Renewable Energy Planning Database maintained for BEIS[119], as of December 2020, there is around 133 MWp solar PV capacity which had either been submitted for planning permission, had planning permission granted or is under construction. This indicates a possible near-future resurgence of renewable generation installations indicating that continued technology cost reductions are making business cases stack up without subsidies.

Figure 8.3: Low carbon electricity generated by technology type between 2014 and 2019[39]



Evaluating progress on **heat** decarbonisation is more difficult due to few details being recorded centrally for biomass boilers, wood-stoves and heat-pumps which can be broken down at region level. BEIS record the number of installations supported by the Renewable Heat Incentive (RHI) broken down by technology type on an annual basis. As of December 2020, the number of installations (and capacity based on a national average per installation) are: air source heat pumps: 858 (8.6 MW), ground source heat pumps: 239 (3.3 MW), biomass systems 104 (2.7 MW) and solar thermal: 165 (0.5 MW). This totals 1,366 installations with an estimated combined capacity of 15 MW, providing an estimated 75 GWh of heat. This represents less than 1% of the estimated county heat demand, although the real figures of such technologies are likely to be slightly higher than reported. For the non-domestic sector, there are a total of 185 installations with an installed capacity of 46 MW; based on average distribution per technology type for the South East, 75% of these are solid biomass boilers. DFES analysis undertaken by SSEN for their 2019 baseline indicates the number of heat pumps in Oxfordshire could be higher at around 4000.

Case Study: Energy Superhub Oxford

Energy Superhub Oxford

Partners: Pivot Power, Oxford City Council, Habitat Energy, Kensa Contracting, Invinity Energy Systems, and University of Oxford. Funder: Innovate UK

- 50MW hybrid battery system
- Transmission grid connected electric vehicle network
- Ground source heat pumps with innovative smart controls

Energy Superhub Oxford (ESO) is one of three demonstrator projects supported by UK Government's Industrial Strategy Challenge Fund. Integrating innovation in transport, electricity storage and heat, it aims to accelerate the development of a smart, low carbon energy system for the city, eliminating 10,000 tonnes of CO_2 in its first year of operation.

The project involves installing the UK's first transmission grid-connected hybrid battery storage system, comprising 50MW lithium-ion and 2MW vanadium flow batteries. These will help to maximise the usage of renewable electricity across the UK and provide local services such as rapid EV charging. The benefit of combining a vanadium flow battery with lithium-ion is that the two technologies behave in different, complementary ways.

Flow batteries do not degrade, and so will be deployed for rapid cycling of small quantities of electricity, preserving the performance of the lithium-ion for larger trades.

The EV network will be the first to connect to the National Grid's transmission network, delivering power to supply up to 100 ultra-rapid chargers. ESO is also exploring 'smart' charging, whereby charging prices will vary according to demand and the availability of renewable power. The project has already enabled the City Council to electrify a substantial portion of its vehicle fleet and install rapid charging points at its Cowley depot. Work is beginning on the 8 km cable system construction to Redbridge Park & Ride which will become the UK's largest public EV charging hub.

Ground source heat pumps combined with smart controls and time-of-day tariffs will provide low carbon heating for social housing in Blackbird Leys and elsewhere.

8.2 Oxfordshire's future energy transition

To achieve net-zero, transformations will be needed in the ways that energy is used, generated and delivered. While change will be driven by the transformation of the national energy system guided by central government policy instruments, how it is implemented at a local level, particularly the speed of transition, could be heavily influenced by Oxfordshire's community ambition.

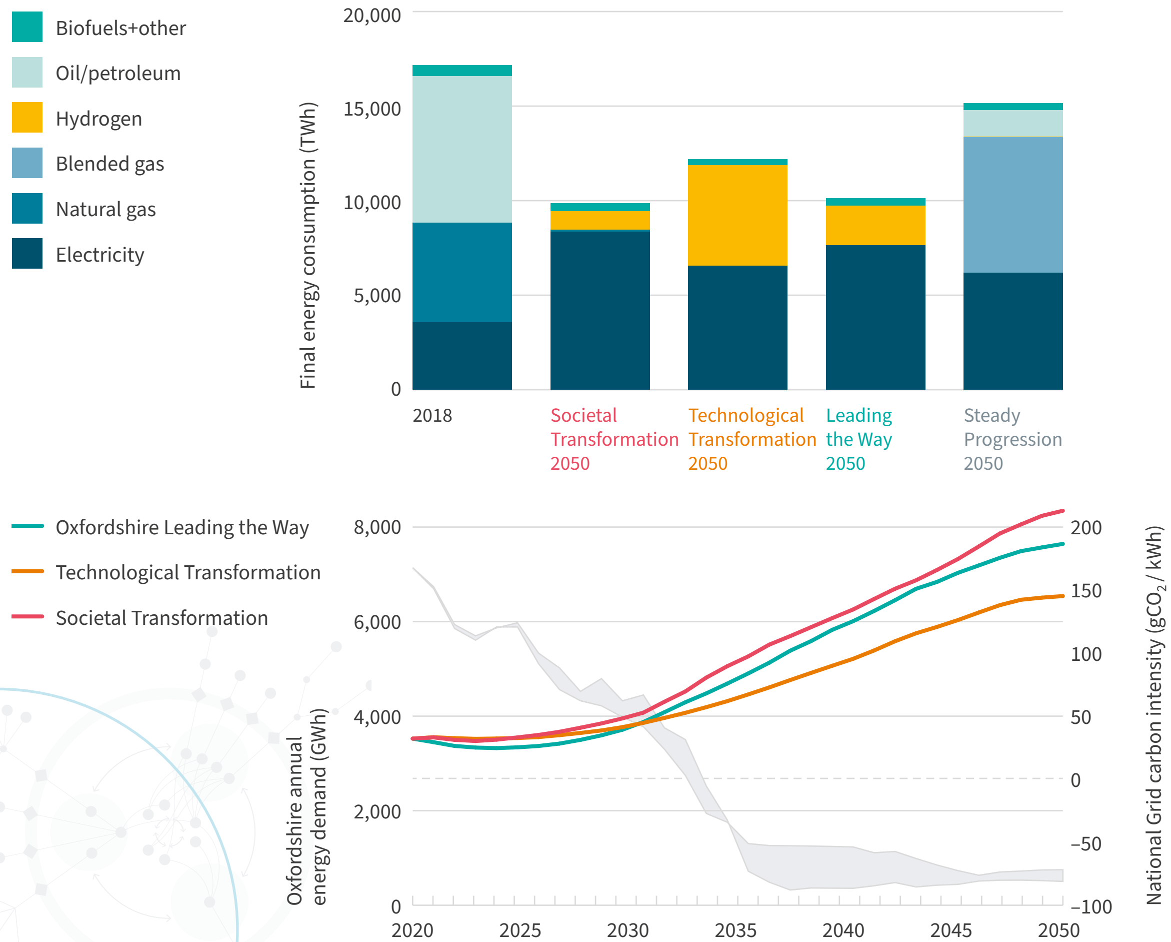


Figure 8.4: Top – forecasted annual end consumer energy demand in 2050; bottom – forecasted annual electricity demand (colours, left axis) and national grid carbon intensity (grey, right axis) for Oxfordshire net-zero pathways

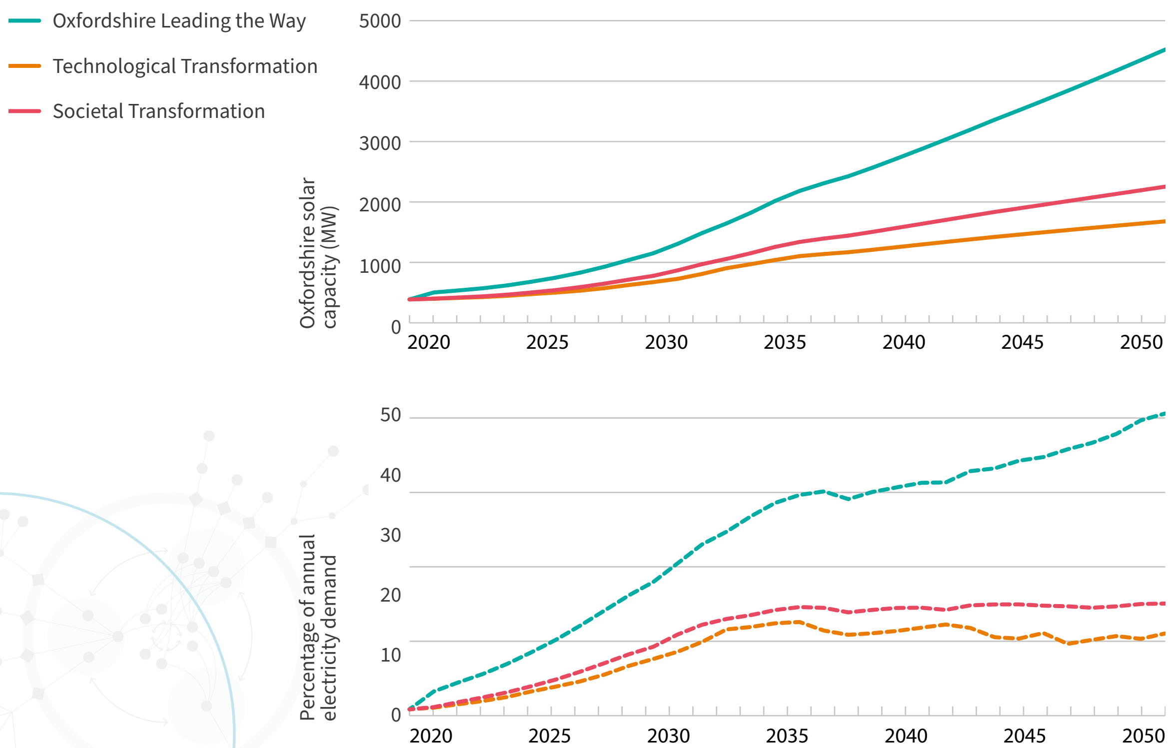
The transition is a story of two parts: energy efficiency and vector change. The route to net-zero will be influenced by society's ability to adopt new technologies and behaviours. This section builds on the three distinct pathways to net-zero developed in Chapter 4.

Energy efficiency is vital for a rapid transition to zero carbon emissions as it reduces energy demand and therefore, the energy generation capacity required. Energy efficiency will be achieved through traditional building fabric improvements but also the shift away from inefficient fossil fuelled heat and transport technologies to more efficient technologies such as heat pumps, electric vehicles and fuel cells. Figure 8.4 (a) shows Oxfordshire's forecasted annual end consumer energy demand in 2050 for all four scenarios where total energy demand is lower than the 2018 baseline as a result of energy efficiency measures. In the three net-zero scenarios, annual final consumption is forecast to be between 9.8 – 12.2 TWh.

Each of the net-zero scenarios involve complete vector change, away from natural gas and petroleum, with their replacements dependent on the complex interaction of policy, markets, technology, environment and user aspiration, spanning the whole system. For example, our **Societal Transformation** scenario represents a system dominated by electricity where users have adopted new, more efficient technologies and practices, whereas the **Technological Transformation** scenario sees extensive use of hydrogen for heating after 2035 as a direct replacement for natural gas.

Electrification is likely to be the dominant vector for the future of transport, particularly in the domestic and light commercial sectors. In addition to the electrification of heat, the result is rapidly increasing electricity demand in all scenarios from 2025 onwards as displayed in Figure 8.4 (b).

Figure 8.5: Oxfordshire PV growth scenarios for Societal and Technological Transformation representing 3% of national solar generation and Leading the Way representing an increase to 6% of national PV generation by 2050. Top: Oxfordshire installed solar capacity (MW). Bottom: solar energy generation as a percentage of local electricity demand



Due to the relative technical ease of generating electricity from renewable sources, electricity supply is expected to achieve rapid decarbonisation in the short-medium term. National Grid predicts that the electricity sector will achieve net-negative emissions by 2035 (shown in grey on the right axis of Figure 8.4 (b)), due to extensive deployment of BECCS (bioenergy with carbon capture and storage), which will be required to offset residual emissions in other sectors; the CCC expect less ambitious electricity decarbonisation, reaching 100% low carbon generation by 2035, but not achieving negative emissions before 2050. In either case, widespread electrification offers the fastest and clearest route for emission reductions in Oxfordshire.

8.3 Enabling the transition – resource

8.3.1 Generation

As highlighted above, **solar** is by far Oxfordshire's largest renewable resource and this will continue to be the case. As a southern county, insolation levels (amount of solar energy per unit area) are higher than most of the UK which should make it a favourable place to locate future PV generation, assuming grid connection fees and the cost of land or its use are not prohibitive. While Oxfordshire should at least aim to sustain (in relative terms) its high contribution to national solar generation, the question remains how much further Oxfordshire could (or should) go? The energy system does not follow geopolitical boundaries so while Oxfordshire cannot decide this alone, the county should push for, and lead on the delivery of, an informed national strategy that ensures a cost effective and equitable system. The FES 2020 scenarios predict between 42 TWh and 64 TWh of solar generation in the UK by 2050, requiring roughly 1.4 GW new capacity added to the grid per year. In our **Societal** and **Technological Transformation** pathways, Oxfordshire maintains its current 3% proportion of national solar supply. As shown in Figure 8.5, this implies a need to generate between 717–852 GWh/yr from solar by 2030 (728 – 868 MW of capacity) and between 1,377 and 2,092 GWh/yr by 2050 (1,679 – 2,253 MW of capacity). This is an increase of between 3.5–5.5 times that of current levels, requiring an additional 43 – 62 MW per year for the next 30 years. This already represents a giant challenge in the context of the 10 MW per year achieved over the last 5 years.

The green line in Figure 8.5 represents a more ambitious local solar pathway, which increases Oxfordshire's contribution to national solar generation from 3% today to 4% in 2030 and 6% by 2050. This leads to 3,868 GWh/year of solar generation in 2050, 1.8 times more than the **Societal Transformation** scenario, requiring a huge 138 MW per year for the next 30 years.

While high ambition is important to build momentum early in the transition, to benefit from such a pathway, Oxfordshire should ensure that financial benefits from its solar capacity are kept local by utilising flexibility to minimise imports and encourage local ownership. From just a carbon perspective, as the national grid decarbonises, the marginal benefit of additional local solar capacity lessens which could impact investment justification. In the extreme case of negative national supply, additional solar capacity beyond our relative national share, could reduce Oxfordshire's ability to offset other hard to decarbonise sectors through electricity.

In terms of local supply, these scenarios for local renewable generation equate to between 23% and 52% of estimated final electricity consumption in 2050. These figures are lower than previous targets recommended in the 2014 Low Carbon Economy report and picked up in the Oxfordshire Energy Strategy (primarily due to higher electricity demand from greater electrification, absolute solar capacity remains similar). However, in light of recent decarbonisation success and more proactive policies at the national level, these represent ambitious and fair contributions from Oxfordshire. UK policy is tending to favour offshore wind due to rapidly falling costs of (66% over the last 4-year period)[139] by committing to increasing capacity to 40 MW by 2030, up from 10 MW today. Such a move will decrease the relative contribution of solar nationally, which could impact the amount of solar which is economically feasible or technically favourable in Oxfordshire. This in turn would reduce the percentage of local demand met by local renewables, without necessarily influencing Oxfordshire's ability to achieve zero carbon emissions.

Depending on how the cost of solar changes over the next 30 years,[140] these targets require of the order of £1.3bn to £3.4bn of solar CAPEX investment (£42m – £110m per year for the next 30 years) based on solar costs of £750/MW. If directly offsetting local demand, this could see a collective £190m – £540m per year saved on avoided electricity imported from the national grid by 2050. However, in practice, making a business case for solar work under current market uncertainty is extremely challenging since the slightly premature removal of the FiT subsidies. As alluded to by the Low Carbon Hub in their recent Project LEO report 'Plug-in Projects – Year 1 Review',[141] the particular lack of long-term visibility of new revenue streams and lack of recognition of any local network benefits currently favours only exceptional projects which combine: large scale (>10 MW), high percentage of self-consumption, availability of long-term Power Purchase Agreements (PPAs) and low-cost availability of grid connections. Without market reform and revenue stability at a national level, it is critical to work with local partners including landowners, local organisations and the DNO to maximise local collaboration on each of these factors. However, as PV and storage prices continue to fall, installations are expected to become increasingly cost competitive again. On a positive note, local support for recent community energy funding has been high, and the Low Carbon Hub is in the process of developing Ray Valley Solar which at 19 MW is thought to be the largest community-owned solar ground mount in the UK, having raised the required £3m target in record time. From initial design, Ray Valley Solar will have the technical and commercial components integrated to make it 'flex-ready' and capable of participating in local and national flexibility markets.

139 Reported change in offshore wind prices in the renewable Contracts for Difference auctions between 2015 and 2019. HM Government (2020), Energy White Paper.

140 Using a figure of £43/MWh over a 20-year lifespan. Committee on Climate Change (2020);,The Sixth Carbon Budget – The UKs path to net-zero.

