A BLUEPRINT FOR A GREEN FUTURE

Cambridge Zero Policy Forum

Report on a green recovery from COVID-19
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Contents

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Front cover: Children from the University of Cambridge Primary School took part in a climate-themed art project with the support of Cambridge Zero. 'Agents for Change' highlighted the importance of addressing climate change and the role that each of us plays in effecting outcomes based on change.
Image credit: Cambridge University Primary School

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Executive Summary

The COVID-19 pandemic has already wreaked an immense toll on lives, livelihoods, and on the global economy. The UK can emerge stronger and more resilient, but to do so we must also face head-on the triple challenge of responding to the threats posed by growing social inequality, the destruction of nature, and climate change. Inequalities *can* be addressed to create a fairer and more just society; nature *can* be valued and supported so we leave it in an improved and resilient state for future generations; and the threat of climate change *can* be limited by rapid reductions in greenhouse gas emissions – indeed, the UK has committed as a nation to reach net-zero emissions over the next few decades. We can make this a story of hope and of opportunity, and one of shaping a future that is, simply, better – for everyone. However, to realise these aspirations we need a coherent and effective plan based on our best evidence and knowledge. To this end, we offer a blueprint for a green future.

With economic activity limited to contain the coronavirus, the global economy faces unprecedented challenges in the coming months and years, including the risk of a protracted depression. Pulling the world out of recession and generating sustainable, inclusive, and resilient growth requires a vision that restores confidence, a comprehensive policy response that delivers investment at scale, and a plan of action from a local to an international level. This must include investment in knowledge capital and innovation, in social and institutional capital to deliver effective government, and in natural capital, not least as COVID-19 has reminded the world of the urgent need to strengthen the quality and resilience of natural assets. Such investment in green stimulus measures has been shown to lead to strong fiscal multipliers with substantially enhanced returns on the investment. Action to address the nexus of threats associated with social inequality, destruction of nature, and climate change can, by definition, result in a nexus of opportunities resulting in benefits across these systems.

This multidisciplinary report outlines complementary investments, policy commitments, institutional frameworks, and systems thinking that will provide security, strengthen the UK's place in the world, and support collaborative global efforts to transition to a green future.

Chapter 1: Creating the Conditions and Incentives for a Green Recovery

A robust, self-perpetuating green recovery will need the right supporting structures. The conditions and incentives necessary for the adoption of sustainable practices need a strong institutional and regulatory framework. Investments in new technologies need to be complemented by programmes to accelerate their adoption and deployment. More broadly, a comprehensive public investment strategy focused around the mutually reinforcing physical, social, natural, and human assets that underpin prosperity is needed. Priorities to deliver this include:

- **Attach clear, measurable environmental sustainability conditions to all COVID-19 recovery spending**. Potential 'green strings' could vary by industry and may include conditioning interest rates on loans to emissions reductions targets consistent with net zero, air and water quality improvements, biodiversity targets, or other environmental outcomes.
- **Expedite the development and use of new economic metrics that capture social and environmental impacts** – including along the supply chain – by investing in the statistical infrastructure for measuring natural, social, and human capital and mandating strict climate and environmental reporting standards for companies.
- **Implement requirements that foster behavioural change in business** – including tightening and mandating reporting standards and requiring supply chain transparency (as in the UK Modern Slavery Act) for social and environmental impacts.
- **Support challenge-oriented research and development**, adopting and adapting the ARPA model, to address the UK Net Zero 2050 target and broader environmental objectives set out in

UK Government commitments under the 25-Year Environment Plan.

- **Provide government leadership to remove the barriers to green innovation and adoption**, for instance by supporting brokering organisations to connect businesses in the circular economy, based on cutting-edge scientific research.

Chapter 2: Supporting Society in the Zero-Carbon Transformation

The COVID-19 crisis has exacerbated underlying societal stresses in the UK including those of social inequalities and regional and intergenerational disparities. There is an opportunity to build a post-pandemic economy that supports climate action and enhances our natural environment through a fairer distribution of resources and consumption. By contrast, recovery measures that fail to acknowledge the climate, nature, and social crises would neither be sustainable, nor a success. Green investment can create new jobs, support new industries, and lead to improved health, wellbeing, and quality of life for all citizens. Our recommendations associated with this include:

- **Establish a Net Zero Delivery Board** to drive through the policy and regulatory changes required across the whole of the economy, to promote greater democratic engagement in policy formation, and to ensure the costs and benefits of a net-zero transition are fairly shared.
- **Facilitate the creation of green jobs** to address rising unemployment, to transform the economy for a zero-carbon future and to restore nature, prioritising areas of high unemployment, labour market exclusion, and regions with the highest proportion of jobs that could be at risk in the transition to a net-zero economy.
- **Review and overhaul the entire lifelong learning portfolio**, including education, training, and re-skilling, to boost societal knowledge and understanding of sustainability and to underpin the employment opportunities of the future.
- **Create a Net Zero Fund** to support a just transition to a net zero economy, locally, regionally and nationally.

Chapter 3: Investing in Zero-Carbon Technology and a Zero-Carbon Industrial Transition

The actions the UK takes to rebuild can simultaneously accelerate the zero-carbon transition and put the UK on track to meet its legally binding target of net-zero emissions by 2050. Sectors in which significant advances and improvements can be made include: energy generation and storage; construction and operation of buildings; transport; and industry. Opportunities also exist for greenhouse gas removal via nature-based and engineering-based approaches. A comprehensive technology-based transition strategy should focus on the following elements:

- **Initiate a focused national research and development programme on zero-carbon energy generation and storage technologies** to target improving performance, efficiency, reliability, and cost, and to underpin the competitiveness of the UK zero-carbon industry by building on existing UK strengths. An example is solar, where the UK has led developments of lead halide perovskite solar cells which could transform the photovoltaics industry if combined with other UK strengths in providing key component technologies such as solar glass.
- **Transform construction regulations and practices.** This requires engagement with all relevant stakeholders to enable the widespread deployment of resource-efficient building design and natural construction materials. Heat pumps should be mandated on new buildings and energy-efficiency improvements to existing buildings incentivised to render heat pumps a viable option.
- **Pursue electrification for all possible vehicles,** reserving biofuels for aircraft and long-haul shipping. Hydrogen may be necessary for some applications, but these should be minimised.
- **Invest in research and development, governance, and public engagement on greenhouse gas removal technologies** since engineering and/or nature-based options will be needed in order to reach a position of net zero by 2050.

Chapter 4: Investing in Resilient and Sustainable Infrastructure

Our built environment is a complex system-of-systems, interlinked within our cities and towns, and which underpins our society and enables it to flourish. Together this accounts for over 40% of the UK's greenhouse gas emissions. It comprises: economic infrastructure which supports the operation of our cities and buildings; social infrastructure largely consisting of buildings which are owned and operated for the public good; and commercial and domestic buildings. Approaches to decarbonising construction and use across these categories typically require different incentive mechanisms and support. Our recommendations include:

- **Adopt a whole-system, whole-life view** of infrastructure and the built environment.
- **Require all new infrastructure assets to quantify their embodied and lifetime emissions, and develop a sustainable construction protocol** to calculate and optimise carbon in design; calibrate design models against real performance; control processes on construction sites; develop and apply sustainability standards for all major building materials and require 3rd party certification; assess, declare, and manage/reduce waste, embodied carbon, and carbon fuel use; and invest in innovation.
- **Incentivise retrofitting of existing homes** through programmes such as a 'Help to Fix' interest-free loan scheme and similar support for housing associations.
- **Reconsider renewable energy proposals such as the Swansea Tidal Lagoon** as part of a broader strategy to fully decarbonise the power sector and effect the full electrification of transport and heating.
- **Accelerate the decarbonisation of transport** through a combination of measures including demand reduction, shared and integrated transport modes, electrification or use of carbon-free fuels, and policy instruments such as road pricing.

Chapter 5: Investing in Nature-based Solutions and Supporting Agriculture and Rural Affairs

Nature-based solutions are those that harness the power of nature to remove greenhouse gases and help people adapt to the impacts of climate change. If designed appropriately, these approaches provide an opportunity to simultaneously respond to the climate, nature, and social inequality crises. Also central to this response is the development of agriculture and land management policies that help deliver nature-friendly farming and increase food security, while offering enhanced environmental protections and support for rural communities. Our recommendations in this context include:

- **Deploy carefully designed nature-based solutions to climate change.** These approaches have strong public support, provide employment and recreational space, and have benefits for physical and mental health. Options to remove greenhouse gases and avoid further emissions include better management, protection, and restoration of peatlands, wetlands, forests, and some types of grasslands, and other measures can provide resilience to climate change impacts such as flooding; the creation of monoculture plantations of fast-growing tree species should be avoided.
- **Create a new National Nature Service** to employ many tens of thousands of people and restore our land, coastlines, oceans, and economy for a greener, more prosperous future.
- **Overhaul policies and incentives in agriculture and rural development,** including subsidies and taxation schemes to reward landowners for benefits provided to society, and tailored support and training to help farmers adopt sustainable practices and invest in innovation.
- **Support sustainable food production, reduce food-system waste and promote healthier diets.** This can help to cut costs in agriculture, public health, and the food industry, as well as bringing down consumer expenses.