141 The Low Carbon Hub (2021), Plug-in Projects – Year 1 Review.

Case Study: Project Local Energy Oxfordshire (LEO)

LEO Local Energy Oxfordshire

Partners: Scottish & Southern Electricity Networks, University of Oxford, Oxford Brookes University, EDF Energy, Piclo, Oxfordshire County Council, Nuvve, Low Carbon Hub, and Oxford City Council.
Funder: Innovate UK

Project Local Energy Oxfordshire (LEO) is creating a smart grid trial to increase our understanding of future smart electricity system models and best practices to transition. This includes understanding the relationships between actors within this emerging energy system, identifying how markets can be unlocked and grown, and skills enhanced. The project involves:

- Designing, developing and demonstrating Market Platforms for Oxfordshire's Local Energy System
- Developing a range of "Plug-in Projects" to test new technologies and business models for enabling network optimisation, flexibility and trading.
- Analysing local energy assets and dynamically controlling energy generation and demand
- Supporting the local Distribution Network Operator to develop the competencies, processes and business models for becoming a Distribution System Operator (DSO).

Another consideration for such a solar commitment is the equivalent land area required to achieve the 2–4 GW capacity identified for 2050 above. Based on 1 MW/hectare for current module efficiencies, the additional capacity identified would require 1,200–2,600 hectares of land or between 0.45–1% of Oxfordshire's land area. This could be reduced by over 50% with the introduction of higher efficiency modules such as those based on perovskite materials being developed by Oxford Photovoltaics. A recent desk-based study undertaken by Energeo in 2020 for Oxfordshire County Council as part of Project LEO identified 46,000 hectares of land which in theory is suitable for ground mount PV.[142] Competition between energy generation and agricultural land use could be minimised by exploring novel 'aglectric' installations which avoid diminishing agricultural output. This could involve raised installations (4m or higher) to allow equipment or livestock movement underneath, adjustable installations which could change orientation during growing seasons or the use of semi-transparent or bifacial panels to minimise shadowing and maximise collection of diffuse light.[143]

142 This analysis excluded Grade 1 and 2 agricultural land, conservation zones, greenbelt land and woodland amongst other criteria.

143 Miskin et. al. (2019), Sustainable co-production of food and solar power to relax land-use constraints.

Ground-mounted solar is not the only option, rooftop solar will continue to contribute as prices fall to make PV an attractive investment opportunity again in a FiT-free market. However, soft costs including construction and labour represent a larger proportion of total installed system costs for rooftop solar which are not falling as sharply as module and inverter costs.[144] The table below provides a breakdown of PV figures by capacity for Oxfordshire based on analysis of the 2018 FiT database, BEIS Renewable Energy Statistics by Local Authority and the Renewable Energy Planning Database. While rooftop PV is estimated to account for 99% of installations in Oxfordshire, it only accounts for around 20% of total capacity. This might be expected to vary within the range 10% – 30% depending on how attitudes and policy towards rooftop solar change over the next 20 years.

	Installations	Installation (%)	Capacity (MW)	Capacity (%)
Oxfordshire Total	10,096		387	
Rooftop	10,068	99.7	74.6	19
Under 10kW*	9,565	95.0	36.0	9.3
10kW – 150 kW*	454	4.5	20.9	5.4
Ground Mount (>1MW)	28	0.3	312.7	81
*estimated from FiT database.				

144 NREL (2020), Solar Installed System Cost Analysis.

A 2012 study by McCulloch and Alkiviades with the Low Carbon Hub assessed rooftop PV potential in Oxfordshire and found the total annual solar resource striking existing Oxfordshire rooftops was equivalent to 2,055 GWh/year (around 2.1 GW); this would meet 57% of current electricity demand and 25–31% of demand projected in our 2050 scenarios. With the large numbers of new housing planned for Oxfordshire, including rooftop solar at build stage to reduce retrofitting costs is a must. Based on the average 4 kW per house achieved on the Bicester eco-town development, the 65,000 new houses yet to be built by 2031 offer 260 MW of potential solar capacity, equivalent to 250 GWh of annual energy generation. The current National Planning Policy Framework and Building Regulations provide little to no incentive for master planners and developers to include solar as standard on newbuilds. While local planning authorities have some ability to dictate better practises through their Local Plans, these are not straightforward taking years to develop, open to challenge and liable to change with different political regimes; there are few examples of this being used successfully even with declared climate emergencies.[145]

Solar thermal is another form of renewable generation which can be installed on rooftops and works by absorbing heat from the sun to heat water. As with solar PV, Oxfordshire's solar resource due to its position in the south is beneficial. However, despite efficiencies up to 90% (compared to solar PV's 15–20%) and subsidies through the RHI scheme, the case for solar thermal rarely stacks up against solar PV for several reasons. Installation costs are typically around £1,400/kW – similar to solar PV but the energy generated is less versatile. Solar thermal requires hot water tanks which are becoming less common as homeowners seek to maximise living space (for more details on how hot water tanks can be used for flexibility, see Mixergy case study in Chapter 7).

145 Oxfordshire County Council (2020), Oxfordshire Cotswold Garden Village Energy Plan.

Finally, annual cost savings on bills are lower if replacing gas due to the relative mismatch in electricity and gas prices. However, in certain cases where roof space isn't limited, particularly for non-domestic applications, solar thermal should continue to contribute, albeit in a small way, to local renewable generation.

While **onshore wind** is the cheapest form of energy generation in the UK at present, Oxfordshire's wind resource is low as a result of modest wind speeds compared to coastal and upland parts of the country. The greatest potential based on wind power density is in the south of the county along The Ridgeway or the Cotswolds to the north west; however, these are also designated AONBs. Energeo's desk-based study for the County Council identified just 1% of Oxfordshire might be suitable for onshore wind, with a potential capacity of 7 GW (in comparison to 46 GW for solar PV). Previous studies for West Oxfordshire District Council and Cherwell District Council have also highlighted the potential conflicts between onshore wind development and safeguarding zones associated with military air bases located throughout the county.[146] A new wind energy study for Cherwell District Council is due to be published in 2021 as part of the evidence base for the Cherwell Local Plan Review 2040.

146 CAG Consultants (2009), West Oxfordshire and Cherwell Renewable Energy and Sustainable Construction Study.

A small number of micro-**hydro** installations have been developed on the River Thames in recent years. However, the remaining usable resource for electricity generation is minimal and barriers such as raising support from locals and river users have been high. There is potential for heat from Oxfordshire's waterways to be exploited through water source heat pumps (WSHP) for buildings near the riverbank or through larger district heat networks. District heat network studies commissioned by South Oxfordshire and Vale of White Horse District Councils for Didcot Garden Town and Culham found the inclusion of Thames connected WSHP could have significant carbon emissions savings but are only financially viable in some limited cases.[147]

Nationally, **bioenergy** has an important role in decarbonising the energy system. When combined with carbon capture and storage (BECCS), it is one of the technologies that can deliver negative emissions needed to offset residual emissions from other sectors. Bioenergy requires a sustainable feedstock which is influenced by the availability of natural resources, waste management and competition with other land uses. All the National Grid scenarios use bioenergy, mainly for power generation, but also in residential biomass boilers, heat networks, difficult to electrify industries (e.g. cement) and biofuels for aviation. As a rural county with around 1% national land area, Oxfordshire arguably should contribute to national bioenergy production (discussed further in Chapter 9 – Land Use), however local demand is expected to be low. Biogas from waste for electricity production is more likely but with all food waste in the county already being used in existing AD plants, any new growth is limited to agricultural waste feedstocks. There is untapped potential to utilise waste heat at AD facilities such as Cassington and Battle Farm which is close by to RAF Benson and Wallingford.

147 AECOM (2017), Didcot Garden Town Heat Mapping and Masterplanning.

Although progress has been slow for **hydrogen**, it is set to play an important role in the future energy system with the Government's recent white paper outlining plans for 5 GW of production by 2030[148] and the FES 2020 identifying at least 190 TWh of energy for hydrogen production in all net-zero scenarios. Hydrogen will either be directly used to replace gas heating where heat pumps are not feasible, or as seasonal storage in a highly electrified scenario. It is also likely to play a role in long distance and heavy transport, shipping and high temperature industrial processes. One barrier for the shift to hydrogen is that it resists incremental change. Repurposing the gas grid for hydrogen requires a major step-change, in contrast to the incremental decarbonisation of the electricity system. Hydrogen is typically produced near where it is used, and it is likely to be generated by either reforming natural gas (Blue Hydrogen) close to the North Sea, or where there is an excess of renewable generation for use in electrolysis (Green Hydrogen). It can also be converted to ammonia for transportation since ammonia stores almost twice as much energy per unit as liquid hydrogen. An ammonia demonstrator at the Harwell campus provides a knowledge base for future development of this technology in the region and is discussed further in the case study below.

The use of hydrogen is uncertain but local heating demand in Oxfordshire might exist in urban centres where existing CHPs and heat networks are converted to hydrogen, or where space limits ground-source and air-source heat pumps. SSEN's DFES analysis predicts in one of its scenarios that Oxford City could see 10 MW of hydrogen generation by 2050.[149] Demand from HGV transport might come from a number of distribution centres located within the county, like those around Milton Park and Didcot, and the major roads, A34 and M40, which pass through the county.

148 HM Government (2020), Energy White Paper 2020.

149 SSEN Distribution Future Energy Scenarios (2021).

There may also be military transport and heat demand for hydrogen, with Oxfordshire host to a number of RAF bases and barracks. Finally, if future solar penetration is high, there may be times where generation exceeds local demand or exceeds local network limits, meaning that hydrogen could be generated using electrolysis behind the meter.

The **decarbonisation of heat** is one of the harder challenges faced by the UK. While our **Technological Transformation** pathway utilises hydrogen as a clean fuel in a like-for-like replacement of natural gas boilers, the electrification of heat using heat pumps will improve overall system efficiency and utilisation. Not only does electrification of heat make decarbonisation easier to integrate with wind and solar generation, heat pumps can operate at up to 400% efficiency, drastically reducing the total energy required for the same heat provision. However, demand for domestic heating is correlated with existing peak electricity demand (between 4 and 7pm), and the large-scale deployment of heat pumps will have significant implications for the electricity network and should be considered alongside heat storage solutions, building energy efficiency, smart technologies and user flexibility. Energy Superhub Oxford is conducting a trial using smart controls and ground-source heat pumps across 60 social housing properties in Blackbird Leys.

Case Study: Green Ammonia Demonstrator

Partners: University of Oxford and Cardiff, Siemens, Engie, and the Science & Technology Facilities Council (STFC)

The Green Ammonia Demonstrator brings together, on a single site, the technologies required to demonstrate the complete ammonia energy cycle (renewable power, storage and conversion back to electricity). The project will help understand the potential of ammonia for the rapid deployment of a bulk, carbon-free hydrogen network.

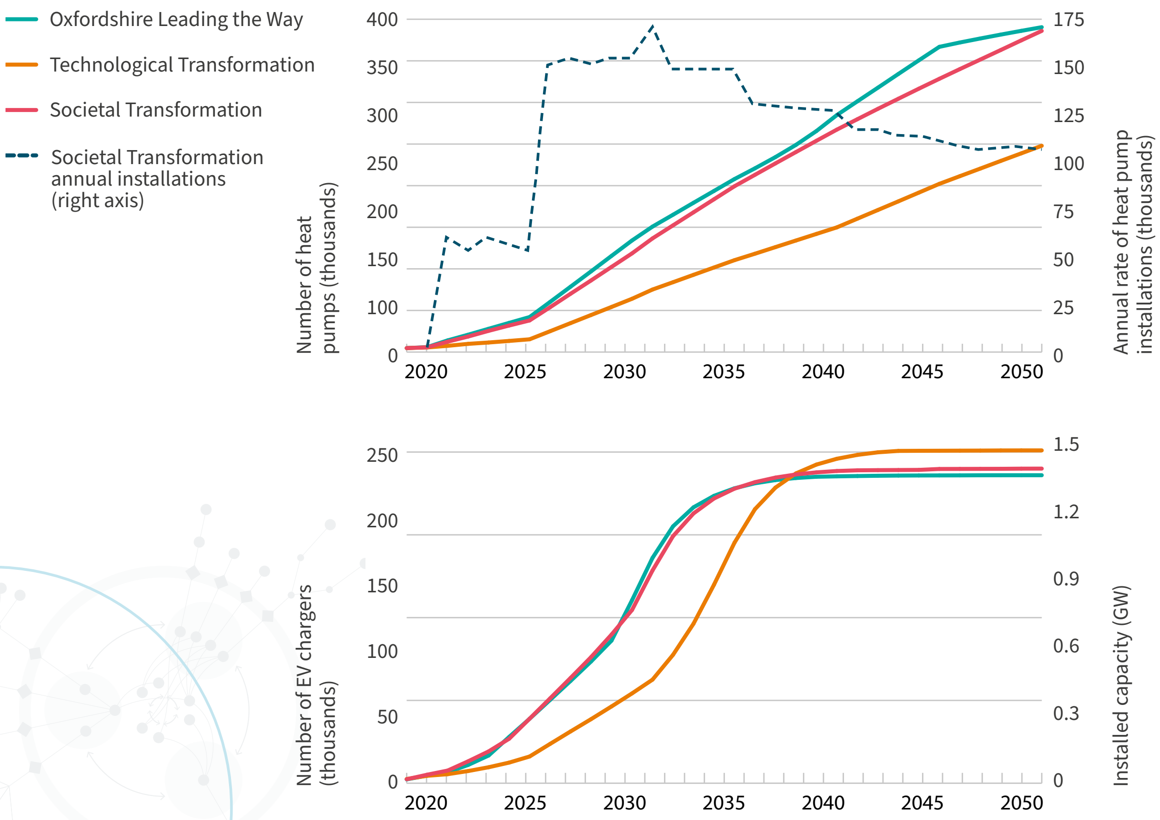
Based at the Rutherford Appleton Laboratory, the system uses electrolysis to produce hydrogen and extracts nitrogen from the air. The system combines these two elements in the Haber-Bosch process to make ammonia which can be used to store energy. When burned to produce electricity, ammonia releases no greenhouse gases.

Heat pumps will be most suitable for areas with a robust electricity supply (urban centres), existing buildings using electric heating (flats and off-gas areas), properties with sufficient space (for ground source heat pumps) and well insulated homes. Geologically, there are some challenges to the deployment of ground-source technology in Oxfordshire due to the type of soil and a shallow artesian aquifer which limits deep boreholes.[150] In the case of the Energy Superhub trial, this has required additional drilling and associated cost. SSEN's DFES 2020 modelling suggests by 2050, for the high societal change scenarios, over 80% of all heat pump installations are domestic, with 70% of all domestic properties heated by a heat pump (20% direct electric).[151] Based on the DFES figures, with a correction for network – administrative boundary mismatch and more ambitious housing growth, zero carbon pathways require an estimated 64,000 to 134,000 heat pumps installed in Oxfordshire by 2030, increasing to between 250,000 and 390,00 by 2050 (Figure 8.6 (a)). The dashed line shows the annual rate of heat pump installations for the **Societal Transformation** scenario peaking at just over 17,000 around 2030, this is in line with national targets of 600,000 per year by 2028.

150 British Geological Survey, Principal aquifers in England and Wales.

151 This analysis was undertaken under the previous 80% CO_2 reduction targets and is being updated to match NGESO's FES 2020 scenarios. It also only includes SSEN's Oxfordshire network which excludes some parts of West Oxfordshire and Cherwell to the north.

Figure 8.6: Top – the number of heat pumps, and bottom – the number and estimated connected capacity of EV chargers installed in Oxfordshire based on DFES trends, but adjusted for anticipated housing growth



Figures presented in the Transport chapter predict between 130,000 and 370,000 **battery electric vehicles** (EVs) in Oxfordshire by 2030, depending on scenario, increasing to between 450,000 and 600,000 by 2050. Assuming average annual mileage of 8,000 miles and average consumption of 0.22 kWh/mile, this equates to electricity demand of between 792 and 1,056 GWh/year. All scenarios suggest some transport will be hydrogen based, particularly HGV, with estimates of demand in Oxfordshire in the range of 400 GWh to 700 GWh for between 9,000 and 28,000 hydrogen vehicles. The relatively high demand per vehicle reflects the lower efficiency of heavier vehicles.

Figure 8.6(b) shows the number of EV chargers as estimated by the DFES. Across all technology types (off-street, on-street, workplace, carpark, destination, en-route and fleet), installed chargers are expected to total between 87,000 and 148,000 by 2030, rising to between 186,000 and 218,000 by 2050; 87% of these are off-street with 5% of both on-street and workplace chargers. Across all pathways, this could see between 1.3 and 1.6 GW of charge point capacity installed on SSEN's Oxfordshire network by 2050.

8.3.2 Flexibility and storage

Storage will be needed throughout the energy system to manage both spatial and temporal (intraday and seasonal) differences in energy supply and demand, while flexibility is needed to support the networks during times of peak power flow. Both become more critical for security of supply as the penetration of variable renewable generation increases on the grid, while the location (transmission or distribution connected) will depend on how distributed the new energy technologies are. Thankfully, technologies already discussed as putting additional strain on the electricity system through increased demand (heat pumps and EVs), may also be able to offer flexibility as a secondary service at least on a diurnal basis.

Batteries offer both electrical storage and flexibility services. They are typically installed with one of four primary purposes: (1) as large standalone installations offering national network services (balancing market), (2) co-located with generation providing the site with price arbitrage opportunities (selling the generation at times of higher prices), (3) commercial behind-the-meter to balance load and avoid periods of high network charges (DUOS and TUOS) or (4) domestic batteries to improve self-consumption of rooftop PV. As markets for flexibility mature and become more accessible, stacking the various revenue streams will become an important part of a batteries business case.

The most likely opportunity for significant electrical storage within Oxfordshire will be co-location with the large solar capacity discussed above; many solar planning applications and grid connection requests include the potential for batteries to be added. However, the lack of long-term bankable revenue, tariff uncertainly (ongoing Targeted Charging and Forward-Looking Charges Review) and high technology costs mean batteries are rarely an investable proposition without subsidy at present. Recent modelling of battery storage with rooftop solar PV at Rose Hill Primary School found a gross marginal revenue of less than £150/year, representing a payback greater than 300 years.[152] To make the technology economical, unit costs must continue to fall while additional flexibility-based revenue opportunities need to be accessible and deliver value across the system. Oxfordshire forecasts based on NGFES baseline trajectories for battery electrical storage (corrected for the higher growth rates assumed here) suggest between 80 – 170 MWe of battery capacity will be installed by 2030 increasing to between 220 – 500 MWe by 2050 depending on pathway. There are currently three large battery applications in Oxfordshire which have been granted planning permission in the Renewable Energy Planning Database totalling 88 MWe. This includes the 50 MWe stand-alone ESO battery and two other solar co-located batteries.

152 Low Carbon Hub (2021), Plug-in Projects – Year 1 Review.

Case Study: Brill Power

BrillPower
REVOLUTIONIZING ENERGY STORAGE

Brill Power is an innovative battery technology company spun out from the University of Oxford with expertise in power electronics, battery modelling and control.

- **Increased lithium-ion battery pack charge rates, reliability and lifetime**
- **Enables 2nd life battery applications**

Brill Power's aim is to enable batteries to reach their full potential, avoiding the unnecessary battery waste that is seen in current systems. With funding from Oxford Sciences Innovtion and other VC investors, the company's game-changing intelligent Battery Management Systems (BMS) technologies increase the lifetime and reliability of lithium-ion battery packs for stationary energy storage and electric vehicles, whilst also delivering safety and sustainability benefits.

The Brill Power BMS offers up to 60% longer battery lifetime, lower lifetime cost, improved safety, faster charge rates and enables 2nd life battery applications.

EVs offer a secondary use, beyond just transport, in supporting the grid through flexibility services in the form of **smart charging** or **vehicle-to-grid** (V2G). National Grid predict over 50% of households will use smart charging by 2050. This could see residential EV peak demand in Oxfordshire limited to around 50 MW, compared to almost 200 MW without smart charging (in the high societal change scenario). There is much more uncertainty with V2G utilisation. Our **societal transformation** scenario estimates that 26% of households will make vehicles available for V2G by 2050, meaning that Oxfordshire could benefit from between 1.6 GWh and 3.5 GWh of storage capacity with peak power generation of between 110 MW and 245 MW.

8.4 Enabling the transition – networks

8.4.1 Electricity

Oxfordshire is supplied by multiple electricity distribution network areas; the majority of the county is supplied by Scottish and Southern Electricity Networks (SSEN), around 87% by area, while the very north of the county, including Banbury, is supplied by Western Power Distribution (WPD) and a small area to the east around Thame is supplied by UKPN. The transition to net-zero will undoubtably have a significant impact on electricity networks in terms of their physical capacity to deliver power and energy, how they are managed and how end users actively engage.

As demand and variable generation increases, bidirectional peaks in power flow could become more extreme without smart network management. The smart grid could also create opportunities for new market models based on peer-to-peer energy trading and energy-as-a-service, integrated with other sectors such as mobility and heat. These changes will be spatially correlated with human and physical geography which requires specific local solutions.

On SSEN's Oxfordshire network, 35% of primary substations are currently labelled as constrained to additional contracted demand, while 61% are labelled as constrained for additional generation (greater than 5 MVA synchronous) due to either downstream (lower voltage) or upstream (higher voltage) constraints.[153]

As smart energy-using devices proliferate, there is greater potential to manage the distribution grid. This potential flexibility enables existing infrastructure to be optimised and costly network reinforcement to be avoided. Recent work undertaken on behalf of Piclo found flexibility could reduce whole system costs by £4.55bn per annum nationally compared with a passive approach, and RIIO-ED2 (Ofgem's next price control process for regulating DNO revenue and spend, covering the period from 2023–2028) will play a crucial role in enabling the smart grid.[154] However, this requires network companies to have a much closer relationship with their network users, communities and local policy makers to ensure coordinated solutions. SSEN's TRANSITION project selected Oxfordshire to develop, demonstrate and assess the tools, data and system architecture required for the smart grid because of the county's appetite for energy innovation and suitability for assessing wider replicability.

153 SSEN (08/03/2021), Generation and Demand Availability Maps. It should be noted that this data only provides an indication of network capability and changes regularly based on the current pipeline of network upgrades and live connection requests.

154 Piclo (2020), Modelling the GB Flexibility Market.

8.4.2 Heat

There are examples of private and commercial district heat networks within Oxfordshire include the 890 kWe gas CHP at NW Bicester Eco Town, a private 1MW biomass heat network on the Ditchley Estate, University of Oxford's Science Area, and the 4.5 MWe gas CHP installed between the John Radcliffe and Churchill Hospitals. While heat networks offer advantages from reduced plant maintenance, the high cost of installation, emission concerns relating to gas CHP, and uncertainty around hydrogen replacement mean they are often unattractive in the short term. District heat networks which make use of waste heat could be more favourable. However, depending on transmission distance and timeframe for demand (including land ownership, physical obstacles and phased housing buildout) installation costs can be prohibitive. In Oxfordshire, there is potential for building waste heat networks at the science parks, data centres, AD sites, refrigeration such as in supermarkets or the previously mentioned Ardley ERF. Oxford City Council has been awarded a £10.9m grant to help transform heating in some of their highest consuming buildings. This includes £1.6m for a water source heat network to heat Hinksey outdoor swimming pool, one of the largest in the south of England.

8.4.3 Digital

The transition to a smart, local, net-zero energy system will be enabled by digitalisation of the assets and networks which are needed deliver it. Reliable and accessible communications and data platforms will be essential for providing the information required by each participant to effectively operate. Households will become Smart Homes as appliances such as washing machines, dishwashers, EV chargers and heat pumps utilise Internet of Things (IoT) technology to deliver the desired service while coordinating with the wider system. Oxfordshire's technology research environment and population of early adopters makes it an ideal place to foster this innovation.

Access and interoperability of energy data is fundamental in unlocking system and user benefits of the future smart grid. It will be key to the emergence of new business models, development of new assets and system operation. Across the universities and research centres, Oxfordshire has a wealth of experience working with data including its use within research but also its storage and management. STFC Rutherford Appleton Laboratory and Harwell Campus is host to JASMIN, a 'super-data-cluster', DAFNI (Data & Analytics Facility for National Infrastructure) and UKERC's Energy Data Centre, an archive of UK publicly funded energy research data.

Historically, monitoring of the low voltage distribution networks has not been a requirement for system operation, but as this changes, installation of monitoring kit on the distribution network is progressing quickly though SSEN's Project LEO and NeRDA (Near Real-time Data Access), while WPD provides access to its data through their System and Network Data Hub. To gain the full potential of energy data, it needs to be analysed in combination with a vast array of other data sets such as land use and socio-economic data and then disseminated in a transparent and accessible way.

This type of analysis underlies much of the DFES work being undertaken by DNOs at present, while Oxfordshire County Council are working on a GIS platform to make these linked spatial and temporal datasets easily accessible to a wider audience.

8.4.4 People

While the range of technical outcomes of Oxfordshire's energy transition have been presented above, the exact route and speed of transition will come down to people: as active users, influencers, and builders of the future energy system. To maximise user engagement and developer coordination, creating and fostering networks of people will be crucial for delivering net-zero. There are many great examples of this already happening within Oxfordshire.

Oxfordshire's strong community action group scene will be invaluable for engaging with users at a community level. As part of Project LEO, the Low Carbon Hub are working directly with local communities to develop Smart and Fair Neighbourhood (SFN) trials which aim to test the social innovation (alongside both technical and financial) required to get approval and mass participation in new equitable energy services at the most local level.[155] The Low Carbon Hub's Peoples Power Station is another great example of ways in which end users are being encouraged to take an active role in the energy system.

Delivering the energy system for 2050 is also reliant on having the supply chains and skilled workforce available to manufacture and install the required infrastructure. Look no further than the recent challenges faced with the Green Homes Grant where homeowners have been unable to access the scheme because of a shortage of qualified contractors. This has also been the experience of Cosy Homes Oxfordshire, a local whole house retrofit service. This can only be fixed through the encouragement of new people entering the sustainable energy building sector and supply chain through training and apprenticeship programmes.

155 The Low Carbon Hub (2021), Developing an ethical framework for local energy approaches.

Photo: Kristine Cinate on Unsplash

9 Land use and sequestration

Chapter author: Alison Smith

9.1 Introduction

Land use has a crucial part to play in reaching net-zero. Vast amounts of carbon are stored in soils and vegetation globally, and land can be either a source or a sink of greenhouse gas emissions depending on how it is managed. Nevertheless, although protecting the carbon stored in existing ecosystems and reducing land use emissions is critical, the potential for land to absorb additional carbon dioxide is limited by the finite land area and competition with food, fuel and fibre production. In addition, ecosystem stress caused by future climate change risks changing many land and water-based sinks into emission sources. The primary goal of climate action must therefore be steep reductions in fossil fuel use, but well designed 'nature-based solutions' can also contribute to both climate mitigation and adaptation, as well as providing wider benefits for biodiversity and human health and well-being.[156]

It is essential to design land use policies to optimise these wider benefits, and also to manage and minimise the inevitable trade-offs. In particular, it is increasingly urgent to co-ordinate land use strategies to address both the climate and ecological crises, which are closely linked. A hard-hitting report by IPBES warned that human activities are putting up to one million plant and animal species at risk of extinction.[157] This message is echoed by the State of Nature reports for England[158] and Oxfordshire,[159] which reveal continued declines in abundance and diversity of many animal and plant species, due to habitat loss and fragmentation, pollution, and climate change.

To address this, the 25 Year Environment Plan for England requires local authorities in England to develop Nature Recovery Strategies. Local councils and wildlife groups are working together to set up a Local Nature Partnership, which brings together key stakeholders in the land use and biodiversity sector. Wild Oxfordshire, the Berks, Bucks and Oxfordshire Wildlife Trust (BBOWT) and the Thames Valley Environmental Records Centre (TVERC) have already worked with stakeholders to produce a map of a draft Nature Recovery Network, which targets habitat restoration in zones that connect existing high value habitats.[160] This was overseen by Oxfordshire's Biodiversity Advisory Group (BAG) and adopted by the Oxfordshire Environment Board (OxEB).

156 Seddon, Smith et al 2021. Getting the message right on nature-based solutions to climate change.

157 IPBES (2019), Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.

158 Hayhow et al. (2019), The state of nature 2019. The State of Nature partnership.

159 Wild Oxfordshire (2017), The state of nature in Oxfordshire, 2017.

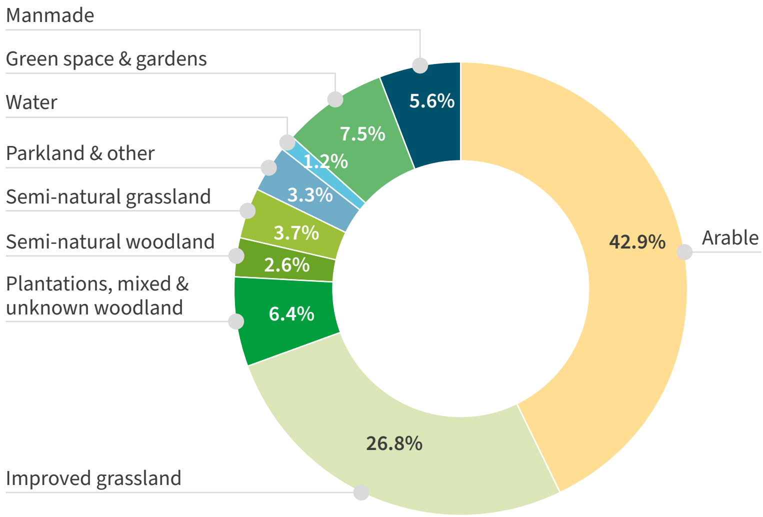
160 Wild Oxfordshire, Draft map of Oxfordshire's nature recovery network.

In this chapter we address the role and impact of land use, land use change and forestry (LULUCF) on Oxfordshire's net-zero ambitions, in terms of carbon emissions, storage and sequestration. Within the scope of this project it was not possible to model agricultural emissions of CO_2, methane and nitrous oxide), but as these comprise 10% of total UK GHG emissions[161] (and the food system as a whole is responsible for around 30% of all emissions) this is a critical area for further research.

9.2 Current land use in Oxfordshire

Land use analysis is based on the Natural Capital map of Oxfordshire.[162] Full details of the methodology and tables of data and assumptions for each scenario are in Annex 1.

Figure 9.1: Habitat areas in Oxfordshire



Oxfordshire is dominated by intensive agriculture (Figure 9.1). Farmland occupies 70% of the county: 43% arable and 27% improved grassland (fertilised pasture). There is only 9% woodland, well below the UK average of 13% and slightly less than the English average of 10%, and most of this is plantation rather than semi-natural[163] woodland. Almost 6% is sealed surfaces (buildings, roads, car parks etc) and a further 7.5% is domestic gardens and other forms of urban green space such as playing fields and allotments. Only 7% is semi-natural habitats other than woodland: this is mainly semi-natural grassland such as floodplain meadows and chalk grassland, and parkland with scattered trees, with very small areas of wetland, scrub and heath. However, there are around 17,000 km of hedgerows and lines of trees along field boundaries in Oxfordshire, plus an unknown number of individual street trees and field trees, which also store and sequester significant amounts of carbon.

The map in Figure 9.2 shows the predominance of arable land (yellow) and improved grassland (pale green). Small patches of semi-natural grassland (bright green) exist in places, and the dark green shows the woodlands of the Chilterns in the south-west, as well as isolated woodlands elsewhere.

161 Defra (2020), Agricultural Statistics and Climate Change.

162 Smith (2019), Natural capital mapping in Oxfordshire – Short report.

163 Note: the term 'semi-natural' is used because very few habitats in the UK can be describes as 'natural' due to a long history of human management of the landscape.