Chapter 6: Global Leadership Opportunities for the UK

A green recovery provides a multiplicity of opportunities for the UK to assume an international leadership role. Many of the challenges discussed here are fundamentally global ones requiring enhanced global cooperation and for countries to take steps which can inspire others to follow. The UK is in a unique position – taking the Presidency of the G7 in 2021, holding a leadership position in the upcoming climate negotiations, and embarking on the formulation of new economic relationships with trading partners – to leverage past experiences, forge new alliances, and galvanise the breadth of actors underpinning an effective post-pandemic recovery. Opportunities include:

- **Demonstrate UK international leadership, building on key global events to respond to the climate, biodiversity, and health crises.** Through the upcoming UN Framework Convention on Climate Change COP26, the Convention on Biodiversity COP, and collaborations in the World Health Organization, mobilise diplomatic channels and all stakeholders to advance a green, just recovery.
- **Help coordinate and deliver a global response to the need for education, awareness, and capacity on climate change and biodiversity conservation** among all stakeholders and at all levels, from global to local, supporting new career and employment opportunities.
- **Leverage pandemic recovery investments to implement the Paris Agreement and the global Sustainable Development Goals.** Promote new investments, economic stimulus finance, and innovative solutions which align with climate change, species extinction, extreme poverty, and other agreed SDG targets, also fulfilling binding treaty obligations.
- **Promote international green recovery cooperation through new economic agreements.** Shape and implement sustainable development commitments from existing and new trade, investment, scientific cooperation, and technology transfer treaties, and leverage economic relationships to more effectively enable a green future.

Introduction

Today we sit at a pivotal moment in history. The toll that COVID-19 has already wreaked in terms of lives and livelihoods is immense and the impact on global economies is stark. But in the months and years ahead, as we look to how the UK can emerge from the pandemic stronger and more resilient, we must face head-on the triple challenge of responding to the threats posed by growing social inequality, the destruction of nature, and climate change. This is the moment for courage and boldness of leadership. This is the moment to reset our priorities and to re-evaluate our relationships with each other and with the world that sustains us. This is our moment to imagine, and then realise, the future we want. A future that is, simply, better – for everyone.

During this decade, we must deliver the transformational change to get on track for net-zero emissions by 2050 and address the wider UN Sustainable Development Goals. The shock to the global system caused by COVID-19 will create new challenges to achieving these ambitions, but it is also revealing new possibilities. The pandemic has exposed the lack of resilience in a system that has already failed to meet the needs of hundreds of millions of people and is unprepared for future shocks driven by climate change, biodiversity loss, and environmental degradation. It has also shown us how quickly and dramatically we can change our behaviours under pressure. This raises big questions about our established economic and societal norms, and the steps we must take in order to emerge as a stronger and more resilient society.[1]

The current status is bleak. In a global population approaching 8 billion, the world's richest 1% have more than twice as much wealth as 6.9 billion; within the UK, societal as well as regional and inter-generational disparities are stark and have been exacerbated by COVID-19. It is thought that one million animal and plant species are threatened with extinction over the coming decades, with current extinction rates around 100 to 1,000 times higher than those of the past several million years. Again and again, in recent years, communities across the UK have experienced the devastation caused by flooding. We have seen ever more extreme heatwaves in the UK and around the world, with the Arctic melting before our eyes as the impacts of climate change start to manifest themselves.

But inequalities can be addressed to create a fairer and more just society; nature can be valued and supported so we leave it in an improved and resilient state for future generations; and the threat of climate change can be limited by rapid reductions in greenhouse gas emissions – indeed, the UK has committed as a nation to reach net-zero emissions over the next few decades. We can make this a story of hope and of opportunity. However, to realise these aspirations we need a coherent and effective plan based on our best evidence and knowledge.

To this end, we offer a blueprint for a green future.

Following deliberate action to limit economic activity to contain the spread of coronavirus, the global economy faces unprecedented challenges in the coming months and years, including the risk of a protracted depression. Pulling the world out of recession and generating sustainable, inclusive, and resilient growth requires framing a vision of the benefits of government action. This is necessary to restore confidence to investors, businesses, and consumers. A sustainable growth path offers just such a vision. But the vision must be matched with a plan of action that will need to be delivered at an international, national, regional, and local level.

Public intervention and leadership will be required to restore confidence and avoid a return to the old model of growth that has proved insufficiently productive,[2] environmentally unsustainable,

1 Cambridge Institute for Sustainability Leadership (CISL) (2020) *The Future We Want*.
2 Rachel and Smith (2015) *Secular drivers of the global real interest rate*.

and socially and regionally divisive. The old model has also proved dangerous in terms of making pandemics more likely with underfunded and ill-equipped public institutions in many cases failing to show resilience in the effectiveness of their response.[3]

As policymakers eventually move from COVID-19 rescue to post-COVID-19 recovery, delivering employment and wage growth and securing public debt sustainability will be a high priority for all countries. A coordinated and ambitious transition to a more resilient, inclusive, and sustainable economy can contribute to a more rapid recovery as well as to long-term prosperity. This requires a comprehensive policy response that delivers investment at scale.[4]

In the recovery phase, the world will face a classic paradox of thrift. This occurs when fear of recession leads business to shed labour and claw back investment, banks to retrench credit, and consumers to cut spending. When everyone responds in this way, gloomy expectations become self-fulfilling in generating a downturn. Expectations align around low-growth equilibrium and the cycle is entrenched. The primary macroeconomic task for policymakers, therefore, is to offset this and stimulate private spending in the short run.

In the long term, the primary objective is to build capacity and resilience by investing in vital complimentary assets which 'crowd in' capacity. These include investment in physical and produced capital assets,[5] by locking into future-proofed, productive, and resilient infrastructure, and not spending public money propping up things like fossil fuel-intensive assets with limited productivity potential. It also requires investment in human capital, creating the skills and jobs necessary for the rest of the 21st century and reskilling workers to enable those affected by change to participate in the new economy – thereby 'levelling up' opportunities and regions.[6]

A global transition to a zero-carbon economy that values nature needs investment in knowledge capital and innovation. It is the key driver of the growth in total factor productivity and will determine our ability to get more out of the resources we have by directing the 'weightless' economy, characterised by intangible knowledge-based services, to foster dematerialisation and decarbonisation. The sheer scale of the zero-carbon transition generates substantial network effects[7] and economies of scale in production and discovery.[8] These are so large that we invariably underpredict the scope for productivity-augmenting clean innovation. This is true not only within clean sectors, for example where we have seen an 80% reduction in key renewable costs such as solar PV and battery storage over the last decade, but also through strong evidence of spill-overs into other parts of the economy, which are much greater than those associated with more mature fossil fuel investments.[9]

It also requires investing in social and institutional capital to deliver effective and functional government with popular support, rebuilding trust in the social contract.[10] It means tackling inequalities, not just in income but also in wealth and in 'access' to goods and services such as health, housing, transport, education, and justice – inequalities exacerbated by COVID-19. Furthermore, it requires investment in natural capital. COVID-19 has reminded the world of the urgent need to strengthen the quality and resilience of natural assets.

3 Settele et al. (2020) *COVID-19 Stimulus Measures Must Save Lives, Protect Livelihoods, and Safeguard Nature to Reduce the Risk of Future Pandemics*.
4 Centre for Economic and Business Research (CEBR) (2020) *As the UK remains in lockdown, Government may need to target more support at manufacturing sector*.
5 World Economic Outlook (WEO) (2014) *Legacies, Clouds, Uncertainties*.
6 Robins et al. (2019) *Financing Inclusive Climate Action in the UK: An investor roadmap for the just transition*.
7 Zenghelis (2019) *Securing and Decarbonising Growth*.
8 Van der Meijden and Smulders (2017) *Carbon Lock-in: The Role of Expectations*.
9 Aghion et al. (2012) *Carbon Taxes, Path Dependency, and Directed Technical Change: Evidence from the Auto Industry*.
10 Organisation for Economic Co-operation and Development (OECD) (2020) *Coronavirus (COVID-19): Joint actions to win the war*.