Figure 9.2: Map of habitats and land use in Oxfordshire

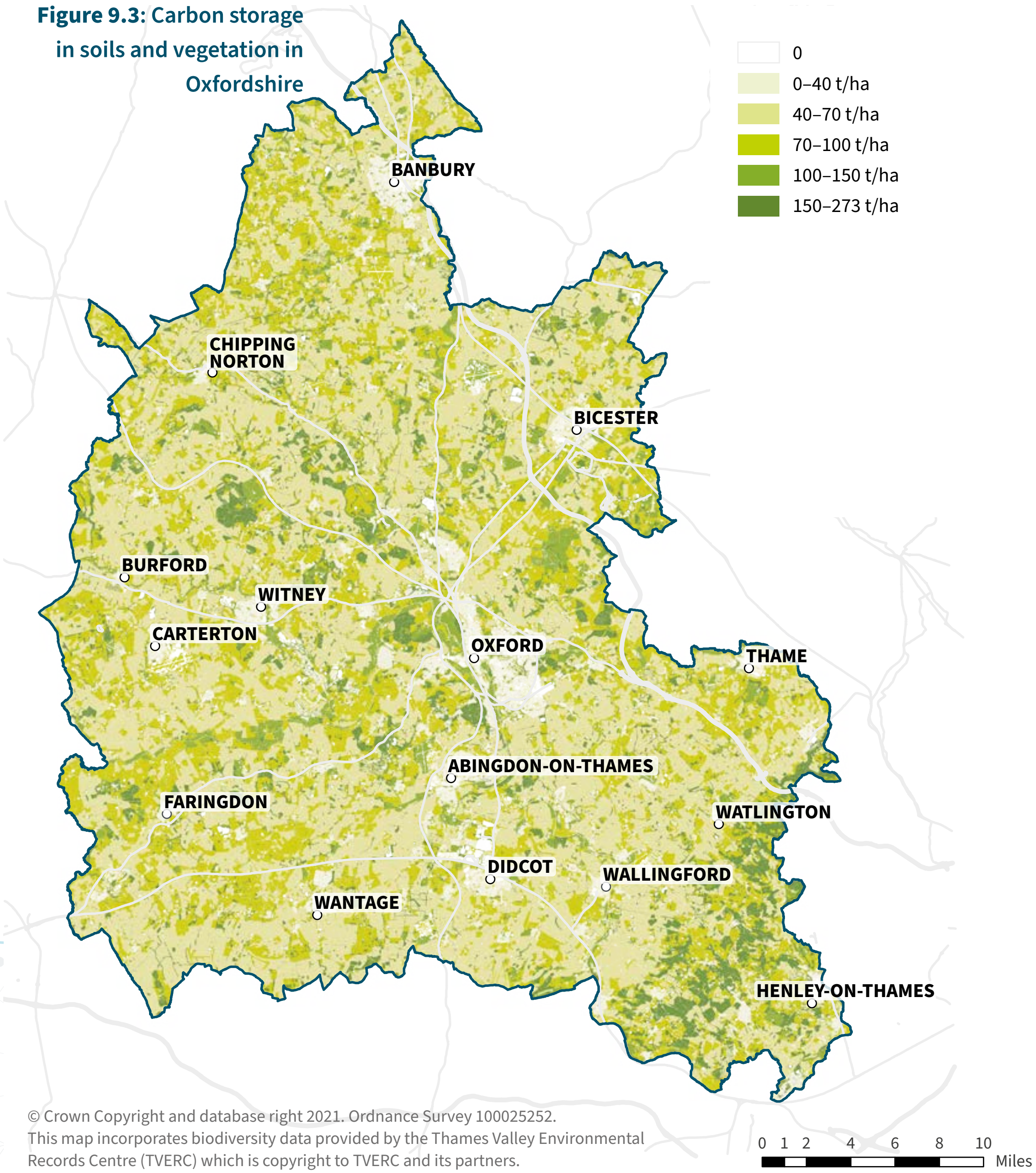
9.3 Estimate of current carbon storage and sequestration

Carbon storage and sequestration was calculated using the areas of each type of habitat multiplied by estimates of carbon stored or sequestered per hectare. For non-woodland habitats we used a range of literature sources. For woodland, we calculated average sequestration rates in different types of Oxfordshire woodland using the Woodland Carbon Code Calculator.[164] We used the Forestry Commission's ecological site classification tool[165] to work out what types of woodland are suitable for Oxfordshire's soil types and climate (warm dry, or warm moist on higher land), and what the range of yield classes (productivity) would be in different soils. For example, only Beech is considered suitable for carbonate soils, but a wider range of species can grow elsewhere. We then assumed average compositions and management regimes for different woodland types, for example we assumed that broadleaved plantations were composed of an average of 80% Beech and 20% Oak, managed with regular thinning and planted at 2.5m spacing. Full details of the methodology and assumptions are in Annex 1.

164 www.woodlandcarboncode.org.uk

165 Forest Research, Ecological Site Classification Decision Support System.

Figure 9.3: Carbon storage in soils and vegetation in Oxfordshire



For semi-natural woodlands we assume that the woodlands are currently 100 years old, so we take the average sequestration rate from ages 100 to 130 years to estimate sequestration from 2020 to 2050. For plantations we take average sequestration rates over 60 years (the typical rotation length), and then subtract the amount lost due to decay of harvested wood products, which we assume to be 50% (i.e. we assume that 50% of all harvested wood is currently locked up in timber construction or other long lived products, with the rest used for short-lived products such as paper, cheap furniture or fuel combustion).

These figures should be treated as a scoping estimate because metrics of carbon storage and sequestration in ecosystems are highly dependent on a range of factors including soil type, soil depth, soil density, soil and vegetation condition, habitat age, tree species, climate, and management. Even if all these parameters are known, data on how carbon storage and sequestration varies with all these factors is patchy and different sources are not in good agreement.

Figure 9.3 maps the carbon storage across Oxfordshire. The woodland areas stand out, and the higher score for grassland compared to arable land can also be seen.

Arable land is a source of emissions due to carbon loss as soils are disturbed during cultivation. This loss is estimated at 0.25 tC/ha/y, or 28,000 tC/y, responsible for an estimated 837,000 tC between 2020 and 2050. It is offset by sequestration, primarily by woodlands and hedgerows[166] (109,000 tC/y) but also by grasslands and other semi-natural habitats, with a small contribution from urban green spaces. As noted above, these estimates are highly uncertain. Individual trees such as street trees and field trees are not included in these estimates due to lack of affordable data. The full breakdown of emission estimates is given in Annex 1.

It is estimated that around 23 Mt of carbon is stored in Oxfordshire's soils and vegetation, and an additional 115,000 tonnes is sequestered each year, so that around 3.5 Mt C would be sequestered between 2020 and 2050 if there was no further land use change. However, the carbon stored in soil and vegetation is lost when land is cleared and topsoil removed for new developments of housing and infrastructure. Analysis of land use change from 2014 and 2020 using OS Mastermap shows that 2,710 ha of agricultural land and other natural surfaces were converted to sealed surfaces and buildings. Even if all the land converted was arable, with a relatively low carbon content of 66 tC/ha, this would equate to a loss of 178,880 tonnes of carbon, equivalent to 29,813 tonnes per year, which reduces the net annual sequestration to 85,000 tC/y, or 312,000 t CO_2/y.

Sequestration calculation methodologies

The figures for Oxfordshire produced by BEIS (see Chapter 3, Figure 3.1) indicate annual sequestration of 26,700 t C, or 98,000 t CO_2. This represents only 31% of our estimate, but with a rising trend over time. BEIS produce their regional figures by scaling-down national land use datasets, and by extrapolating from trends in land use change prior to 2007. Our land use figures are based on the detailed natural capital map of Oxfordshire, which is more accurate, and based on more recent data than the BEIS figures. However the main difference arises because we assume continued sequestration of carbon by all woodlands, in line with the figures calculated from the Woodland Carbon Code as described above, whereas BEIS assume that all woodlands older than 100 years have reached an equilibrium and no longer sequester carbon. We also take account of carbon sequestration by hedgerows and lines of trees, gardens, and urban green spaces, which are ignored in the BEIS estimates.

166 Hedgerows and lines of trees come from an experimental dataset provided for research purposes only by Ordnance Survey, and this data should be treated with caution. We have assumed a width of 2.5m for hedgerows and 6m for lines of trees, and subtracted this area from the areas of arable and improved grassland (half and half).

9.4 Opportunities to enhance carbon storage and sequestration.

A range of options could be considered to protect and enhance carbon storage and sequestration in ecosystems. Protecting the carbon stored in soil, which far exceeds that stored in vegetation (even for woodlands), is particularly important. However, as land use change involves trade-offs with other uses, any major initiatives must involve extensive consultations and should be planned in partnership with landowners and other stakeholders. Potential options include:

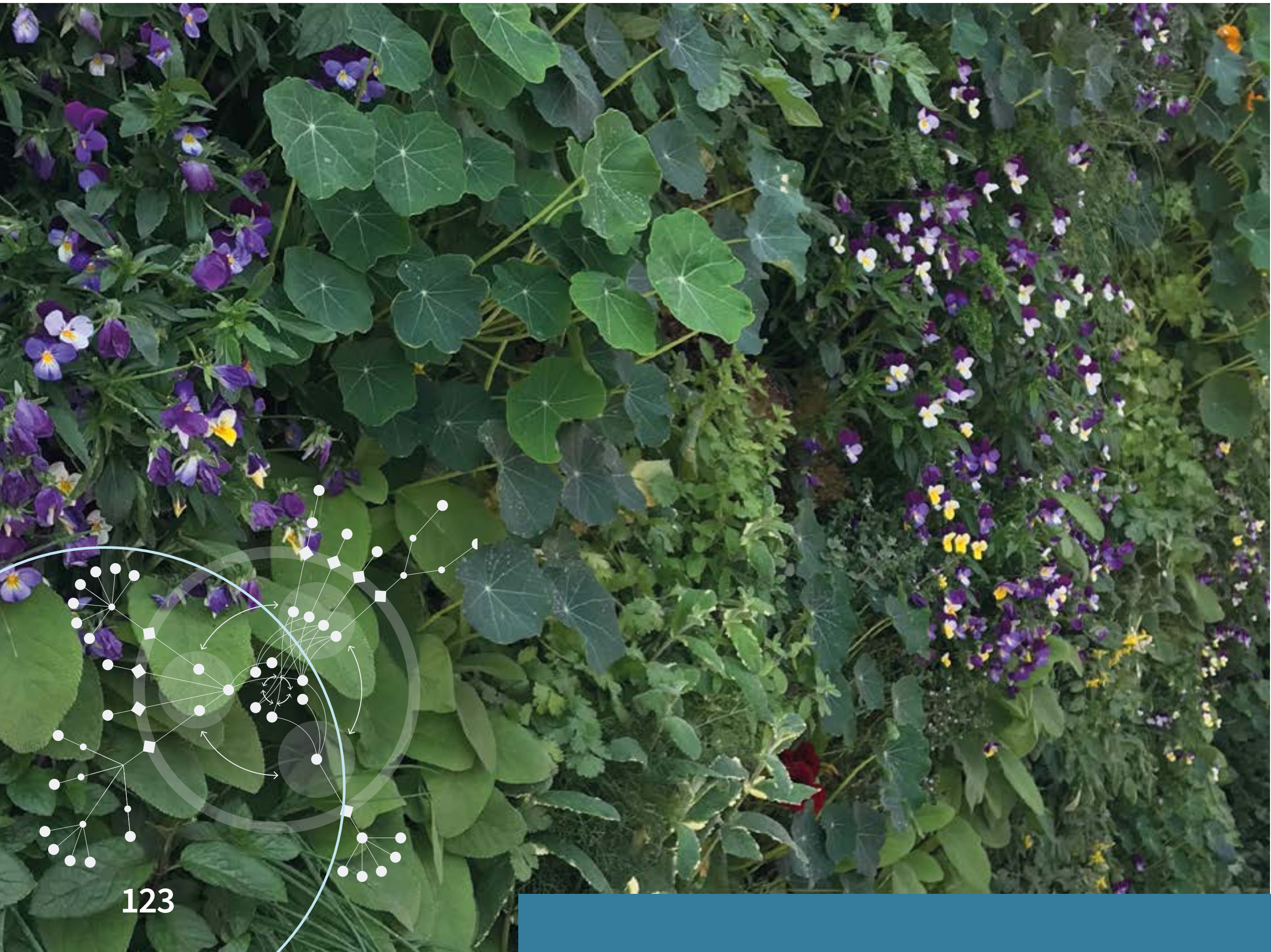
- **Increasing tree, shrub and hedgerow cover**. New trees can be planted, or areas can be left to regenerate naturally if there is a seedbank in the soil or woodland nearby. Natural regeneration will avoid the initial loss of carbon that occurs when soil is disturbed during tree planting, though the sequestration rate may be slower at first as it takes longer for trees to establish.
- **Restoring other habitats**. Semi-natural grasslands, shrub, heath and wetlands can store large amounts of carbon in soils. Ponds and waterbodies also sequester carbon in their sediments, as well as being relatively quick and easy to create. Rewilding an area through natural regeneration can lead to a diverse mix of habitats with significant biodiversity benefits.
- **Sustainable agricultural management** can reduce emissions and enhance soil carbon, such as through use of cover crops, no-till agriculture and/or organic farming methods.
- **Bioenergy crops**. Short rotation coppice or *Miscanthus* grass can be grown for bioenergy, although the net carbon benefit depends on the life cycle emissions after energy use for planting, fertilising, harvesting and processing is taken into account.
- **Urban green infrastructure** such as green walls, green roofs, parks, street trees and sustainable drainage systems can store carbon while providing a range of other benefits such as stormwater management and urban cooling.[167]

167 Schüder, I (2020), Making the case for investing in Green Infrastructure in Oxfordshire. A report commissioned by Oxfordshire County Council.

Photo: Dmitry Grigoriev on Unsplash

9.4.1 Making space for sequestration

Creating woodland or other semi-natural habitats, growing bioenergy crops or installing solar panels will involve loss of farmland. This is turn could simply displace emissions, because land elsewhere, either in the UK or overseas, could be converted to farmland to replace the lost food production. In fact, this could even lead to an increase in emissions if production shifts to less productive land, or if high carbon habitats such as tropical forests are converted to farmland as a result. There are various options for avoiding or reducing this emission 'leakage' and freeing up space for carbon sequestration:



- **Avoiding loss of high grade farmland** (grades 1, 2 or 3a) will reduce the impact of land-use change.
- **Dietary change**. Half of all wheat production and two thirds of all barley production in the UK is for animal feed,[168] so cutting meat and dairy consumption will significantly reduce the area needed for both cropland and grazing land. It will also reduce direct GHG emissions of methane from enteric fermentation in the guts of cattle and sheep and nitrous oxide from manure production and fertiliser use, thus reducing the need for other land-using emission reduction options such as biofuel production for BECCS.
- **Reducing food waste**. Similarly, reducing the estimated 14% of food that is currently wasted in UK households and the additional amount wasted in the supply chain will reduce both the area of land needed to produce food and also the direct emissions from producing, transporting, storing and disposing of wasted food.
- **Increasing agricultural productivity** can reduce land requirements, but this may also increase emissions and environmental impacts such as water and air pollution if it involves additional fertiliser use or mechanisation.
- **Agroforestry** (trees in pasture or among crops), hedgerow trees, street trees and trees in residential gardens can all add trees to landscapes without reducing agricultural production.
- **Reducing the land lost for new urban development**, including by increasing housing density (e.g. more mid-rise buildings and flats), making use of brownfield sites, building close to existing rail stations and other public transport hubs to remove the need for new roads, encouraging active travel and car sharing to reduce need for car park space, building compact mixed developments, and focusing on meeting the local need for affordable housing rather than large investment properties.

Photo: Steph Ferguson

168 Defra (2020), Agriculture in the UK Statistics, Tables 7.2 and 7.3.

9.5 Scenario definitions

Here we describe in more detail how we have applied the four scenarios presented in Chapter 4 to the land use sector.

9.5.1 Development and green infrastructure

As described above, urban development on greenfield sites involves direct loss of carbon as topsoil is removed and vegetation cleared, and also reduces the land available for future carbon sequestration or renewable energy options, as well as potentially displacing food production and associated emissions elsewhere. Reducing the footprint of new developments is therefore critical to enable land use to contribute to emission reduction. However, there is a trade-off between increasing the dwelling density and building in essential green infrastructure to provide health and wellbeing benefits, green travel routes and habitat for wildlife.

It is also vital to protect existing habitats within new developments. For example, the plans for North-West Bicester Eco-town were designed to preserve existing hedgerows, woodlands and streams, building them into an attractive active travel network of footpaths and cyclepaths.

We assume that in the **Societal Transformation** and **Oxfordshire Leading the Way** scenarios, strong planning policies such as supplementary planning guidance are used to insist on sustainable, compact mixed developments with high quality walking and cycling infrastructure. Local plans allocate land for development that is close to existing or new rail stations and bus routes. Education and awareness campaigns encourage a shift to active travel, car sharing and public transport use that enables car ownership to be reduced to one car or less per household, thus reducing the area required for car parking.

Although all dwellings have some private outdoor space, there is less emphasis on large private gardens and greater provision of shared green spaces including wooded areas and sustainable drainage systems such as raingardens and retention ponds. All newly built flats, schools and commercial buildings feature green roofs on half of the roof area, with green roofs covering 14% of total rooftop area across the county by 2050. All semi-natural habitats are protected from development and any existing hedgerows and trees are incorporated into the design as green infrastructure features. Together with greater use of mid-rise (3 and 4 storey) dwellings and flats, and a focus on delivering affordable housing, this increases typical housing density to 60 dwellings per hectare (d/ha).

In contrast, the **Steady Progression** scenario remains at the current average density of around 20 d/ha, and the **Technological Transformation** scenario shows some improvement but only achieves a density of 30 d/ha; both these scenarios fail to protect existing habitat features and therefore more carbon is lost due to site clearance.

9.5.2 Food production

With current diets, there is only enough farmland in the county to produce the equivalent of 74% of our food requirements[169] (see Annex 1 for methodology). This would decrease to 41% by 2050 as the population grows from 650,000 to 1,000,000, driven by construction of new housing. This means that Oxfordshire imports a significant level of 'embodied emissions' in the food that is produced elsewhere.[170]

169 Winney (2020), Land-use trade-offs between a proposed Nature Recovery Network, housing and food production in Oxfordshire. MSc dissertation, Environmental Change Institute, University of Oxford. Based on extrapolation of the analysis for Oxford City using relative populations. Low Carbon Oxford (2016) FoodPrinting Oxford: How to feed a city.

170 Low Carbon Oxford (2016), FoodPrinting Oxford: How to feed a city.

Under **Societal Transformation** and **Oxfordshire Leading the Way**, we assume that there is a successful campaign to persuade people to eat 75% less meat. This is in line with the Livewell diet advocated by the World Wide Fund for Nature, which in turn is derived from a low-carbon version of the Eatwell Plate recommended by Public Health England for a healthy balanced diet.[171] This could free up 34,000 ha of farmland (13% of the current farmland area) for other uses while also allowing Oxfordshire to effectively meet the equivalent (in terms of calories) of 100% of its own needs for food production at present, although this would fall back down to 74% by 2050 due to population growth.