Against this framing, sustainable, resilient, and inclusive investments have attractive short- and long-run characteristics. In the short run, clean energy and sustainability-focused infrastructure (such as insulation retrofits, building wind turbines and broadband networks, planting trees, restoring wetlands) is labour intensive but not susceptible to offshoring or imports.[11] Consequently, such investments generate high short-run multipliers.[12,13]

In the long term, the economic multipliers are also high, as the maintenance and operation of more productive renewable technologies makes them more productive (i.e. less labour-intensive), ecosystem services are restored, and energy and resource cost savings are passed to the wider economy.[14] Moreover, action to address the nexus of threats associated with social inequality, destruction of nature, and climate change can, by definition, result in a nexus of opportunities that will create benefits across these systems.[15,16,17]

Previous studies[18,19,20,21] set out the opportunities associated with low-carbon, resource-efficient growth. Government spending in a recession not only generates positive benefits, it also prevents negative effects on future supply,[22] where capital is irreversibly scrapped and labour skills are lost forever as a result of protracted under-utilisation. With unemployment spiralling to record levels in many countries, there are many durable jobs that are hugely productive from the sustainable growth point of view. By investing in enabling natural assets, technological innovation, and resource efficiency, the risk adjusted returns to many complementary assets can be expected to increase.

How big are the potential multiplier effects? Surprisingly big. Investment to get people back to work and stimulate domestic spending in the short run, while building capacity and supply in the medium and long run, has been shown to deliver a strong bang for every publicly borrowed buck.[23] Each percentage point of GDP spent on investment can be expected to increase GDP ultimately by around 2 to 3 percent.[14] The IMF Fiscal Monitor (September 2020) makes a strong case for increased public investment in "job-rich, highly productive, and greener activities" in spite of growing public debt, and suggests the current multiplier could be around 2.7.

This report outlines complementary investments, policy commitments, institutional frameworks, and systems thinking that are fundamental to shaping a better, more secure, green future. This means aligning UK and global investment with net zero across all areas of the economy to accelerate technological innovation and promote the flow of private investment towards low- and zero-carbon assets. It means prioritising nature and the sustainable use of our natural resources. And it means operationalising action on nature, climate, and broader sustainable development goals at international, national, regional, and local levels – with knowledge-sharing, investment, and support for education, training, and capacity-building.

The reaction to the present crisis has shown the possibility of rapid changes in ways of doing things. It offers an opportunity to embed behaviours that are positive for climate, nature, and productivity,

11 Pollin et al. (2008) *Green Recovery: A Program to Create Good Jobs and Start Building a Low-Carbon Economy*.
12 Houser et al. (2009) *A Green Global Recovery? Assessing US Economic Stimulus and the Prospects for International Coordination*.
13 Jacobs (2012) *Green Growth: Economic Theory and Political Discourse*.
14 Hepburn et al. (2020) *Will COVID-19 fiscal recovery packages accelerate or retard progress on climate change?*
15 Karlsson et al. (2020) *Climate policy co-benefits: a review*.
16 Quam et al. (2017) *Assessing Greenhouse Gas Emissions and Health Co-Benefits: A Structured Review of Lifestyle-Related Climate Change Mitigation Strategies*.
17 Wüstemann et al. (2017) *Synergies and trade-offs between nature conservation and climate policy: Insights from the "Natural Capital Germany – TEEB DE" study*.
18 The New Climate Economy (2018) *The 2018 Report of the Global Commission on the Economy and Climate*.
19 Rydge et al. (2018) *Sustainable growth in the UK: Seizing opportunities from technological change and the transition to a low-carbon economy*.
20 Zenghelis (2016) *Building 21st century sustainable infrastructure: Time to invest*.
21 Zenghelis (2016) *Building 21st century sustainable infrastructure: Institutional Reform*.
22 DeLong and Summers (2012) *Fiscal policy in a depressed economy*.
23 Auerbach and Gorodnichenko (2012) *Fiscal multipliers in recession and expansion*.

and to promote a fair and just transition to a more resilient, zero-carbon society that is in greater harmony with the world that sustains us. The opportunities to boost productivity by investing in resource-efficient, clean innovations are not new, but the pandemic has given this vision a new and urgent dimension.[24,25,26]

A well-designed package for a sustainable, green recovery can help strengthen the UK's place in the world. As the UK assumes the leadership of the G7 and aims to deliver a successful and ambitious COP26 climate conference in 2021, a domestic economic recovery based on sustainable, inclusive, and resilient growth, and a broader definition of prosperity that includes social and natural capital, will provide added credibility to foster collaborative global efforts to transition to a green future.

Introduction

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24 Zenghelis (2020) *Can policy steer us to a greener, fairer recovery?*
25 Agarwala (2020) *Is this a good time to pursue environmental objectives?*
26 Coyle et al. (2020) *What kind of economy do people want if we 'build back better' after Covid-19?*

Chapter 1: *Economy*
Creating the Conditions and Incentives for a Green Recovery

- **Attach clear, measurable environmental sustainability conditions to all COVID-19 recovery spending**. Potential 'green strings' could vary by industry and may include conditioning interest rates on loans to emissions reductions targets consistent with net zero, air and water quality improvements, biodiversity targets, or other environmental outcomes.
- **Expedite the development and use of new economic metrics that capture social and environmental impacts** – including along the supply chain – by investing in the statistical infrastructure for measuring natural, social, and human capital and mandating strict climate and environmental reporting standards for companies.
- **Implement requirements that foster behavioural change in business** – including tightening and mandating reporting standards and requiring supply chain transparency (as in the UK Modern Slavery Act) for social and environmental impacts.
- **Support challenge-oriented research and development**, adopting and adapting the ARPA model, to address the UK Net Zero 2050 target and broader environmental objectives set out in UK Government commitments under the 25-Year Environment Plan.
- **Provide government leadership to remove the barriers to green innovation and adoption**, for instance by supporting brokering organisations to connect businesses in the circular economy, based on cutting-edge scientific research.

A robust, self-perpetuating green recovery will need the right supporting structures. The institutional and regulatory context can help create the necessary conditions and incentives.

Potential immediate actions include using 'green ties' to tie bailouts to environmental improvements, and creating an instant and permanent demand for green products through public procurement. Research and development (R&D) can be refocused around mission-oriented green challenges, regulations can spur behavioural changes to make business more compatible with environmental commitments, and government can help to scale-up and accelerate the adoption of clean tech and green business models (e.g. the circular economy).

Within the commitment to 'build back better'[1] is an acknowledgement that the UK must build back differently: with different goals and different strategies to achieve them. A comprehensive public investment strategy that focuses on building the complementary assets – physical, social, institutional, human, and natural capital – that underpin economic progress can 'build-in' goals such as sustainability, resilience, and reductions in regional and other disparities through 'levelling up'. With low interest rates and excess economic capacity, the conditions are ideal for a broad public investment campaign to develop the assets necessary to level-up the UK. But whilst government will be the initial driver of recovery, ultimately there must be an incentive structure created for businesses and households to maintain it. Such institutional capital is central to the durability of a green recovery.

1 Gov.UK (2020) *PM: A New Deal for Britain*.

Regulatory and institutional actions for zero-carbon investment

A number of regulatory and institutional actions could be taken to align investment in the UK and globally with net-zero ambitions. In particular:

1 | Tie bailouts to green performance targets

Bailout packages offered to struggling firms should be tied to green performance targets to align short- and long-term incentives with net zero and wider environmental objectives.[2] For instance, aviation bailouts could require complete emissions offsetting, elimination of short-haul domestic routes for which rail is a viable alternative, and the use of newer, more energy efficient aircraft. An open letter from 13 aviation associations suggests such measures may be welcomed by the industry.[3]

Similar 'green ties' could be targeted towards specific industries and locations to ensure maximum value for money.[4] Examples could include: agriculture (improved soil carbon storage and reduced run-off); transport (proportion of net-zero energy used), vehicle manufacturing (emissions standards and share of electric vehicle sales); and hospitality (meeting nutritional standards and reducing food waste).