Under the **Technological Transformation** scenario, there is no dietary change but there is a focus on increased productivity in farming. This includes use of gene editing and GMO techniques, more use of artificial intelligence for precision agriculture, and more indoor cultivation for horticulture such as vertical farming and hydroponics (although horticulture uses a very small proportion of farmland). In the CCC scenarios,[172] there is an assumption that crop productivity increases by 39% (Medium ambition) or 65% (High ambition), though this is acknowledged to be very ambitious as yield increases for the main UK cereal crops have stalled in recent decades.[173] In our scenario we assume that crop productivity increases by 39%, in line with the CCC Medium Ambition scenario, and that livestock productivity increases by 10% due to improvements in animal health. For **Steady Progression** we assume an increase of 10% for crops, in line with recent trends, and no increase for livestock. For the other two pathways we assume an intermediate increase of 20% for crops and 5% for livestock.

171 WWF (2017), Livewell diet revised report.

172 CCC (2018), Land use: Reducing emissions and preparing for climate change.

173 For example the five year average wheat yield has increased by 6% since 2000, from 7.8 to 8.4 t/ha. From analysis of Defra (2020), Agriculture in the UK, Table 7.2.

Although conventional arable cultivation results in a large loss of soil carbon due to erosion and oxidation when soils are ploughed, there is a significant potential for reversing this loss through ‘regenerative agriculture’ techniques. These include low or no-till agriculture, use of cover crops to prevent soil erosion, adding manure or compost to the soil, reduction of over-grazing, and use of a more diverse mix of plant species in pastures. For example, arable soil carbon levels at East Hendred Farm have doubled from approximately 3% to 6% over ten years. A recent study showed that these techniques can increase soil carbon by around 18%.[174] Although it is likely that soil carbon will eventually saturate, the large area of farmland means that even an increase of a few percent in soil carbon could be significant if widely replicated across the county. In Oxfordshire, FarmEd[175] are leading a drive to raise awareness of regenerative agriculture, and Tolhurst Organics (see case study) have shown how carbon-negative farming is possible even without the use of animal manure.

We assume that under **Steady Progression** and **Technological Transformation**, regenerative agriculture remains a niche activity, growing to cover only 1% of farmland by 2050. Under **Societal Transformation** and **Oxfordshire Leading the Way**, we assume that there is widespread uptake of these techniques, reaching 50% of all farmland by 2030 and 80% by 2050, with consequent benefits for carbon sequestration as well as biodiversity and soil erosion.

174 Crystal-Ornelas et al (2021), Soil organic carbon is affected by organic amendments, conservation tillage and cover cropping in organic farming systems: a meta-analysis.

175 FarmEd, What is regenerative agriculture?

Case study: Tolhurst Organics

Tolhurst Organics lies just outside the village of Whitchurch-on-Thames in south Oxfordshire. It is one of the UK's longest established organic vegetable growing business, with a 7 ha field and a 1ha walled garden. The main income source is a veg box scheme supplying families in Reading and Oxford.

Environmental awareness is at the core of the business, with the aim of supplying vegetables to customers with the lowest possible carbon footprint. In 2012, a study by University of Surrey found that total emissions of the farm came to 16.6 t/ CO_2e per year, less than the total sequestration of 21t of CO_2e per year, meaning the whole farm was 'carbon positive' by over 4t CO_2e per year.

With no animals on site, the farm has managed to continually build organic matter levels without the use of external inputs. This is achieved through use of green manures and a tillage policy of shallow and timely cultivations. Additional sequestration is provided by creating habitat for wildlife. Hedgerows are allowed to grow wide, accounting for 17% of total sequestration; a small woodland area and a willow coppice account for over 24% of sequestration, and 9% is from field margins.

9.5.3 Solar power

In the **Societal Transformation** (ST) and **Oxfordshire Leading the Way** (OLW) scenarios we assume that efforts are made to reduce the displacement of food production by integrating solar power with agriculture, using the 'ag-electric' techniques described in Chapter 8, for half of the area of solar farms, split equally between arable and grazing land. There is also more support for rooftop solar, with 25% of solar capacity installation being on rooftops in ST and 30% in OLW. Solar panels cover 9% of the total rooftop area in ST, and a very ambitious 20% in OLW, by 2050.

In **Technological Transformation**, there is a less strategic approach to land use and the focus is more on energy technology, so solar farms are not shared with food production. Only 10% of solar capacity is installed on roofs. This effectively displaces food production out of the county, causing displaced emissions as land elsewhere is converted for agricultural use.

9.5.4 Planting trees and restoring other habitats

Ongoing work to create an Oxfordshire Tree Opportunity Map considers opportunities for different types of woodland, agroforestry, hedgerows and street trees. The goal is to double tree cover in Oxfordshire from the current 9% (23,000 ha) to 18%, which is consistent with the High Ambition scenario in the CCC land use and climate report. We have built on the methodology being used to create the Tree Opportunity Map for our scenario assumptions (see Annex 1).

Under **Steady Progression**, we assume a modest rate of new woodland planting of 60 ha per year, driven by continued agri-environment and biodiversity net gain funding. This is consistent with the National Forest Inventory, which records a 72 ha increase per year from 2014 to 2018, some of which could be due to improved accuracy of the inventory. Restoration of other habitats is limited to 5 ha per year of semi-natural grassland.

Under **Societal Transformation** and **Oxfordshire Leading the Way**, we assume that dietary change frees up large amounts of farmland for tree planting and habitat restoration, enabling tree cover to be doubled. With farmers, local authorities and residents all committed to this goal, this is achieved not just through planting woodlands on farmland but also through agroforestry, new hedgerows (half of field boundaries currently have hedgerows; we assume this increases to 75%), and new trees in urban parks and amenity green space (such as round the outside of playing fields) and residential gardens.

In line with the Tree Opportunity Map guidance,[176] there is a strong emphasis on planting the right trees in the right place, avoiding high grade farmland in order to minimise loss of food production. Biodiversity co-benefits are maximised by favouring a diverse mix of native broadleaves such as beech, oak and native shrubs, and not planting trees on priority habitats such as semi-natural grassland.

A range of other carbon-rich habitats are also restored, doubling the area of shrub, heath, wetlands, chalk grassland, dry acid grassland and floodplain meadows from 4.5% to 9% (Table 9.3). This habitat restoration and native woodland planting will be primarily targeted within the Nature Recovery Network in order to help connect existing habitats.

Floodplain meadows are particularly important, as only 3% remain in England, with the rest being lost for intensive agriculture or development. Restoration, by reconnecting rivers with their floodplains and ceasing arable cultivation, can boost carbon sequestration, reduce soil loss and improve water quality. Some of the meadows in Oxfordshire are already being restored and there is good potential for further restoration (see Chimney Meadows case study).

In contrast, under **Technological Transformation**, there is less willingness to change behaviour (including diet), as society relies on technical solutions. This constrains the amount of land available for tree planting, and there is also reluctance from farmers, local authorities and residents to add agroforestry, hedgerows and urban trees. As a result, the target to double tree cover is not met, with only around 6,000 ha being added by 2050. The trees planted are mainly fast-growing non-native monocultures destined for harvested wood products including biofuel, so there are few benefits for biodiversity, and even a loss of biodiversity as, with a less strategic and co-ordinated approach to land use, some trees are planted on high-value habitats such as floodplains and high grade farmland. There is no further restoration of open habitats, because tree-planting is prioritised.

176 Oxfordshire Trees for the Future, Creating a tree opportunity map.

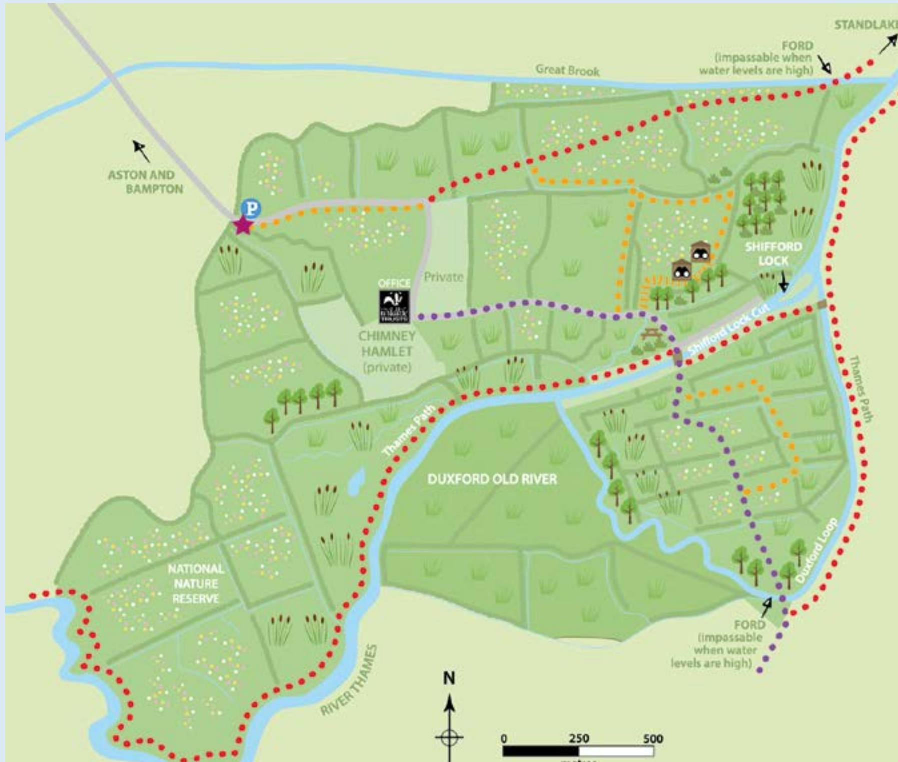
Case study: Chimney Meadows Wetland Restoration Project

Partners: Berks, Bucks & Oxon Wildlife Trust (BBOWT), Hydro International, and The European Agricultural Fund for Rural Development, Environment Agency, Oxfordshire County Council

- Annual net mitigation of –484.59 t/CO_2e through carbon sequestration
- Planned creation of 'naturalised' bypass channel of ~550 m to create new wetland habitat and improve fish passage
- Plans to use ~46 ha of land around Duxford Ford for floodplain restoration

Chimney Meadows is a 308 ha nature reserve near Bampton, Oxfordshire. It is part of a chain of nationally important wetland habitats in an ancient floodplain landscape formed by the Thames and has been shaped by farming over centuries. Most of the reserve was intensive arable farmland prior to 2003, when BBOWT started to restore the area to a mosaic of floodplain meadows, wetlands, pasture and wet woodland. As part of these restoration efforts, it has been estimated that creation of 88 ha of species-rich meadow together with 6 ha of woodland, scrub and hedgerows would sequester an additional 484 tCO_2/year. Additional carbon benefits are expected from a new Wetland Restoration Project at Duxford Old River Land, which was added to the reserve in 2017.

The reserve provides other ecosystem services including flood protection, water quality regulation, health and recreation benefits and wild species diversity. Renaturalising the floodplain so that the land floods earlier and retains water longer will help to protect communities downstream from flooding, while the reedbeds and meadows will help filter out pollutants, improving water quality. The restored habitats provide huge benefits for biodiversity, including iconic species such as the Curlew and Water Vole, and there are plans for a new fish passage, a naturalised bypass channel of around 550 meters connected to the Thames through culverts. If planning permission is granted this work would begin in the Summer of 2021.



9.5.5 Bioenergy

The UK currently imports most of its bioenergy resources. For example only 11% of the feedstock for transport biofuels was produced in the UK in 2019.[177] Imports have grown from 11 TWh in 2008 to 40 TWh in 2017, driven by the Renewables Transport Fuel Obligation, the Renewable Heat Incentive (biomass boilers) and the Renewables Obligation (electricity generation).[178] Only 96,000 ha was used for bioenergy crops in the UK in 2019, 1.6% of the UK's arable land. This was mainly maize for anaerobic digestion, with smaller amounts of wheat and sugar beet for bioethanol, Miscanthus and short rotation coppice.[179]

All four scenarios depend on increasing use of bioenergy, as a transport fuel for HGVs, aviation and shipping; for biomass heating; and for BECCS as a negative emission technology. However, to produce the feedstocks locally would require between 37% and 56% of the land in Oxfordshire (see Annex 1), which would displace food production to other locations in the UK or overseas. We have therefore specified a much lower area of biofuel production in our scenarios, acknowledging that the remainder must be imported. Although the UK has set criteria for 'sustainable' biofuel production, producing such large quantities of biofuel feedstock will inevitably compete with land needed for food production or wildlife habitat overseas, leading to indirect impacts on GHG emissions and biodiversity.

177 Department for Transport (2020), Energy and Environment Data Tables ENV0502 Renewable fuels by country of source feedstock.

178 National Grid ESO (2020), Future Energy Scenarios July 2020. Interactive report, p61.

179 Defra (2020), Area of crops grown for bioenergy in England and the UK, 2008 to 2019 dataset.

For comparison, the Climate Change Committee's high ambition land use scenario assumes that 1.2 Mha is used for bioenergy crop cultivation in the UK, of which Oxfordshire's share (based on energy demand) would be around 17,000 ha. However this is only for Miscanthus, short rotation coppice and forestry, not transport biofuels which presumably will have to continue to be imported.

Additional energy demand reduction and deployment of renewable energy, going beyond the FES scenarios, could reduce the need for BECCS, thus reducing the need for bioenergy imports and associated impacts. For example, there is potential for further behaviour change such as switching off unused lights and appliances or changing social norms regarding thermal comfort (so that heating thermostats can be adjusted downwards). This would be consistent with an extended version of the ST and OLTW scenarios.

9.6 Scenario analysis

9.6.1 Carbon impacts

Table 9.1 shows the impact of the four scenarios on the carbon stored in soils and vegetation in Oxfordshire, as tonnes of carbon and the equivalent CO_2. Under **Steady Progression**, stored carbon decreases from 23 Mt in 2020 to 21.5 Mt carbon by 2050 as land is lost to development. However, the three net-zero pathways all enhance stored carbon as well as increasing the ability of ecosystems to sequester carbon in future years. **Societal Transformation** stores and sequesters the most carbon, with net sequestration reaching 19% of the current annual emissions by 2050. This is possible because farmland is freed up for tree-planting and habitat restoration due to dietary change, more compact developments reduce land take, and existing high-carbon habitats are protected from development.

Oxfordshire Leading the Way stores a little less carbon because more land is taken for biofuel production and ground-mounted solar installations. In **Technological Transformation**, some farmland is freed up through improved agricultural productivity but net sequestration is lower, at 11% of current annual emissions.

However, these estimates do not include the impact of emissions produced outside Oxfordshire from imports of food and biofuels (see next section). Although these 'Scope 3' emissions are outside the scope of this report, it is important to be aware of them.

Table 9.1 Carbon stored and sequestered by soils and vegetation in the baseline (2020) and each scenario in 2050.

Carbon	Baseline	SP	ST	TT	OLTW
Carbon stored, Mt C	22.9	21.1	27.5	23.8	25.1
Carbon sequestered, kt C/y	116	109	217	146	203
Carbon loss due to development, kt C/y	−30	−29	−6	−21	−6
Net carbon sequestration, kt C/y	86	80	212	125	198
Carbon sequestered 2020 to 2050, Mt C	3.5	3.3	6.5	4.4	6.1
Carbon loss due to development 2020 to 2050, Mt C*	−0.9	−0.9	−0.2	−0.6	−0.2
Net carbon sequestered 2020 to 2050, Mt C	2.6	2.4	6.3	3.7	5.9
CO_2	**Baseline**	**SP**	**ST**	**TT**	**OLTW**
CO_2 stored, Mt CO_2	83.9	77.2	100.7	87.4	91.9
CO_2 sequestered, kt CO_2/y	424	401	796	536	746
CO_2 loss due to development, kt CO_2/y	−109	−106	−21	−78	−21
Net CO_2 sequestration, kt CO_2/y	315	295	776	458	725
CO_2 sequestered 2020 to 2050, Mt C	12.7	12.0	23.9	16.1	22.4
CO_2 loss due to development 2020 to 2050, Mt CO_2*	−3.3	−3.2	−0.6	−2.3	−0.6
Net CO_2 sequestered 2020 to 2050, Mt CO_2	9.5	8.8	23.3	13.7	21.7
CO_2 sequestered as a % of total 2018 CO_2 emissions from all sources (BEIS estimate 4.1 Mt)	8%	7%	19%	11%	18%

* Carbon loss due to development is the carbon lost due to vegetation clearance and removal or disturbance of soil when sites are prepared for development, which is assumed to occur in the year the development takes place (although actually soil carbon loss may continue over several years from the date of clearance).

9.6.2 Constraints on available land

Although there is good potential to enhance carbon storage and sequestration by Oxfordshire's ecosystems, there will be trade-offs with other carbon reduction options and housing development, as shown in Table 9.2. The top part of the table shows the land use change for the different carbon reduction options in each scenario and the lower part shows how this affects the proportion of Oxfordshire's demand for food and bioenergy feedstock crops that can be met within the county.