Potential policy options include tying interest rates on loans to environmental targets or converting loans to grants if targets are met. Further measures include requiring net-zero reporting standards, for instance by tightening and implementing recommendations by the FSB Task Force on Climate-related Financial Disclosures (TCFD),[5] and supporting the development of complementary reporting standards by the new Task Force on Nature-related Financial Disclosures (TNFD).[6]

2 | Utilise state and local investment banks

Investment banks with green and sustainable missions can catalyse the transition towards a more sustainable, smart, and inclusive economy whilst providing effective means of smoothing economic cycles.[7,8,9]

We support a number of groups who have called for the establishment of a National Investment Bank[10] with a focus on managing and reducing risk in infrastructure projects and leveraging private finance towards a domestic green delivery pathway. At a local level, a green mission for community banks – better known as credit unions in the UK – can be key in bringing the changes needed to local communities. Community banks and credit unions tend to focus on the needs of firms and families within the communities they serve and as such they can play a role in fostering economic recovery with a bottom-up approach.[11,12]

3 | Green public procurement

Public procurement policies can be designed to spur clean innovation, growth, competitiveness, and local development. Public procurement accounted for around 14% of the UK's GDP and 32% of the total public expenditure in the UK in 2017.[13] Government procurement can be used to bolster demand for green products across sectors, especially in transport and construction.

2 Vivid Economics (2020) *Green Stimulus Index (July 14th 2020 update)*.
3 International Air Transport Association (IATA) (2020) *EU COVID-19 Green recovery funding for the decarbonisation of civil aviation: An Open Letter to EU Ministers and European Commissioners*.
4 Bateman et al. (2013) *Bringing ecosystem services into economic decision-making: land use in the United Kingdom*.
5 TCFD (2017) *Recommendations of the Task Force on Climate-related Financial Disclosures*.
6 Task Force on Nature-related Financial Disclosures.
7 Mazzucato and Macfarlane (2017) *Patient strategic finance: opportunities for state investment banks in the UK*.
8 Egli et al. (2018) *A dynamic analysis of financing conditions for renewable energy technologies*.
9 Geddes et al. (2018) *The multiple roles of state investment banks in low-carbon energy finance: an analysis of Australia, the UK and Germany*.
10 COP26 Universities Network (2020) *A net-zero emissions economic recovery from COVID-19*.
11 EPA (2018) *Clean Energy Finance: Green Banking Strategies for Local Governments*.
12 Geobey and Weber (2013) *Lessons in operationalizing social finance: the case of Vancouver City Savings Credit Union*.
13 Organisation for Economic Co-operation and Development (OECD) (2019) *Government at a glance 2019*.

Because this instrument is available at all local and regional levels, it is consistent with a 'levelling up' agenda – fostering local economies and boosting competitiveness and innovation by creating market opportunities, particularly for small and medium-sized firms. However, smaller businesses still struggle to win government contracts. In 2017, only 22.5% of the government procurement spending went to small and medium-sized enterprises (SMEs), with barely 10% going directly to contracts signed between small business and the government.[14]

While evidence suggests that sustainable standards must keep rising, government procurement programs should include flexible design features that comprise the adaptation of contracts and bids (in size or costs) to facilitate the involvement of small firms.[15,16,17] This would help create the conditions to engage all firms, including SMEs, in the pursuit of more sustainable production and consumption processes aligned with national and international environmental targets.

Implement requirements that foster behavioural change in businesses

Business action and leadership on climate has shifted dramatically in recent years as a result of increasing demands from influential stakeholders — including investors, supply chain partners, regulators, and civil society — for greater transparency and targets. Expecting dramatic and rapid change on the basis of voluntary actions is not enough, however, as many companies selectively set priorities and targets that are in line with their existing efforts.[18,19]

Pressure from investors can generate behavioural change, but its effectiveness is held back by the relatively nascent state of and lack of consistency among Environment, Social, and Governance (ESG) and climate risk frameworks, metrics, and reporting requirements.[20,21] Moves to mandate TCFD reporting should be accelerated, as should efforts to fully integrate climate-related financial risk within regular supervisory activities, as indicated by the Prudential Regulation Authority's Dear CEO Letter in July 2020.[22] Preparing to mandate the TNFD when it is rolled out would help finance and business anticipate and improve their reporting on these increasingly predominant frameworks.

However, whilst more stringent environmental reporting is needed, these current frameworks do not go far enough. A key shortcoming is the exclusion of environmental impacts along the supply chain (namely Scope 3 emissions). To improve real-world outcomes, ESG reporting standards need rigorous independent scientific and statistical verification. Government could support such robust oversight of ESG metrics to avoid 'greenwash' or accusations of it. More generally, the development and use of new economic metrics that capture social and environmental impacts – including along the supply chain – needs to be expedited by investing in the statistical infrastructure for measuring natural, social, and human capital (e.g. UK Office for National Statistics, UK Natural Capital Committee, and UN System of Environmental Economic Accounts).

Actions by supply chain partners (buyers, private, and public) can unleash significant opportunities for carbon emissions reduction, with supply chains generating on average more than five times the emissions of a company's own operations.[23] Supply chain pressure can similarly begin to tackle issues

14 Davies et al. (2018) *Government procurement: The scale and nature of contracting in the UK*.
15 Tarantini et al. (2011) *A life cycle approach to GPP of building materials and elements: A case study on windows*.
16 Ghisetti (2017) *Demand-pull and environmental innovations: Estimating the effects of innovative public procurement*.
17 EC (2012) *GPP Green Public Procurement. A collection of good practices*.
18 Howard-Grenville et al. (2019) *Sustainable development for a better world: contributions of leadership, management, and organizations*.
19 PwC (2015) *Make it your business: Engaging with the Sustainable development goals*.
20 Grewal et al. (2020) *Material sustainability information and stock price informativeness*.
21 Berg et al. (2019) "*Aggregate Confusion: The Divergence of ESG Ratings*.
22 Bank of England (2020) *Managing climate-related financial risk – thematic feedback from the PRA's review of firms' Supervisory Statement 3/19 (SS3/19) plans and clarification of expectations*.
23 CDP (2019) *Changing the Chain: Global Supply Chain Report*.

like biodiversity loss and land degradation when customers work alongside supply chain partners to invest in improved practices. Commitments by leading firms to require their suppliers to comply with their own climate targets are emerging: Apple recently announced it will require its suppliers to achieve carbon neutrality by 2030[24]; Walmart started project Gigaton to work with suppliers on reducing their combined carbon footprint[25]; and BT Group is partnering with its suppliers to reduce their emissions and spur eco-innovation.[26]

Companies can be induced to understand the performance of their supply chains simply because of the potential increase in resilience that may be associated with better stakeholder relations driven by supply chain transparency. BlackRock's 2020 report has argued that better performance of sustainability funds through the COVID-19 crisis is partially driven by better governance and supply chain transparency characteristic of high ESG-rated companies.[27] But Government regulation also plays an important role in driving supply chain requirements.[28] Government-mandated supply chain transparency requirements have been effective in targeted areas (e.g. the UK Modern Slavery Act; the French Corporate Duty of Vigilance Law) and even when data on supply chain impacts are difficult to gather, establishing the processes to do so is an important first step.[29]

Business behavioural change is also influenced by the presence of board members who are well-versed in ESG and climate risk issues, and board committees and decision processes that explicitly pay attention to these issues, as well as the engagement of senior leaders with external stakeholders.[30,31] Such governance arrangements could be integrated into requirements for bailouts, and required explicitly as part of mandating TCFD/TNFD reporting.

Actions to mobilize private sector investments in cleantech innovation

There are several near-term actions that could be taken to revitalize the UK economy by mobilizing private investments in innovation towards a zero-carbon economy.

1 | Developing a UK research programme based on the US Advanced Research Projects Agency (ARPA) model, focused in new net-zero technologies, would provide a flexible, responsive, and challenge-oriented R&D platform for supporting high-risk, high-reward activities, including those in the private sector. The ARPA model differs from traditional R&D structures in terms of more flexible hiring and a mission-oriented approach.[32] It was adapted by the US government in 2009 from its origins in Defense to Energy (ARPA-E). By 2019, ARPA-E had allocated over $3 billion.[33]

New research shows that ARPA-E funding is associated with mobilising additional cleantech start-up innovation activities, measured by patents, when compared to start-ups receiving other, more conventional US Department of Energy (DOE) R&D funding and to the broader group of US clean-tech start-ups.[34] ARPA-E funded start-ups also tend to do better in terms of business outcomes (i.e. in terms of their ability to attract subsequent private funding, firm survival, and acquisitions or initial public offerings) compared to those funded by other US government programs. ARPA-E funding has also been associated with higher publication and patenting outcomes across a wider set of award recipients, not just startups.[35] Even though ARPA-E projects are supposed to be high-risk, ARPA-E

24 Apple (2020) *Apple commits to be 100 percent carbon neutral for its supply chain and products by 2030*.
25 Walmart Sustainability Hub (2017) *Project Gigaton*.
26 BT (2020) *Tackling climate change and environmental challenges*.
27 BlackRock (2020) *Sustainable investing: resilience amid uncertainty*.
28 Folke et al. (2019) *Transnational corporations and the challenge of biosphere stewardship*.
29 Kim and Davis (2016) *Challenges for global supply chain sustainability: Evidence from conflict minerals reports*.
30 Eccles et al. (2014) *The impact of corporate sustainability on organizational processes and performance*.
31 DesJardine et al. (2019) *Bouncing back: Building resilience through social and environmental practices in the context of the 2008 global financial crisis*.
32 U.S. National Academies of Sciences, Engineering, and Medicine (2017) *An Assessment of ARPA-E*.
33 Gallagher and Anadon (2020) *DOE Budget Authority for Energy Research, Development, and Demonstration Database*.
34 Goldstein et al. (2020) *Patenting and business outcomes for cleantech startups funded by ARPA-E*.
35 Goldstein and Narayanamurti (2018) *Simultaneous pursuit of discovery and invention in the US department of energy*.

funded start-ups have similar business outcomes compared to a broader group of cleantech start-ups controlling for a range of factors.[34] Recent UK research also found that, particularly for SMEs, public funding for R&D in firms can be an effective complementary instrument to other policies such as R&D tax credits, improving value for money from public funding by boosting patents and business outcomes.[36] US-based research found that US DOE Small Business Innovation Research (SBIR) R&D grants for SMEs resulted in improved outcomes for SMEs.[37]

All of this suggests that ARPA-E's unique operating features and functions have been important in the US innovation ecosystem and could usefully be trialled in the UK, and that additional support for R&D in cleantech small firms could help improve competitiveness and environmental goals. At the same time, ARPA-E support for R&D does not fill all net-zero funding gaps. The documented lower rate of successful exits for investors in cleantech start-ups in the US compared to biotech and IT start-ups[38] also suggests that a larger role of governments supporting demonstration, niche markets, and deployment is needed (see Chapter 3: Technology).

2 | The UK government could increase its provision of other additional complementary resources for firms innovating in cleantech, helping bring new solutions up to scale in the form of providing scientific and technical (e.g. licensing) expertise and also increasing the provision of testing facilities, such as those available at the US national labs.[39] Research suggests that start-ups working on joint technology development with national laboratories and licensing technologies from national laboratories can be successful in attracting private funding towards green innovation,[39] and that research facilities accessible to private firms can help private firms.[40]

3 | Additional government leadership and public investment is needed to support demonstration projects, create niche markets, support early deployment, and foster learning by doing – further reducing costs and enhancing competitiveness and efficiency.[41,42,43,44] This involves expanding funding for technology demonstration projects, considering revamping mechanisms such as the Energy Technologies Institute, and providing scale-up support in the form of standards, feed-in tariffs, auctions, or procurement for different technologies and sectors.

Supporting cross-sector innovation and innovations in business models

Cross-business and cross-sector innovation can be held back by organisational transaction costs – barriers to knowing or trusting what others do – more so than lack of good ideas or available resources. Research on the circular economy demonstrates that simple interventions like brokering organisations, such as the UK's former National Industrial Symbiosis Programme, supported by government funding, can help companies connect across sectors and find opportunities for carbon emission savings, waste reduction, and increased employment.[45,46,47]

However, actually creating the necessary connections between companies and sectors to support a circular economy requires significant ongoing investment of time and resources (and appropriate incentives) to reap the benefits. If outcome metrics, like waste diverted or carbon emissions

36 Pless (2018) *Are "Complementary Policies" substitutes? Evidence from R&D subsidies in the UK*.
37 Howell (2017) *Financing Innovation: Evidence from R&D grants*.
38 Gaddy et al. (2017) *Venture Capital and Cleantech: The wrong model for energy innovation*.
39 Doblinger et al. *Governments as partners: the role of alliances in U.S. cleantech startup innovation*.
40 Anadon et al. (2016) *The pressing energy innovation challenge of the U.S. national labs*.
41 Anadon and Nemet (2013) *The U.S. Synthetic Fuels Program: Policy consistency, flexibility, and the long-term consequences of perceived failures*.
42 Nemet et al. (2018) *The valley of death, the technology pork barrel, and public support for large demonstration projects*.
43 Nemet (2019) *How Solar Energy Became Cheap: A Model for Low-Carbon Innovation*.
44 Santen and Anadon (2016) *Balancing solar PV deployment and RD&D: A comprehensive framework for managing innovation uncertainty in electricity technology investment planning*.
45 Paquin et al. (2014) *Is there cash in that trash? Factors influencing industrial symbiosis exchange initiation and completion*.
46 Paquin and Howard-Grenville (2013) *Blind dates and arranged marriages: Longitudinal processes of network orchestration*.
47 Ashton (2008) *Understanding the organization of industrial ecosystems: A social network approach*.

mitigated, are too narrowly construed, the activities undertaken can narrow to deliver on these to the potential exclusion of other benefits, such as jobs created, reduction in material intensity, or biodiversity protection.[45] Moving beyond weight-based metrics in resource and waste strategy to include carbon, natural capital, and social impact metrics[48] can also help incentivise more effective cross-business collaboration. Government can further support business collaboration for circular economy through mandating requirements for recycled material content and regulation that supports reuse and repurposing of materials,[49] in addition to recycling.[50]

A key concern in supporting cross-sector innovation is how to overcome competitiveness trade-offs that may arise from decarbonisation efforts, especially as such trade-offs will fall unequally across sectors and industries. These trade-offs usually affect specific types of actors (e.g. SMEs) or sectors (e.g. energy intensive industries) and are a commonly cited excuse to delay mitigation efforts.[51] However, decarbonisation policy instruments can be designed to minimise possible trade-offs among different socio-economic goals and to promote 'co-benefits'.[52,53,54]

SMEs often face greater barriers to eco-innovation such as prohibitive capital requirements.[55] Promoting innovation, green investment, and competitiveness among SMEs, targeted initiatives that demonstrate organisational benefits and cost-saving opportunities for small producers can be effective.[56] Special energy auctions for small producers or the combination of feed-in-tariffs for small producers and auctions for incumbents may facilitate faster cost reductions whilst reducing negative competitiveness impacts on small firms or new entrants.[57,58,59]

Chapter 1: Creating the Conditions and Incentives for a Green Recovery

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48 DEFRA (2019) *Resources and waste strategy for England: monitoring and evaluation*.
49 UKGBC (2020) *UKGBC Circular Economy Policy Asks*.
50 DEFRA (2020) *Circular economy measures drive forward ambitious plans for waste*.
51 Zhang et al. (2017) *Co-benefits of global, domestic, and sectoral greenhouse gas mitigation for {US} air quality and human health in 2050*.
52 Stokes and Warshaw (2017) *Renewable energy policy design and framing influence public support in the United States*.
53 Ansolabehere and Konisky (2014) *Cheap and Clean: How Americans Think about Energy in the Age of Global Warming*.
54 Deng et al. (2017) *Co-benefits of greenhouse gas mitigation: a review and classification by type, mitigation sector, and geography*.
55 United Nations Economic Commission for Europe (UNECE) (2011) *International Conference Promoting Eco-innovation: Policies and Opportunities*.
56 Del Río et al. (2015) *Distinctive features of environmental innovators: an econometric analysis*.
57 Del Rio and Linares (2014) *Back to the future? Rethinking auctions for renwable electricity support*.
58 Del Rio et al. (2017) *A techno-economic analysis of EU renewable electricity policy pathways in 2030*.
59 Lucas et al. (2017) *Design and Assessment of Renewable Electricity Auctions in Sub-Saharan Africa*. (In: Pueyo and Bawakyillenuo *Green Power for Africa: Overcoming the main constraints*.)

Chapter 2: *Just Transition*
Supporting Society in the Zero-Carbon Transformation

- **Establish a Net Zero Delivery Board** to drive through the policy and regulatory changes required across the whole of the economy, to promote greater democratic engagement in policy formation, and ensure the costs and benefits of a net-zero transition are fairly shared.
- **Facilitate the creation of green jobs** to address rising unemployment, to transform the economy for a zero-carbon future, and to restore nature – prioritising areas of high unemployment, labour market exclusion, and regions with the highest proportion of jobs that could be at risk in the transition to a net-zero economy.
- **Review and overhaul the entire lifelong learning portfolio**, including education, training, and re-skilling, to boost societal knowledge and understanding of sustainability and to underpin the employment opportunities of the future.
- **Create a Net Zero Fund** to support a just transition to a net zero economy – locally, regionally, and nationally.