As mentioned in section 9.5.2, Oxfordshire currently has enough farmland to produce the equivalent of 74% of its food requirements, so 26% has to be imported, which will cause emissions elsewhere. However, shifting to the Livewell diet with 75% less meat consumption would currently enable the county to produce all of its food requirements as well as freeing up 34,000 ha of land for other uses. Nevertheless, even with the Livewell diet, the scale of population growth planned for Oxfordshire would reduce food self-sufficiency back to only 74% by 2050. Under **Steady Progression**, loss of farmland due to planned housing developments reduces food production so that by 2050 only 40% of our food requirements can be met. Under the zero carbon pathways, additional loss due to ground-mounted solar, tree planting, biofuel feedstock crops and habitat restoration places further pressure on food production, but this is partly offset by agricultural productivity improvements.

Table 9.2 Constraints on land use and implications for imported impacts

	Steady progression		Societal transformation		Technological transformation		Oxfordshire leading the way	
	2030	2050	2030	2050	2030	2050	2030	2050
Farmland used for tree planting, hedgerows, scrub or wetland (ha)	605	1815	6228	18685	2094	6282	5562	16685
Farmland restored to rough grazing (grassland or heath) (ha)	50	150	2667	8000	0	0	1333	4000
Hectares of land used for ground-mounted solar generation	390	670	610	1,500	610	1,200	600	2,600
Hectares of land used for bioenergy feedstock crops	0	0	10,000	10,000	20,000	20,000	25,000	25,000
Land converted to buildings and sealed surfaces	6,000	9,342	2,225	3,483	4,539	6,974	2,225	3,483
Land converted to private gardens	1,289	2,272	980	1,429	859	1,576	980	1,429
Land converted to public urban green space	1,879	3,213	1,667	2,838	1,621	2,795	1,667	2,838
Total area of new development	9,168	14,827	4,871	7,751	7,020	11,345	4,871	7,751
Farmland lost to development	7,746	13,404	4,871	7,751	5,597	9,922	4,871	7,751
Total farmland lost for housing and carbon reduction	**8,778**	**16,001**	**23,710**	**43,936**	**28,301**	**37,404**	**37,033**	**55,036**
Crop productivity increase compared to 2020	5%	10%	10%	20%	13%	39%	10%	20%
Livestock productivity increase compared to 2020	0%	0%	2%	5%	3%	10%	2%	5%
Population (driven by housing increase)	814,326	1,000,458	814,326	1,000,458	814,326	1,000,458	814,326	1,000,458
Farmland required to feed Oxfordshire (ha) without productivity improvements	280,505	408,179	168,172	244,717	280,505	408,179	168,172	244,717
Farmland required to feed Oxfordshire (ha) with productivity improvements	277,301	399,279	160,001	221,703	267,310	358,342	160,001	221,703
Farmland remaining (ha)	167,366	160,143	152,434	132,208	147,843	138,740	139,111	121,108
Percentage of food demand met in Oxfordshire	**60%**	**40%**	**95%**	**60%**	**55%**	**39%**	**87%**	**55%**
Percentage of bioenergy feedstock crop demand met in Oxfordshire	**0%**	**0%**	**10%**	**10%**	**20%**	**20%**	**17%**	**17%**
Hectares of land outside Oxfordshire needed for food (assuming same productivity)	109,934	239,136	7,567	89,495	119,467	219,602	20,890	100,595
Hectares of land outside Oxfordshire needed for bioenergy feedstock crops	96,447	96,447	88,724	88,724	80,113	80,113	122,006	122,006

Under **Societal Transformation**, a combination of the Livewell diet and more compact housing development reduces the pressure on farmland, so that 95% of food demand can be met in 2030, but population growth reduces this to 60% by 2050. **Oxfordshire Leading the Way** is similar, but higher solar and biofuel production means that food sufficiency is slightly lower, at 87% in 2030 and 55% in 2050. **Technological Transformation** has double the improvement in agricultural productivity, but without dietary change food production falls to 39% of demand by 2050.

9.6.3 Summary: Is net-zero or zero carbon possible?

Although we have shown how the land use sector within Oxfordshire can be a net sink for emissions, can it reach zero carbon emissions, and what role can it play in helping the UK as a whole to reach net-zero, by offsetting residual emissions from sectors such as aviation and heavy industry?

To reach strict Zero Carbon, we would have to completely eliminate carbon emissions from the oxidation of soil organic matter and decay of vegetation that occurs when land is cleared for development, cultivated for agriculture or prepared for tree-planting. In the farming sector, all farming would have to be regenerative, i.e. more organic matter would need to be added to the soil than removed. The case study of Tolhurst Organics shows that this is possible, through the addition of compost and use of cover crops, while other regenerative agriculture projects are exploring new techniques such as mob grazing. However, zero carbon would also require an end to all development that removes topsoil and vegetation (i.e. all conventional housing and infrastructure development), leaving only the option of development on brownfield land.

Our analysis indicates that the less stringent target of net-zero within the land use sector in Oxfordshire is already being achieved at present, as sequestration offsets the annual losses from agriculture and development. However this does not take account of embodied emissions in the food and biofuels that we currently import, which we have not been able to quantify within the scope of this report. We are likely to move further away from this goal as the population increases.

Housing growth within Oxfordshire (and the wider OxCam Arc) indirectly affects our ability to contribute to net-zero for the UK as a whole. The Arc has a high proportion of the UK's most productive agricultural land: it covers 8.8% of England but contains 20.5% of the Grade 1 land, 15% of Grade 2 and 9.5% of Grade 3. Large scale housing growth on productive farmland in this region will displace food production to less productive areas, which is likely to increase overall emissions.

9.7 A pathway for sustainable land use decisions in Oxfordshire

This analysis has shown that a significant amount of carbon is stored in Oxfordshire's soils and vegetation, but this is at risk as habitats are cleared for housing or renewable energy development. There is potential to enhance carbon stocks and sequester as much as 20% of current annual emissions, but this depends on land being freed up through consumer choices to eat less meat, and strong planning policy to reduce the land taken and habitats lost to development.

However, even with optimum land use policies, the high projected growth in population will limit our ability to meet food and bioenergy demands within the county, meaning that a high proportion must be imported. This will lead to further emissions elsewhere, undermining efforts to reach net-zero within the county boundary. This highlights the importance of pursuing efforts to minimise the footprint of new development, encourage dietary change, cut food waste, sustainably enhance agricultural productivity, encourage land sharing for solar and food production, and reduce energy demand.

These measures not only reduce carbon emissions but also have significant potential health and economic co-benefits. For example, food waste costs the average family £700 per year, and over-consumption of animal produce is associated with health issues including obesity, diabetes and cancer.

If well planned, sequestration options such as woodland planting or habitat restoration can help to provide a range of other benefits including natural flood management, air and water quality improvement, soil erosion protection, and pleasant green spaces for recreation. Benefits for health and wellbeing can be maximised by locating new woodland and parkland close to where people live, such as in the Oxford greenbelt. Networks of attractive tree-lined footpaths and cycle paths can also encourage active travel, while green space and street trees can help to reduce the urban heat island effect and reduce surface water flooding. Investing in nature thus helps to make landscapes and communities more resilient to future climate change impacts.

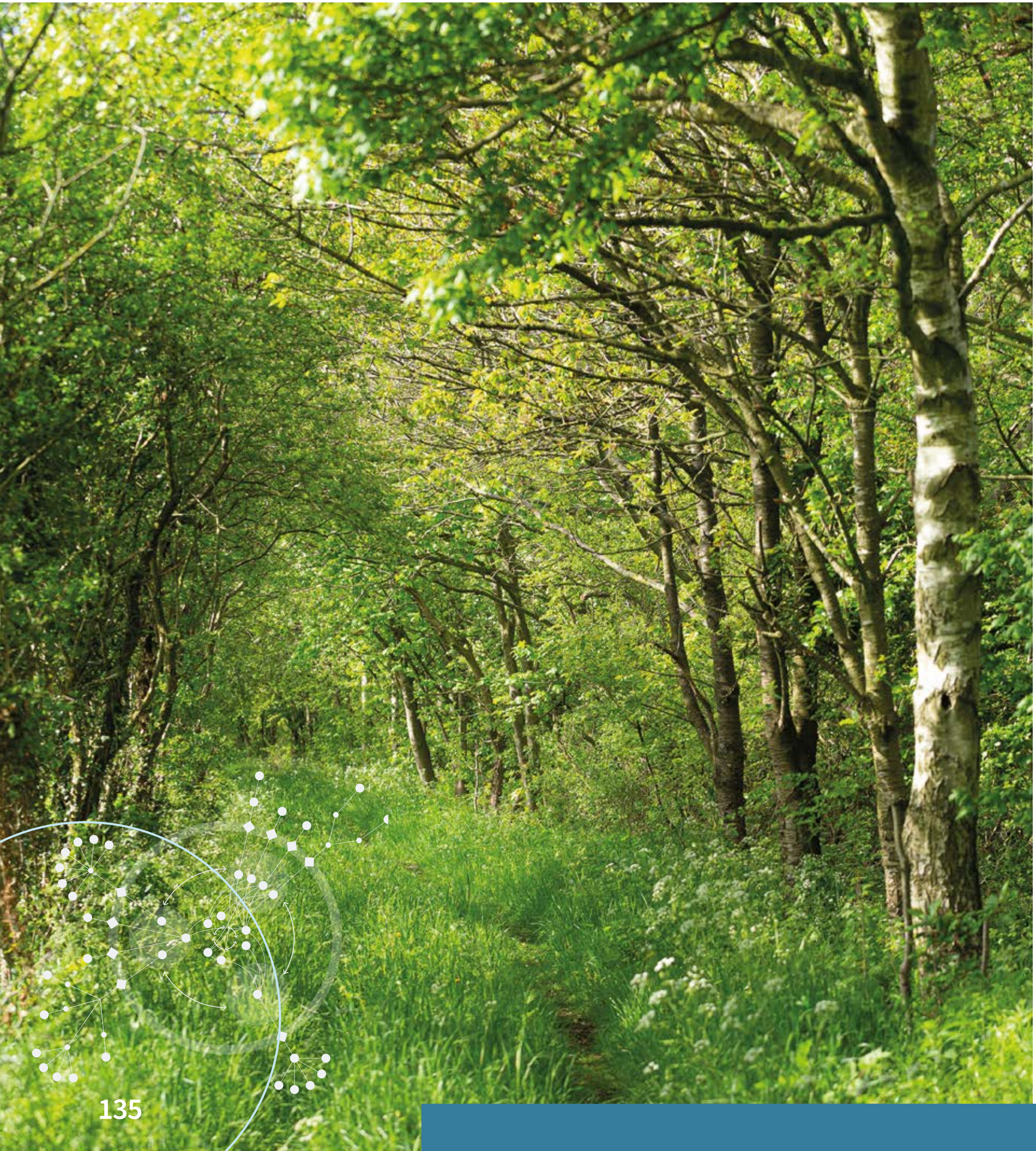
The economic and social value of these additional ecosystem service benefits can be very significant, as demonstrated in the OxCam Arc Local Natural Capital Plan pilot[180]. A recent report on the benefits of investing in Green Infrastructure in Oxfordshire suggests that investing £50M per year over 30 years could bring benefits worth £6 billion.[181]

There is strong potential for significant biodiversity benefits but only if interventions are planned carefully, using a diverse mix of native species, maintaining a balanced mix of habitat types and locating the right habitat in the right place. For example, floodplains are best restored as floodplain meadows, which are a nationally scarce habitat, rather than being used for planting woodland. Trees should never be planted on the few remaining examples of semi-natural grassland or heathland remaining in Oxfordshire.

Plantations of faster growing, non-native conifer species are useful for providing timber and typically sequester carbon at a higher rate than native trees for the first few decades of growth, but this carbon may be released when the trees are harvested, unless the wood is used to make long lived timber products. However, non-native tree species have little biodiversity value compared to native trees such as oak and beech that support hundreds of species of insects, birds, bats and fungi. In future, there is a need to select a diverse mix of species that are resilient to expected climate change, pests and diseases.

180 Ox Cam LNCP.

181 Schüder, I (2020). Making the case for investing in Green Infrastructure in Oxfordshire. A report commissioned by Oxfordshire County Council.



There can also be trade-offs associated with woodland management. For example, targets to 'bring more woodlands into sustainable management,[182] involve regularly thinning and extracting trees and clearing understorey vegetation and shrubs to provide woodfuel and timber and promote tree growth. This large scale extraction of biomass gives woodlands a 'tidy' appearance appreciated by some visitors but can have negative impacts on biodiversity by removing cover and food resources for birds and other wildlife, which affects other visitors adversely.[183] However, other management options such as leaving hedgerows to grow larger rather than trimming every year can have benefits for both carbon storage and wildlife.

All land use change options will affect not only biodiversity but also landscape, heritage and amenity. These are important considerations when planning solar farms, biofuel plantations, afforestation, housing and infrastructure.

To maximise co-benefits and avoid undesirable trade-offs, stakeholders need to be supported to work together, ideally via the proposed Local Nature Partnership. Landowners and farmers need the right support and incentives to be able to protect and restore ecosystems on their land. Forthcoming changes to agri-environment support mechanisms such as the proposed ELMs scheme, replacing the CAP mechanisms, will be critical, as will the forthcoming Biodiversity Net Gain legislation, but there is much that local stakeholders can also do to develop and promote best practice. There is also a need for better metrics, monitoring and assessment of the actual carbon and biodiversity impacts of different habitat restoration options being conducted in Oxfordshire.

182 Sylva Foundation and TOE (2016), In a nutshell.

183 Heyman, E et al. (2011). Openness as a key-variable for analysis of management trade-offs in urban woodlands. *Urban Forestry & Urban Greening*, 10: 281–293.

Photo: David Griffiths on Unsplash

10 Conclusions and recommendations

This report has provided a comprehensive assessment of Oxfordshire's carbon emissions, including recent trends in transport, the built environment, energy and land use. The county is currently on track to achieving the 50% emissions reduction target by 2030 set out in the Oxfordshire Energy Strategy, on the basis of substantial achievements in decarbonising electricity supply and increased energy efficiency. However, progress remains slow when it comes to decarbonising transport, reducing reliance on fossil fuels for heating, and enhancing the natural environment for increased carbon sequestration.

Photo: Ben Seymour on Unsplash

This study set out four scenarios for Oxfordshire from today to 2050. Our **Steady Progression** scenario falls well short of stated climate aims, and illustrates the scale of change needed to achieve net-zero. The three pathways which achieve net-zero by 2050 adopt distinct approaches to eliminating carbon emissions from Oxfordshire's economy. **Societal Transformation** is led from the bottom up, with householders adopting new technologies and practices, and community groups corralling action. **Technological Transformation**, by contrast, relies on systemic changes driven at the national level, including the deployment of hydrogen for heating and other technical solutions which require the least change to individual behaviour. Finally, **Oxfordshire Leading the Way** mirrors the widespread cultural and behavioural changes seen in **Societal Transformation**, and combines this with high deployment of new local electricity generation using solar photovoltaics.

Despite their distinct differences, the three net-zero pathways have several features in common, with similar implications. Each of them involve:

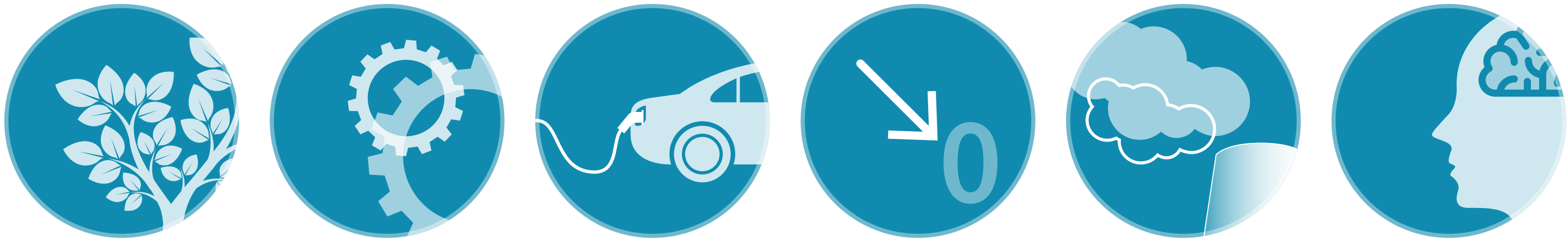
- the substantial expansion of solar generating capacity in Oxfordshire. Large ground-mounted solar parks are preferred in **Technological Transformation**, with others seeing the widespread deployment of rooftop arrays. The business case for new installations will rely on the falling price of photovoltaic panels and battery storage, and will face the challenge of geographically varied grid constraints.
- a major programme of retrofit for existing homes and non-domestic buildings, led by strong and consistent national policy including significant subsidy.
- a strict approach to planning, regulation and compliance for new homes and developments so that they do not result in increased carbon emissions from the building, transport, or energy sectors.
- substantial increases in electricity demand, driven by heat and transport, requiring grid reinforcement and flexibility provided by various means.
- the phase out of gas boilers and fossil-fuelled modes of transport.
- a need for innovation in food production to maintain or increase output while agricultural land makes way for development, and Oxfordshire grows its fair share of biofuels.
- a reduction in overall travel demand.
- restoration of ecosystems and natural capital, for enhanced sequestration and increased biodiversity.