The COVID-19 crisis has exacerbated underlying societal stresses in the UK including those of social inequalities and regional and intergenerational disparities. The UK has one of the highest levels of inequality (as measured by Gini coefficient) amongst wealthy countries, and currently the income of the richest 20% of people is over six times higher than the poorest 20%.[1] Even pre-COVID-19, rising inequalities in the UK had measurably reduced life expectancy in women, especially amongst those at greatest disadvantage.[2] The crisis has further stretched the supporting structures, not least the national public health functions.

There is an opportunity to rebuild the UK economy in the wake of the pandemic to be stronger, fairer, and more resilient, and to do so in a way that supports the required climate action and enhances our natural environment through a fairer distribution of resources and consumption that ensures issues of gender, ethnicity, class, and age have no repercussions in relation to energy services, employment, mental and physical health, and welfare.[3] By contrast, recovery measures that fail to acknowledge the climate, nature, and social crises would neither be sustainable, nor a success.

The conventional view is that significant economic, social, and environmental benefits can be delivered by Government investment to kick-start infrastructure projects up and down the country, from upgrading the housing stock[4] to boosting infrastructure for walking and cycling.[5] Indeed, if carefully designed and with close attention to value-for-money and equitable distribution, such measures can create new jobs, support new industries, and lead to improved health, wellbeing, and quality of life for all citizens.

Building on these investments, we suggest the following seven elements should be considered to support society to make a zero-carbon transformation when planning the recovery from COVID-19.

1 ONS (2020a) *Household income inequality, UK: financial year ending 2020 (provisional – released: 22 July 2020)*.
2 Marmot et al. (2020) *Health Equity in England: The Marmot Review 10 Years On*.
3 Abram et al. (2020) *Just Transition: Pathways to Socially Inclusive Decarbonisation*.
4 Gov.UK (2020a) *Chancellor's Plan for Jobs to help the UK's recovery*.
5 Gov.UK (2020b) *PM kickstarts £2bn cycling and walking revolution*.

1 | Establish a Net Zero Delivery Board to drive through the policy and regulatory changes required across the whole of the economy, and ensure the costs and benefits are fairly shared

Delivering a rapid zero-carbon transformation in an integrated and equitable way across the whole economy is a complex task made even more challenging by the disruption caused by COVID-19. Given the need for a whole-of-government approach, a Net Zero Delivery Board (NZDB) would provide a critical role in coordination and maintaining ambition. Building on the success of the 2012 Olympic Delivery Authority, the NZDB would be convened by the Cabinet Office as a non-departmental public body. Its governance infrastructure would ensure representation from across government departments and relevant agencies, the devolved administrations, local authorities and metro mayors, industry, financial institutions, NGOs, trade unions, and civil society groups.

Building on the Citizens' Assembly approach,[6,7] the NZDB would also be tasked with exploring innovative ways of democratically engaging the wider public and would ensure open and transparent discussion of the political and ethical choices decarbonisation entails. The NZDB would be responsible for formulating and delivering a Net Zero Delivery Plan that would integrate various departmental plans across government to ensure there is a coherent and fair approach to achieving decarbonisation. This should include a recognition of the fact that the effects of climate change and related policy responses will be experienced very differently across place, time, socio-economic status, and cultural grouping, including race, and should explicitly acknowledge the interests of the young and future generations. The NZDB would enable fast decision-making and accountability for meeting interim goals.[8] The NZDB would also prioritise the co-ordination of the necessary investment for a zero-carbon transition in public services including health and social care,[9] and more generally it could have a population health function, bringing together all that we know about the relationship of health and economy to sustainability.

2 | Accelerate the transition to zero-carbon living by enabling infrastructure and circular economy initiatives

The way we live, travel, work, eat, consume, socialise, and relax, alongside how we use public and private infrastructure, determines our carbon footprint and can put pressure on the natural world. Lower impact lifestyles can be made widely accessible and attractive for all as part of a wider push to tackle overconsumption. In order to mainstream green behaviours, an enabling infrastructure and political support are needed.

Central to this is investment in solutions to deliver zero-carbon thermal comfort in homes (high standards of home insulation paired with decarbonised heating and cooling), zero-carbon mobility (facilitating the switch to electric vehicles; supporting safe, reliable, accessible, and convenient public transport and walking/cycling), and urban planning to promote sustainable lifestyles (see Chapter 4: Infrastructure). Targeting investment and offering focused subsidies will ensure these solutions are available and affordable for all.

Other important infrastructure investments that can support a transition to zero-carbon living include enabling everyone to access and benefit from the digital revolution by prioritising the provision of affordable fibre broadband internet for all. Digital inequalities are of ongoing concern, and differences in connectivity, software, hardware, skills, and usage reinforce one another,[10] with demographic, economic, social, cultural, political, and infrastructural factors all creating potential

6 Citizens' Assembly (2020)
7 Renwick et al. (2018) *What kind of Brexit do voters want? Lessons from the Citizens' Assembly on Brexit*.
8 Allwood et al. (2019) *Absolute Zero*.
9 NHS (2020) *A Net Zero NHS*.
10 Robinson et al. (2020) *Digital inequalities 2.0: Legacy inequalities in the information age*.

barriers to digital inclusion.[11] Prioritising digital inclusion, which may also help address more general regional disparities, requires education and training for those without digital skills, and active compensation for any worsening of experience, access, transparency, and accountability associated with the 'digital by default' approach to service provision.[12,13]

Another key area for investment is to provide access to good-quality green space, especially to those in deprived areas. Evidence shows that living in a greener environment can promote and protect good health and mental wellbeing, and improve social cohesion. For instance, it is estimated that £2.1 billion per year could be saved in health costs if everyone in England had good access to green space, due to increased physical activity in those spaces.[14] As these benefits vary according to age group, generation, culture, affluence, and rurality, it will be important to enable and promote the use of green spaces.[15]

A more circular economy which promotes the efficient and repeated use of resources can bring economic, environmental, and societal benefits.[16] In particular, reducing resource use is not only profitable but also has environmental benefits and creates jobs.[17] At a global level, it is estimated that 7 to 8 million new jobs (net) could be created by 2030 in a circular economy scenario, with sales work offering the most new jobs.[18] Many of the technologies needed to disassemble end-of-use products (e.g. clothes, food, and cars) and to re-manufacture them are still relatively immature, to the extent that the world is just 8.6% circular.[19] As such, significant additional labour is required in the short-term. As the technologies mature and circular industries become more efficient, the jobs associated with systems change will reduce but the resource savings, including reduced need for imports of materials, will give long-term benefit with flow-on effects to the wider economy. The labour-intensive activities of repair, maintenance, and reuse will continue to create work, and by not taxing renewable resources, including labour, policymakers could accelerate this circular transition.[20,21]

More sustainable practices could be promoted and embedded. For instance, local sustainable production and consumption could be supported by encouraging shops to stock locally-sourced, seasonal, and affordable products. Shifts in purchasing patterns would need to also support the transition of farmers and workers within the international agricultural supply chains which currently feed the UK (see Chapter 5: Nature). The distribution of food within the UK also requires attention, as it is estimated that today 1.2 million people in the UK are living in deprived 'food deserts' with limited access to affordable fresh food,[22] and a heavy focus of profitable take-aways.

3 | Facilitate the creation of new green jobs

We currently face the risk of a deep recession. Many people have been furloughed for months, unemployment and the number of redundancies are steadily rising,[23] many businesses are suffering,[24] and the UK economy looks set to contract substantially.[25] In response to similar scenarios around the world, governments have pledged $10 trillion of COVID-19 response packages.[26]

11 Al-Muwil et al. (2019) *Balancing Digital-By-Default with Inclusion: A Study of the Factors Influencing E-Inclusion in the UK*.
12 Watts (2020) *COVID-19 and the digital divide in the UK*.
13 Blank and Lutz (2018) *Benefits and harms from Internet use: A differentiated analysis of Great Britain*.
14 Public Health England (2020) *Improving access to greenspace: A new review for 2020*.
15 Douglas et al. (2017) *Green space benefits for health and well-being: A life-course approach for urban planning, design and management*.
16 Ellen MacArthur Foundation (EMF) (2019) *Completing the Picture: How the Circular Economy Tackles Climate Change*.
17 Lavery et al. (2013) *The next manufacturing revolution: non-labour resource productivity and its potential for UK manufacturing*.
18 ILO (2020) *Policy Brief: COVID-19 and the world of work. Jump-starting a green recovery with more and better jobs, healthy and resilient societies*.
19 Circle Economy (2020) *Circularity Gap Report 2020*.
20 Stahel (2012) *Walter Stahel on the Performance Economy*.
21 Webster (2015) *The circular economy: a wealth of flows*.
22 Kellogg's (2018) *Can everyone access affordable, nutritious food? A picture of Britain's deprived food deserts*.
23 ONS (2020b) *Employment in the UK: October 2020*.
24 ONS (2020c) *Coronovirus and the latest indicators for the UK economy and society: 22 October 2020*.
25 Bank of England (2020) *Monetary Policy Report and Financial Stability Report - August 2020*.
26 McKinsey and Company (2020) *The future of business: Reimagining 2020 and beyond*.

An attraction of green stimulus packages is that they can support the creation of jobs in the short, medium, and long term.

Additional high-, medium-, and low-skilled labour is required in the design and building of new infrastructure for a zero-carbon transition (e.g., renewable energy, insulation, low-carbon heating, electric vehicle infrastructure, cycle networks, etc.), in building resilience to future climate change (e.g. flood defences), and in the implementation of nature-based solutions such as landscape restoration and appropriate tree planting (see Chapter 5: Nature) – followed by the operation and maintenance of these new assets and in supporting the required reskilling and retraining.[27] Investment in low-carbon projects can lead to secondary new employment in associated suppliers and distributors, planners, and administrators. As described earlier, the developing circular economy can also provide new jobs, and there may be opportunities to learn from lower- and middle-income countries where repair and reuse are already commonplace,[28] creating local jobs which are more evenly distributed geographically.

Short-term job and enterprise creation schemes need to sit within a sustainable medium- and long-term strategy that provides a pipeline to support the evolving zero-carbon transition and associated jobs over the coming decades. That means, for example, investing today in research and development of the technologies that will provide the manufacturing and implementation jobs of tomorrow (see Chapter 3: Technology) and in the education and training that will provide future employees with the necessary skills.

There is a serious risk that the distribution of winners and losers from a zero-carbon transition reinforces existing disparities. Some regions are vulnerable to continued de-industrialisation or economic exclusion. The East Midlands, West Midlands, and Yorkshire and the Humber are the three regions with the highest proportions of jobs in sectors such as transport and manufacturing that could be at risk in the zero-carbon transition,[29] but also are areas with great potential for the new industries needed for this transition. Former industrial areas, seaside towns, and some London Boroughs were also worst hit by recent welfare reform and other austerity measures, compounding pre-existing inequalities.[30,31] The zero-carbon transition will only be successful, inclusive, and sustainable if it addresses these vulnerabilities and persistent between-country and within-country geographical inequalities.

One set of interventions could be spatially targeted fiscal policies applied to regions with higher levels of deprivation and joblessness,[32] to invest in green industrial clusters and low-carbon infrastructure. Job stimulus packages can also be targeted to the regions most in need, providing compensatory investments and initiatives, and ensuring that new jobs are decent ones – meaning that they are safe, formal, paid a living wage, offer security and worker rights, with employees who are consulted and empowered.[33]

4 | Educate, train, and re-skill for a sustainable future

There is both a need and a demand for education, training, and skills enhancement to shape a work-force and broader society for the challenges and opportunities of the coming decades. The need is exemplified by the skills required for the new jobs in industries and sectors aligned to a zero-carbon transition outlined above. This means reviewing and overhauling the entire lifelong learning

27 ILO (2020) *Policy Brief: COVID-19 and the world of work. Jump-starting a green recovery with more and better jobs, healthy and resilient societies*.
28 Preston and Lehne (2017) *A Wider Circle? The Circular Economy in Developing Countries.*
29 Robins et al. (2019) *Investing in a just transition in the UK: How investors can integrate social impact and place-based financing into climate strategies*.
30 Beatty and Fothergill (2016) *The uneven impact of welfare reform: financial losses to places and people*.
31 Gray and Barford (2018) *The depths of the cuts: the uneven geography of local government austerity*.
32 Gbohoui et al. (2019) *The Great Divide: Regional Inequality and Fiscal Policy*.
33 ILO (2019) *Decent work*.

portfolio to increase societal knowledge and understanding of sustainability and related issues and to underpin the employment opportunities of the future. If we are to prosper and thrive in our changing society and in an increasingly interconnected and competitive world, both our mental and material resources will be vital. Encouraging and enabling everyone to realise their potential throughout their lives will be crucial for our future prosperity and wellbeing.[34] Equal access to education and targeted vocational training for lower skilled workers is also vital to ensure that the creation of quality 'green' jobs does not just benefit the already advantaged.[35]

Children born today will be retiring towards the end of the century. Over that time, society will face complex uncertainties and this means there is a need to reconceptualise what education is and to consider how it is providing for those who will be living/leading/enacting/surviving in the latter part of this century and the beginning of the next.[36] Areas of particular importance that are currently under-represented in the educational offering include digital advancement, environmental risk and change, health and wellbeing, civic studies that encompass knowledge of history in an inclusive manner, and discussion of the future of democracy. These literacies should be integrated into the school curriculum in innovative ways that both inform and empower. At the secondary education level, OCR has recently completed a consultation on creating a new GCSE in Natural History.[37] This could be one element of a refreshed educational offering that emphasises the natural world and our place in it, and sets students on a path to be part of shaping the solutions to climate change and other threats.

Apprenticeships, university education, professional qualifications, and in-job training/development all need to be examined and adjusted to ensure they are providing the skills and training needed to support future needs. Vocational Education and Training (VET) is imperative for the large-scale up-skilling and reskilling necessary for economic recovery; in rolling out VET, the prioritisation of training for the least educated people will offer protection from poverty and exclusion.[38] The successful Swiss apprenticeship system values apprenticeships as 'different but equal' to an academic education, and is backed up by state finance and extensive firm buy-in.[39]

Another focus is the provision of training to generate capacity in zero-carbon research, development, manufacturing, and operations, along with climate-relevant knowledge in lawyers, accountants, and regulators. It is essential to take a broad view of the skills needed, encompassing the full spectrum from agriculturalists implementing sustainable practices to computer scientists driving relevant digital innovations. We do not know what the jobs of the future will be, but a focus on skills and readiness to learn will provide a robust platform.[40] Setting in place a more comprehensive system of continued training and, where relevant, reskilling throughout adult life will also promote resilience.

The over-65s are a rapidly growing segment of society and should also form part of a holistic educational offering. For example, digital skills are unevenly distributed by age, and with an aging population, older people may struggle to keep up with new digital developments. This should be addressed through lifelong learning.[41]

5 | Act local by supporting local government to create an inclusive green society

Achieving an inclusive green society will require engagement and action at a local level. Two-thirds of all district, county, unitary, and metropolitan councils have now declared a climate emergency, with

34 Foresight Mental Capital and Wellbeing Project (2008)
35 Abram et al. (2020) *Just Transition: Pathways to Socially Inclusive Decarbonisation*.
36 Biddulph and Flutter (2021) *Unlocking Research: Inspiring Primary Curriculum Design*.
37 OCR (2020) *Phenomenal response to our consultation on creating a new Natural History GCSE*.
38 Cedefop and ETF (2020) *The importance of being vocational: challenges and opportunities for VET in the next decade*.
39 Graf (2014) *The Swiss Apprenticeship System: Its Institutional Specificities and Strengths in International Perspective*.
40 ILO (2019a) *Skills for a greener future*.
41 Cambridge Institute for Sustainability Leadership (CISL) (2020) *Working towards a climate neutral Europe: Jobs and skills in a changing world, UK: CLG Europe*.

several setting a goal of carbon neutrality by 2030.[42] Given their role in, for example, handling waste, providing or subsidising public transport, managing roads and parking, running some schools and other large institutions, providing leisure opportunities, and as a landowner, local government could play a key role in shaping the overall national response. To do so, however, local governments need to be empowered and provided with dedicated funding, recognising that past austerity measures fell hardest upon local governments in the poorest areas,[43] with national recognition growing of this acute need.

A dedicated Net Zero Fund could be established as part of regional economic development funding to help deliver a net-zero economy through a just transition at a local and regional level, and to ensure those negatively disrupted are given the resources and support to succeed in the future.[44] The role of green public procurement is also important here, and is addressed in Chapter 1: Economy. Examples of local investment include the district heat network installed by Bristol City Council for more efficient and cleaner heating that one day could be powered by a carbon-neutral energy source, and the investment in solar farms by Cambridgeshire County Council as both an income stream and a move towards their goal of carbon neutrality by 2050.