10.1 High level implications for local policy and community action

Co-benefits of the transition. If the phase-out of carbon emissions is managed effectively, there are a variety of economic, social and environmental benefits which can be achieved. These include the creation of high-skilled, well paid jobs in the zero carbon sector; creating cohesive and desirable places to live by empowering local communities to drive action; improving air quality; improving health through active travel and energy efficient homes; and regenerating ecosystems and habitats for wildlife.

Oxfordshire Leading the Way is the scenario which is likely to generate most co-benefits. Here, the transition is community-led, involving lifestyle change and innovative business models which drive the circular economy. Although substantial investment is required, the benefits of this are felt locally, with a high proportion of clean energy installations owned by local residents, and zero carbon products and services delivered by local businesses. By contrast, **Technological Transformation** sees fewer co-benefits in Oxfordshire, as investments are focused outside the county into hydrogen production, CCS and offshore wind, and there are even some trade-offs for biodiversity.

Shattering myths



"We should plant trees to offset our emissions"

... we need to protect existing trees, but planting new trees can remove only a small fraction of current emissions, and we need to restore a mix of native ecosystems to reverse biodiversity loss.

"We need a more skilled & qualified workforce"

... the skills challenge is not just a supply problem, we also need demand for skills, which means new kinds of jobs and business models in new markets for zero-carbon solutions.

"Electric vehicles are coming to save us"

... switching to cleaner fuels is insufficient for net-zero. We also need to reduce our transport demand and complete more of our journeys by walking, cycling, public and shared transport.

"Net-zero can be achieved by 2030"

... without relying on offsets,and without significant new powers for local authorities, achieving net-zero ahead of the national target will be extremely challenging.

"Fossil fuels are needed for economic growth"

... renewable energy and other zero-carbon solutions represent opportunities for more efficient use of resources. Unlike spending on fossil fuels, investment can be kept local.

"It all comes down to individual behaviours"

... while lifestyle change and sustainable choices will be crucial, these are influenced by infrastructures, systems of provision and social norms. Reshaping these requires action from myriad actors.

The need for disincentives. While the net-zero transition will generate a variety of opportunities for businesses and householders, there is also a need to disincentivise high-carbon activities. These may include the implementation of zero-emissions zones in Oxfordshire's towns and villages, not just Oxford City; or using planning powers to develop policies that align with net-zero carbon developments by applying 15-minute neighbourhood principles, implementing active travel infrastructure, and including ecosystem restoration. It will also mean rejecting planning applications or discouraging major inward investment associated with unsustainable development and the fossil fuel economy. Enforcement of existing regulations such as the Minimum Energy Efficiency Standards (MEES), or of contract-terms with operators of electric vehicle charging infrastructure remains a challenge for resource-constrained local authorities, but will become increasingly important.

Equity, justice and inclusivity. It is becoming increasingly clear to policy-makers at all levels that the transition must be fair and inclusive. Each pathway to zero carbon outlined in our scenarios chapter has implications for equity and justice. **Technological Transformation**, for instance, involves the least disruption to existing behaviours and lifestyles, with high use of private vehicles, lower rates of building retrofit, and hydrogen boilers installed as 'drop-in' replacements for gas incumbents. While private transport and heating in buildings are fully decarbonised in this scenario, these solutions do little to address inequality, as electric vehicles remain unaffordable to many, and the high cost of hydrogen coupled with leaky buildings means that heating bills increase, impacting the poorest hardest.

In both **Societal Transformation** and **Oxfordshire Leading the Way**, individuals and communities play an active role in driving down carbon emissions by adopting active travel, making greater use of public transport, installing rooftop solar, eating less meat and adopting flexible energy practices. However, the capacity to engage in such behaviours is unevenly distributed. Access to public transport is considerably more limited in rural areas compared with Oxford City, while active travel modes require physical capabilities which are not possessed by all. The ability to adopt the technologies to drive down emissions such as electric vehicles, heat pumps, solar panels and domestic batteries varies according to wealth, income and whether residents own their own homes and have access to off-street parking.

Achieving zero carbon emissions in Oxfordshire will require substantial investment as well as changes in the ways businesses and individuals move and use energy. These transformations can be leveraged to reduce inequality and empower marginalised groups, and there is a crucial role to be played by stakeholders such as the local authorities, the Growth Board, OxLEP and major employers to drive progressive change through their policies and strategies for investment. This includes support for local initiatives such as the Community Action Group network and the Oxfordshire Social Enterprise Partnership, as well as local authorities promoting flexibility practices and community-scale investments in solar generation or domestic energy efficiency, to achieve economies of scale.

Local differences in net-zero targets, and the implications of pre-2050 targets

While each local authority in Oxfordshire has set an aspirational date for area-wide net-zero emissions, these vary widely. Oxfordshire County Council is planning for 2050, in line with the UK goal, while Cherwell DC seeks to work with partners to achieve net-zero, district-wide, by 2030. These differences have substantial implications for policy, investment and local action which could be significant given the collaborative effort required.

Our net-zero scenarios each focus on 2050, reflecting the scale of change needed across all sectors of the economy. The implications of ambitions to eradicate emissions before then, without resorting to carbon offsetting, are clear. Near-term and extensive transformations would be needed in everyday lifestyle and consumer choices, alongside significant investment in electrified transport and a comprehensive rollout of building insulation and heat pump technologies, delivered by a rapidly trained, skilled workforce. While the ambition expressed by local policy-makers in setting net-zero targets ahead of the national target is important for mobilising investment, motivating residents to change behaviour and supporting policy change, the scale of investment, and change in usage of transport, energy and land are enormous. Without significant devolution of additional powers to local authorities, it will be extremely challenging to implement the policies required to deliver net-zero before 2050. However, there are additional ways to demonstrate leadership on climate change as well as target setting, such as in using planning powers to insist on zero-carbon development, implementing low traffic neighbourhoods and zero emissions zones.

The planning system. The planning system needs to be aligned with zero carbon targets, as it can influence the design and viability of many of the solutions needed to address climate change. It can determine the conditions under which strategic renewable projects can go ahead, and set policy and guidance for the design and layout of our built environment. It is one of the only ways that the spatial elements and design standards for energy efficiency and carbon reduction can be applied as a condition of planning. So, whilst the Climate Change Act has set the national net-zero goal, this can only be truly achieved if it is properly 'planned' for at the local level.

Most adopted Local Plans, many of which were largely developed prior to the adoption of net-zero targets, do not reflect the level of challenge and difficulty inherent in reaching these targets by 2050, and the implications this will have for the planning system and place-making more widely.

The transition to net-zero will require: super energy-efficient design in new developments, incorporation of a fit-for-purpose electric charging network, mass retrofit and energy efficiency upgrades of aging building stock, removal of gas networks to allow for low carbon heating alternatives, and significant modal shift away from private fossil-fuelled vehicles to active modes of travel and public transport.

The local planning system does not have the power to make all these changes alone, but it has a key role to play in driving changes related to publishing design guidance for zero-carbon standards for new builds, supporting strategies for local infrastructure, and determining the spatial patterns of land use. Greater weight needs to be given to climate issues if planning is not to act as a brake on zero-carbon ambitions . Local planning has very little power over carbon-emitting activities such as agriculture, aviation, and shipping, as well as nationally-significant infrastructure decisions.

Future Local Plans, Oxfordshire Plan 2050 and the Oxfordshire Infrastructure Strategy must incorporate the need for substantial grid upgrades to service an extensive electric vehicle charging network and the electrification of heat; allocate land for new solar installations; and prioritise building-fabric in both new build and retrofit when identifying regeneration opportunities. There is a critical role to play in minimising land take and transport emissions by specifying the creation of compact, walkable developments close to existing or planned public transport links, and incorporating walking and cycling infrastructure into all new developments. Planners can also protect and enhance existing woodland, hedgerows, wetlands and other carbon-rich habitats from development.

Meanwhile, the current national building regulations are insufficient to create, or even identify, true zero-carbon buildings. This is due to the 'energy performance gap' between design and reality, the incomplete assessment method, and the fact that the regulations exclude energy used by plug-in appliances. Better standards, tools, methods, skills and collaborative teams are needed to make zero-carbon buildings a reality, as demonstrated by the Passive House approach.[184] The forthcoming Future Homes Standard marks a welcome end to nearly a decade of national policy stagnation for housing, but the detail of the new policy is yet to be decided and is not due to come into force before 2025. There is uncertainty over exactly what the standard will be, how it will be applied, and how it might align with the ability of local authorities to set different requirements over different timescales.

184 Passivehouse.com.

It is also helpful to set metrics not only for carbon, but for total energy use, so that new-builds do not put added strain on an electricity grid which is coming under pressure from the electrification of vehicles and heating – in line with local and national zero-carbon goals.[185]

Whilst there are limits to local planning authorities' power to raise the bar for new developments' energy and carbon performance or influence building regulations through design guidance, the relative 'weight' of these duties and powers has not yet been thoroughly tested in legal terms. This may result in some hesitancy, but local planning authorities need to take bold steps now towards achieving zero emissions buildings and adopt policies that drive drastic and rapid emissions reductions from transport, energy and land use. An increasing number of local authorities are already using their local powers to raise energy standards higher than those set by national building regulations. Ambitious examples from Cherwell DC and West Oxfordshire DC include their NW Bicester policy and Salt Cross Area Action Plan[186] respectively. Examples from elsewhere include Reading Borough's Zero Carbon Policy and the London Plan that stipulates all new major residential developments must be 'zero carbon'.

If the local planning system is to genuinely contribute to the net-zero transition and not act as a barrier, then it is also imperative that planning authorities are adequately resourced and skilled, and supported by a strategic approach at the county or subregional scale.

185 UKGBC (2020), The Policy Playbook: Driving sustainability in new homes – a resource for local authorities.

186 At the time of writing, the Salt Cross AAP is being examined by the Planning Inspectorate.

COVID-19. More than 1000 people in Oxfordshire have lost their lives to COVID-19, and the pandemic has had a severely detrimental impact on nearly all residents and businesses in Oxfordshire. In the short term, energy demand and carbon emissions have fallen by roughly 8%8 – a significant change, but moderate given the unprecedented disruption to daily life caused by 'lockdowns'. As the economy gets back on its feet, it is imperative that the sustainable practices adopted by businesses and individuals, such as telecommuting and active travel, are supported and sustained. As businesses struggle to stay afloat following the COVID-19 pandemic, there is a risk that investment in zero carbon measures are deprioritised. And yet, businesses are more aware than ever of the need to build resilience, and ensuring that their products, services and operations are compatible with a zero-carbon future is now a crucial component of effective risk management. Unlike the period following the economic downturn in 2008, recent evidence suggests that public support for climate action is likely to remain high,[187] so that although strong policy interventions such as low traffic neighbourhoods and bus-gates will continue to divide opinion, local policy-makers can continue to push the zero carbon agenda with confidence.

Infrastructure. The forthcoming update to the Oxfordshire Infrastructure Strategy is due to include climate related indicators when evaluating the need for strategic infrastructure. While it goes without saying that all investments in local infrastructure should be compatible with zero carbon emissions, there is also a need to systematically review the role of existing infrastructure in 'locking in' high carbon practices, and plan for change. This includes, for instance, railway electrification and the allocation of road space to walking and cycling.

187 CAST, 2020. How has COVID-19 impacted low-carbon lifestyle and attitudes towards climate action? (CAST Briefing 04). Centre for Climate Change and Social Transformations.

In an effort to address one of the biggest challenges associated with the zero-carbon transition, the Scottish government designated energy efficiency as a national infrastructure priority, and has experimented with Local Heat and Energy Efficiency Strategies as a means to coordinate actions across neighbourhoods, not just in individual buildings. Our review of progress since 2014, and Chapter 7 on heating in buildings, showed that progress on domestic energy efficiency continues to be inadequate. National regulation is needed to provide a framework in which energy efficiency and demand reduction can integrate with changes on the supply side for heat. New forms of governance will be needed, as well as new markets for building retrofit, skills investment and innovations in new business models.

Green infrastructure has a vital role to play in a zero-carbon Oxfordshire, yet consideration of this in the first Oxfordshire Infrastructure Strategy was limited to an inventory of designated areas such as nature reserves. The update brings an opportunity to incorporate the new Oxfordshire Natural Capital map,[188] which shows the multiple benefits of all types of green infrastructure including semi-natural habitats, domestic gardens, watercourses, footpaths, verges and farmland. This enables and encourages a more nuanced view of the synergies and trade-offs between green and grey infrastructure, as discussed in Chapter 9. The natural capital map shows high value assets, highlighting the need to protect high grade farmland, to minimise the footprint of new development, and to protect existing habitats including trees, hedges and semi-natural grassland from development. There are also opportunities for synergies such as new green walking and cycling routes to encourage active travel, and restoration of habitats to provide natural flood management, erosion protection and air and water quality benefits.

188 Smith (2019), Natural capital mapping in Oxfordshire: short report.

Embodied carbon. This report has focused on direct emissions (Scope 1) and those associated with purchased energy (Scope 2). However, there are emissions 'embodied' in the goods and services imported into the county, including the materials used for constructing new housing, the batteries used in electric vehicles, and food and biofuels that must be produced elsewhere when land in the county is used for carbon-reducing activities such as planting trees. In the next decade, the priority must be on reducing Scope 1 and 2 emissions. However, as the emissions associated with energy and transport usage reduce over time, the relative proportion of embodied emissions will grow. Whilst it is often difficult to accurately quantify embodied emissions, climate change will need to be increasingly factored into procurement decisions and supply chain governance, whether those are major investments in construction materials for new homes, or everyday purchases such as food. A shift towards a circular economy based on reducing waste and unnecessary consumption will play a large part in reducing the embodied emissions imported in material goods.

Data at the 'Grid Edge'. As the energy system becomes increasingly decentralised, gathering the spatial and temporal information needed to optimise grid management, enable flexibility markets and inform low carbon technology investment is crucial. Compared with a centralised system, collecting data from thousands of distributed assets presents a major challenge. As highlighted in this report, data on renewable heat generation, energy efficiency installations and electric vehicle charging infrastructure is currently insufficient in terms of coverage and granularity, considering their critical role in driving down emissions. In Project LEO, SSEN and partners are directly addressing this problem by installing monitoring devices across the low voltage distribution network. There is a need for similar efforts to monitor progress in decarbonising heat, transport and enhancing natural capital.

Skills. With historically low levels of unemployment, businesses in Oxfordshire have highlighted in recent years the challenges associated with recruitment.[189] Niche high-tech industries requiring advanced technical skills or scientific knowledge already face difficulties finding suitable employees. Challenges around skills and training are likely to proliferate into sectors such as construction, HVAC and automotive maintenance, as these trades play a crucial role in delivering the solutions to decarbonise buildings and transport. At present, there is very low demand for the work that is required to decarbonise these sectors, and where there is a low demand for skilled work there is, by definition, a low demand for skills training. The challenge of low-carbon skills is therefore more than simply a lack of provision; it is a lack of real demand for (and use of) skills in the workplaces where the zero-carbon activity will be needed.[190] To tackle these issues effectively requires a much greater level of coordination between policies for energy, industrial strategy and education.[191,192] There is an important role for government in anticipating the types and quality of work required in a zero-carbon economy and in setting out occupational standards to complement the energy performance standards that will also be needed.[193,194]

189 OxLEP (2019), Skills and labour market research evidence pack.

190 Keep, E. (2016). Improving skills utilisation in the UK – some reflections on what, who and how? SKOPE research paper 124, August 2016. Centre on Skills, Knowledge and Organisational Performance, Oxford: University of Oxford.

191 Wolf, A. (2004). Education and economic performance: simplistic theories and their policy consequences. *Oxford Review of Economic Policy*, 20(2): 315–333.

192 Green, A. (2016). Low skill traps in sectors and geographies: underlying factors and means of escape. Institute for Employment Research, University of Warwick, September 2016.

193 Killip, G. (2013). Transition management using a market transformation, approach: lessons for theory, research and practice, from the case of low-carbon housing refurbishment in the UK. *Environment and Planning C: Government and Policy*, 31: 876–892.

194 Killip, G. (2020). A reform agenda for UK construction education and practice. *Buildings and Cities*, 1(1): 525–537.

Partnership working. One of Oxfordshire's strengths when it comes to the low carbon economy is the extent to which key stakeholders are willing to collaborate, and the membership of the steering group for this report provides evidence of this. This is a strength which can be further built upon, with the expansion of existing networks such as Oxfordshire Greentech, Community Action Group network and Low Carbon Hub CIC. The Oxfordshire Growth Board recently proposed the creation of a new environment advisory group which was supported by all local authority leaders. If properly resourced, this could drive forward the agenda set out in the Oxfordshire Energy Strategy, and begin to develop an action plan to meet climate goals. It is hoped that the evidence and modelling in this report will directly inform this advisory group, as well as the work of the proposed Local Nature Partnership.

Financing the transition. Local authorities have experienced significant funding cuts in the last decade, and COVID-19 has led to further financial woes. Although the current model of funding competitions is problematic at a national scale,[195] Oxfordshire's councils have been very successful in developing projects to attract central government investment in transport and energy innovation in recent years. While the Climate Change Committee rightly highlights the need for funding to increase skills and capacity at the local level, Oxfordshire's local authorities have nearly unparalleled knowledge and expertise on low carbon innovation. Nonetheless, with increased attention and the proliferation of projects in recent years, officers have been under strain.

In particular, there is a need for increased know-how relating to green finance, sustainable procurement, and the challenge of translating sustainable innovation projects into ongoing operations and contract management.[196] Increasing specialist resources across the local authorities will not only help to drive local action, but can also be used to support other regions in their own net-zero transitions.[197]

There remains uncertainty over the future of core funding for programmes to drive down emissions, for instance it is so far unknown which priorities the Shared Prosperity Fund will focus on. With the dissolution of the European Structural Investment Funds (ESIF), there is a risk that key areas such as funding for energy efficiency and eco-innovation in SMEs is lost. Local actors should lobby central government for investment on zero-carbon initiatives across multiple sectors, and for funding streams to be flexible to give local decision-makers maximum influence over expenditure. While the loss of ESIF presents a risk to the zero-carbon transition, there is now an opportunity to re-evaluate investment priorities for the Shared Prosperity Fund, and to streamline administrative processes.[198]

195 CCC (2020), Local Authorities and the Sixth Carbon Budget.

196 The City Council's experiences of deploying EV charging infrastructure as part of Go Ultra Low Oxford and Energy Superhub Oxford are illustrative.

197 Schwanen, T., 2015. The bumpy road toward low-energy urban mobility: Case studies from two UK cities. *Sustainability*, 7: 7086–7111.

198 National Centre for Universities and Business (2018), What comes after the end of European Regional Development Funding?

The 2014 Low Carbon Economy report recommended that an Oxfordshire Green Bond could be a means for raising investment in support of the deployment of renewable energy technology and other assets. This remains the case, as highlighted by the Growth Board Scrutiny Panel in March 2021.[199] The Low Carbon Hub have pioneered community investment in renewables, and there is an opportunity for local authorities to put their weight behind similar financial models. West Berkshire Council launched a Community Municipal Investment in July 2020 and have so far raised over £537,000 for a series of solar projects. Bristol's LEAP initiative is aiming to bring together a range of energy and infrastructure investment opportunities, using a joint venture model.[200] They are currently procuring a strategic partner to help realise their vision for £1bn green investment, recognising that the majority of funding for the zero-carbon transition will come from the private sector. Another potential opportunity for financing zero-carbon initiatives such as renewable generation is the Oxfordshire Local Government Pension Fund, which recently implemented a climate change policy committing to switching 11% of its assets into a low carbon fund. The Trust for Oxfordshire's Environment, BBOWT and Wild Oxfordshire are also aiming to develop an Oxfordshire Carbon and Nature Fund to channel both private and public investment into sustainable Nature-based Solutions with both biodiversity and carbon benefits.

199 Oxfordshire Growth Board Scrutiny Panel (2021), Recommendations from the Private Investment In Public Infrastructure Projects Task and Finish Group.

200 Bristol City LEAP.

10.2 Sectoral implications and recommendations

10.2.1 Innovation for zero carbon

All three net-zero scenarios require sizeable changes to our current way of life. With the **Technological Transformation** and **Oxfordshire Leading The Way** scenarios, mass scale-up and roll-out of technological innovation is a necessity, which will only be achievable through supporting the existing low-carbon innovation ecosystem to grow with adequate policies, investment and consumer-led behavioural shifts. Zero-carbon innovations need to not only deliver efficient carbon reductions at scale but also incorporate consumer-facing solutions that reduce demand, and ease the behavioural shift required to maximise the efficacy of these technologies.

With this in mind, we identify three key areas for focus in the coming years:

A green economic recovery: As we begin to overcome and recover from the COVID-19 pandemic, it is imperative that people and businesses in Oxfordshire seek to embed those innovative behaviours and practices developed through 'lockdown'. Businesses have never had to be so agile, and as we pursue a green recovery, leaders should consider how consumer choices and staff preferences may change. Whereas public concern for climate change fell after the recovery from the economic downturn starting in 2008, there are signs that the public will support strong climate policies after the current recession.[201] The period of flux in the coming years will present opportunities to low carbon innovators to provide the goods and services to drive both the economic recovery and the path to net-zero.

201 CAST, 2020. How has COVID-19 impacted low-carbon lifestyle and attitudes towards climate action? (CAST Briefing 04). Centre for Climate Change and Social Transformations.

Raising investment/funding: According to a survey conducted by Advanced Oxford in 2020, the biggest challenge facing innovative companies is raising investment[43]. Despite significant investment made by organisations such as Oxford Sciences Innovation (OSI), Oxford University Innovation and the Oxford Investment Opportunity Network, there remains a need for financial support to drive the sustainability transition. While attention often goes to innovative start-ups, large incumbent businesses in manufacturing, energy, transport, construction and other sectors are those which will generate the greatest investment in zero carbon solutions. The opportunities represented by low carbon innovation in Oxfordshire should be promoted by economic development stakeholders such as OxLEP, to attract new venture, corporate and institutional investors, and encourage low carbon businesses to locate here.

Building an inclusive low-carbon economy: Whilst low-carbon innovation in Oxfordshire is thriving, the majority of those in environmental professions are white, male, and middle-class.[202] Within the low-carbon innovation sector, there is a need for greater diversity,, including greater ethnic diversity and a more equal gender balance. The Oxford branch of Women in Sustainability is active and popular, but there are no equivalent networks bringing together those involved in the sustainability movement from ethnic minority groups. With increasing awareness amongst all stakeholders of the need for an inclusive and just transition, more effort is needed to foreground diversity. More profoundly, the challenge of a zero-carbon economy will be to integrate some aspects of carbon management into many sectors that have not traditionally been seen as 'green'. Many low- and middle-income jobs in service sectors will need to change in subtle, but far-reaching ways if zero-carbon is to be a reality. The zero-carbon imperative needs to be reflected in industrial and economic policy, and it needs to be done in ways that are just and inclusive.

202 Policy Exchange (2017), The two sides of diversity.

10.2.2 Transport

All three net-zero scenarios require phasing out close to 100% of fossil-fuel powered vehicles for transport (improve), but also some reduction in travel demand (avoid) and increases in the share of public, shared and active travel (shift). Internet connectivity has become a crucial factor for reducing demand for travel, and choices over the location, density and mix of housing, amenities and services will determine Oxfordshire's ability to decarbonise transport.

The implications for decarbonised transport should be considered at all stages of the planning process, from policy writing and land allocation to planning permission for individual developments or changes of use. Local Plans and accompanying design guidance should set out policies and objectives for place-making and integration with the County-level Local Transport and Connectivity Plan. Local government and community positions should also highlight opportunities for and threats to local amenities, from green space to post offices, that avoid and shift travel.

Engagement with individuals and businesses will also be essential to enabling 'Avoid' and 'Shift' of Travel. Employers should be engaged in identifying opportunities to use internet connectivity to enable remote working and reduce commuting. Employers will also play a role in supporting variable schedules that optimise both essential and occasional commuting by public transport. Those involved in retail, freight and logistics will need to collaborate with the public sector to find new ways to store and deliver goods.

All pathways to net-zero transport involve the rapid and extensive electrification of vehicles and rail. Not only will this drive up demand for electricity, but it will place significant demands on the existing grid infrastructure. Linked to the need for better data and information at the 'grid edge', there is need to incorporate those involved in grid management (namely SSEN) into transport planning discussions. Flexibility practices can mitigate the need for costly grid upgrades, and should be promoted by a wide range of stakeholders, not just those within the energy industry.

Switching from road building to road space reallocation and demand management measures will support other investments to decarbonise transport, offer value for money, and have co-benefits for place-making and public health, but such solutions need community support. Measures such as the zero emissions zone, workplace parking levy, and controlled parking zones can raise funds for investment in active travel and public charging infrastructure. Public engagement is necessary to ensure such schemes are equitable and inclusive.

COVID-19 has generated significant uncertainty over the future of rail travel and the viability of rail improvements. Uncertainties are also inherent in the governance structures within the transport sector and divided responsibilities for decarbonising transport. To renew confidence in public transport, especially rail, public engagement and communication with residents and businesses will be essential, as will Oxfordshire's strengths in creating networks and collaborations between sectors and that integrate policy and regulation at all levels of government.

10.2.3 Building energy efficiency and heating

Building energy efficiency has widely recognised benefits beyond energy saving, cost saving and CO_2 emissions. In the housing sector energy retrofit is key to eradicating fuel poverty and generally making homes healthier and more comfortable. There are co-benefits for health and social care services of warm and efficient homes, and retrofit is recognised as part of Oxfordshire's Joint Health and Wellbeing Strategy.[203] Retrofit is also good for jobs, and has been identified by many economists as a key strategic action to boost economic recovery from the Covid-19 pandemic, while also contributing to climate mitigation.[204] Even so, evidence from the BEIS-supported retrofit supply chain demonstrators (including Cosy Homes Oxfordshire) points to a very immature market for retrofit, and a supply chain that is wary of government-backed initiatives after the high-profile failures of the Green Deal and the Green Homes Grants scheme. Better national policy is needed before significant progress can be made, and various government consultations are promised, including for a Heat and Buildings Strategy.

For non-domestic buildings stronger regulations are also needed, but so is an ongoing engagement with property owners and managers to make continuous improvements over time. The key challenge is to align efficiency and heat decarbonisation goals with each organisation's strategic objectives. Given the wide variety of organisations covered by the term 'non-domestic sector' there is no 'one size fits all' approach in terms of technology or investment.

203 Oxfordshire Joint Health and Wellbeing Strategy (2018–2023).

204 For example, New Economics Foundation (2020), A green stimulus for housing: The macroeconomic impacts of a UK whole house retrofit programme.

Organisations need bespoke support from a network of skilled business and energy advisors so that decarbonisation options are considered at key moments of capital investment and operational management. Energy Solutions Oxfordshire has begun some of this work, and it could be usefully extended and expanded. The facilitation of networks can be an effective way to share good practice and build up a community of practice around decarbonisation.

The planning system also needs to be better prepared for, and disposed to, some of the changes that will be needed in buildings and streetscapes. Visual amenity and heritage value are important factors to weigh in the balance of planning decisions, but a zero-carbon future will, out of necessity, involve some disruptive changes to familiar built environments. There is a need to re-balance priorities so that more actions to improve energy efficiency can be achieved, even where that makes minor changes to the appearance of buildings. Oxfordshire could usefully take a lead in a nationally relevant debate about planning priorities, framed around the need to make subtle but profound changes in the built environment for a zero-carbon future.

10.2.4 Renewable energy

Solar PV is Oxfordshire's largest renewable resource and will need to be exploited in all plausible net-zero scenarios. For Oxfordshire to lead the way, the annual rate of solar installation needs to increase by 5–10 times compared with the previous five years, and then sustain for the next three decades. Recent trends have fallen short of this due to reductions in Government support, although there is evidence the market is starting to recover. Nonetheless, even in our most ambitious scenario, Oxfordshire will continue to rely on zero- (and ultimately negative) carbon electricity imported from outside the county.

Ambitious early action will build momentum and Oxfordshire has a well-established community of local energy action groups, early adopters and a proven appetite for community funded energy projects which must be nurtured and used as a springboard for mass adoption. To maximise local value, installations which directly reduce local electricity imports (behind-the-meter installations such as rooftop PV and local PPAs) should be targeted and could benefit from local facilitation. While technology costs continue to fall, pre-installation costs (including network connection), risk management and sector expertise remain barriers for easy development. Local partnerships that include community groups, landowners, SMEs and DNOs can help overcome these barriers through knowledge sharing, strategic infrastructure planning and novel financing arrangements.

Solar PV is not the only low carbon generation option in Oxfordshire. Bioenergy, hydro and wind have all been exploited to varying degrees and their potential should continue to be considered. While still relatively small, agricultural waste and onshore wind offer the largest untapped resource besides solar. Onshore wind, a non-starter in recent years due to central government planning policy, could contribute in the future if local attitudes and political will respond to the climate emergency. Oxfordshire is part of a wider national energy system which does not align with local political geographies. The county is unlikely to be a net exporter of energy in the next 30 years, so to achieve zero emissions as fast as possible, Oxfordshire's stakeholders have a role to play in providing the expertise, ambition and finance to guide national strategy. Reducing energy demand is critical to achieving net-zero in all pathways and must occur in a multitude of ways including improved building fabric, active travel and electrification of transport and heating.

Mass adoption of EVs and heat-pumps will reduce emissions quickly due to their high efficiency and a rapidly decarbonising electricity system, but their uptake needs to be supported with charging infrastructure, building fabric-retrofit, and a workforce of skilled installers. As Oxfordshire has few industrial activities considered difficult-to-electrify, reaching a net-zero energy system faster than 2050 is possible, but cannot be done drastically ahead of the national system.

However, electrification poses challenges for electricity networks which will require infrastructure upgrades and smart network management to overcome additional strain placed on an already constrained system. Flexibility and data at the grid edge are required to maximise infrastructure utilisation in a cost-effective way. Local partnerships must work together with network companies to ensure local context-specific solutions are incorporated as early as possible. The innovation projects already underway (such as Project LEO) must be capitalised on.

Finally, the fastest and deepest decarbonisation pathways require societal change which puts people at the heart of delivering a net-zero energy system; from users being actively engaged in the energy system to the installers and intermediaries delivering the new technologies which must be embraced. Local authorities, local businesses and knowledge hubs have an important role to play as trusted entities to foster this societal change.

10.2.5 Land use and sequestration

There is intense competition for land for agriculture, housing and infrastructure, which can limit the deployment of low carbon options such as ground-mounted solar, biofuels, tree planting and ecosystem restoration. Simply outsourcing our demand for land-based resources such as food and biofuels will only displace emissions elsewhere. Smart land use planning is essential to minimise these constraints. This should be carried out in partnership with all relevant stakeholders, including county and district councils, landowners, farmers, local communities, researchers and wildlife groups. The proposed new Local Nature Partnership would be the ideal forum for developing a low carbon land use strategy that achieves multiple benefits while minimising trade-offs, and this could build on the existing natural capital map of the county, but it is essential that it should be adequately resourced and funded, and supported through partnerships with researchers. Our analysis leads to several recommendations for land-use planning, including:

- Minimising the footprint of all new development by optimising housing density while also building in connected green and blue spaces. In typical urban extensions, housing densities of 60 dwellings per hectare should be possible with good design, use of mid-rise 3 and 4-storey dwellings, compact developments with a variety of services and amenities, and a shift away from private car ownership towards more active travel, public transport and shared car use to minimise land needed for car parking.[205] Much higher densities are possible in urban centres.

205 For example, the Essex Design Guide mandates densities of 75 dph for ‘Compact’ developments and 65 dph for ‘Large sustainable developments’

- Reducing the need for car travel and new road links by siting new developments close to existing or potential high quality public transport links (including new rail stations where appropriate).[206] Supporting combined solar and agricultural ('aglectric') techniques to enable food production to continue within ground mounted solar farms
- Encouraging adoption of rooftop solar as far as possible.
- Preventing loss of high grade agricultural land (grade 1, 2 and 3a) to development.
- Encouraging dietary change to reduce meat and dairy consumption to 25% of current values, in order to free up farmland for carbon sequestration and habitat restoration. Councils and businesses can lead the way in their own food procurement (whilst still catering for those who require low fibre diets for health reasons).
- Supporting ambitious energy demand reduction measures to reduce the need for negative emission technologies such as BECCS, which have a very high land requirement for biofuel feedstock. Due to constraints on total land area, our scenarios produce only around 20% of Oxfordshire's share of the UK's biofuel feedstocks based on land area or population (which would require between 37–56% of the county's land), leaving the rest to be provided by imports. This could have significant implications for emissions and biodiversity overseas, as biofuel production could displace land needed for food production and lead to indirect deforestation.
- Well designed nature-based solutions including restoration of native woodland, floodplain meadows, chalk grassland, scrub, heath, wetland and ponds will bring both carbon sequestration and a vast range of other benefits including flood and erosion protection, air and water quality improvement, local cooling, habitat for pollinators and other wildlife, and pleasant spaces for recreation and interaction with nature. However these benefits require good planning, working closely with the proposed Local Nature Partnership and local communities to ensure that the right habitats are created in the right place and for the right purpose.
- The emerging Local Nature Partnership must be fully funded and supported (included through research partnerships) to engage stakeholders in the development of a Local Natural Capital Plan that meets zero carbon and biodiversity targets, while optimising co-benefits and minimising trade-offs for climate adaptation, health and other goals.
- It was not possible to analyse the sustainability of Oxfordshire's food system within the scope of this report but this is an important area for future work.

206 Transport for New Homes (2018), Project summary recommendations.

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