A number of cities and regions such as Edinburgh, Belfast, Leeds, and Cambridgeshire and Peterborough have established independent commissions bringing together the private, public, and third sectors to consult, provide advice, and catalyse action on climate and the environment at a local level. Learning from these initiatives, independent commissions could be established and supported at a local level across the country. A network of such commissions would allow for collaborative sharing of best practice and new learning, building on existing initiatives such as the Place-based Action Network and activities of the Local Government Association.[45,46]

6 | Support and incentivise smaller businesses on their pathways to zero carbon

While many large multinationals may have dedicated teams to design a zero-carbon transition and manage risk, smaller businesses need to be supported along this route. This will include providing accessible and affordable training for staff, and upskilling and increasing the knowledge of management, for example through local Chambers of Commerce (see Chapter 1: Economy). It will also include sharing market insights about demand, supply, and future scenarios, and supporting smaller businesses to manage risks and uncertainties in this transition.

There is an opportunity for small and medium-sized enterprises to respond to the growing demand for low-carbon and carbon-positive solutions, either direct to consumers or as suppliers in larger companies' supply chains. Doing so requires these companies to robustly demonstrate their carbon performance. The tools to enable this are developing, but robust data – provided, for example, through blockchain technology – will need to be deployed in an accessible and affordable way. This shift will enable smaller companies to verify and report on their carbon performance time- and cost-efficiently (see Chapter 1: Economy).

In addition, the finance needs of such companies need to be addressed, as access to patient and low-interest capital is a major barrier to a rapid uptake of scalable solutions. Again, a Net Zero Fund could support this. A greater variety of finance is needed as well as a greater volume, so the spectrum of start-up to scale-up is supported effectively. Social enterprise models, which create meaningful employment and other positive social externalities through their core business operations, need additional support to grow successfully if inequality is to be tackled at the root, particularly as these enterprises are often locally rooted and so help their communities to weather exogenous shocks.

42 Climate Emergency (2020) *List of Councils who have declared a Climate Emergency: 6th February 2020*.
43 Gray and Barford (2018) *The depths of the cuts: the uneven geography of local government austerity*.
44 IPPR (2020) *Further, Fairer, Faster: putting people at the heart of tackling the climate and nature emergency*.
45 Place-based Climate Action Network (PCAN) (2020) *Driving climate action in UK cities and communities*.
46 Local Government Association (LGA) (2020) *Climate change*.

7 | Encourage and incentivise responsible, green citizenship

Communities across the UK can play an active role in demanding, designing, and delivering a fairer, greener future – and diverse citizen groups of all ages, incomes, locations, races, and religions need to be consulted and supported in this regard. Citizen engagement offers greater participation, transparency, and accountability. A shift is needed from today's 'high-carbon, resource-intensive' lifestyles towards a society in which sustainable options are widely accessible and readily affordable and waste is discouraged, resulting in changing patterns of consumption. Positive and responsible engagement with nature should be imagined, encouraged, and promoted, in part through marketing sustainable options combined with prohibiting the advertisement of unsustainable options.[47,48,49] Positively engaging public perceptions, emotions, and discourses is also important because these influence how people make sense of their own roles and responsibilities in relation to global challenges.[50,51,52]

There is great potential to significantly increase the equity, speed, and scale of the zero-carbon transformation and to encourage more nature-friendly practices through appropriate regulatory and incentive structures that re-calibrate individual norms in ways that, as noted above, can be easily adopted and welcomed across the diversity of communities and cultures in the UK. The most effective approach is at community and societal levels to change behaviour.[53] Within this, but playing a more limited role, will be those tailored to individuals with personalised information.[54]

Change needs to engage all sectors of society, and initiatives need to recognise people's diverse circumstances. Various socioeconomic factors can indicate high-emitting households in terms of energy use at home, e.g. income level, housing type, and household composition.[55] Some groups will have more resources to make a change while others require more financial support; some groups will be particularly influential in terms of setting new norms, with the worst polluters being where the biggest household-level improvements can be made.

Community-based organisations and grassroot non-profit groups all have a vital role to play in facilitating local, collective reflection on carbon footprints and in inspiring creativity to tackle climate and biodiversity challenges through local innovation. Such community activity is often more obvious in more affluent areas where time capacity and incomes are relatively secure. This relies on capacity within community, which in turn assumes time and engagement in this agenda. Many communities are heavily focused on day-to-day survival, and attention is needed to investment that allows diverse community action to grow. Green community projects, such as the building of community gardens, can provide significant social and environmental benefits if appropriately embedded and co-created with the community as a whole. Such community groups and projects should be supported, with priority access to grants and training for lower income communities, and the best of these being championed.

47 Peattie (2015) *Sustainability marketing*. (In: Reisch et al. *Handbook of Research on Sustainable Consumption*.)
48 Futerra (2020)
49 Boyle et al. (2020) *Smoking out the climate: lessons from the advertising ban on tobacco for tackling the climate emergency*.
50 Barford (2014) *Representing, in The SAGE Handbook of Human Geography: Two Volume Set*.
51 Barford (2016) *Discourses supporting socio-economic inequality in Kenya, Mexico and the United Kingdom*.
52 Barford (2017) *Emotional responses to world inequality*.
53 Marteau et al. (2012) *Changing human behavior to prevent disease: the importance of targeting automatic processes*.
54 Nielsen et al. (2020) *How Behavioral Interventions Can Reduce the Climate Impact of Energy Use*.
55 Wang and Meng (2019) *Understanding high-emitting households in the UK through a cluster analysis*.

Chapter 2: Supporting Society in the Zero-Carbon Transformation

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Chapter 3: *Technology*
Investing in Zero-Carbon Technology and a Zero-Carbon Industrial Transition

- **Initiate a focused national research and development programme on zero-carbon energy generation and storage technologies** to target improving performance, efficiency, reliability, and cost, and to underpin the competitiveness of the UK zero-carbon industry by building on existing UK strengths. An example is solar, where the UK has led developments of lead halide perovskite solar cells which could transform the photovoltaics industry if combined with other UK strengths in providing key component technologies such as solar glass.
- **Transform construction regulations and practices.** This requires engagement with all relevant stakeholders to enable the widespread deployment of resource-efficient building design and natural construction materials. Heat pumps should be mandated on new buildings and energy-efficiency improvements to existing buildings incentivised to render heat pumps a viable option.
- **Pursue electrification for all possible vehicles**, reserving biofuels for aircraft and long-haul shipping. It may be necessary to use hydrogen in some applications, but these should be minimised.
- **Invest in research and development, governance, and public engagement on greenhouse gas removal technologies** since engineering and/or nature-based options will be needed in order to reach a position of net zero by 2050.

Global CO_2 emissions are expected to fall 5-10% in 2020 as a result of COVID-19 restrictions imposed around the world, with an estimated peak fall of 31% in UK daily emissions.[1,2] This drop in emissions will only be temporary, however, unless the recovery from COVID-19 is used as an opportunity to invest in zero-carbon technologies and a sustainable industrial transition. With the right approach, the actions the UK takes in the months ahead to rebuild from the COVID-19 pandemic can simultaneously accelerate the zero-carbon transition and put the UK on track to meet its legally binding target of net-zero emissions by 2050.[2]

Re-engineering the energy system, from generation to storage to use, is essential if the UK is to achieve net-zero carbon by 2050.[3] Focused effort is also required to decarbonise building construction and operation, all forms of transport, and all industrial processes. Reaching net zero will require the rapid, more efficient, and lower-cost deployment of technologies already available today.[4] But also needed is R&D investment into new, breakthrough technologies that can bring big improvements in efficiency and affordability, along with engagement across sectors to ensure low- and zero-carbon options are implemented effectively.

There is real value in understanding better where, how, and by when significant technological advancements can be brought to market. It is, therefore, important to identify where there is the most room for improvement. This 'headroom' can be measured by inefficiencies in energy conversion steps, embedded energy (and economic) costs in manufacture and deployment, materials usage, etc. In many areas, the headroom is very large. One example of success from the recent past is the lighting

1 IEA (2020) *Global Energy Review 2020*.
2 CCC (2020) *Reducing UK emissions, Progress Report to Parliament*.
3 National Grid ESO (2020) *Future Energy Scenarios 2020*.
4 Allwood et al. (2019), *Absolute Zero: Delivering the UK's climate change commitment with incremental changes to today's technologies*.

revolution to LEDs, made possible by the breakthroughs in gallium nitride semiconductor devices. On the 'to do' list is solar technology which runs well below efficiency limits – silicon solar cells generally convert at most 20% of incident solar energy to electricity.

Here we will highlight four sectors in which significant advances and improvements can be made: energy generation and storage; construction and operation of buildings; transport; and industry. We will also review the opportunities for greenhouse gas removal via nature-based and engineering-based approaches.

Decisions on how best to deploy the different solutions require detailed quantitative analysis considering a complex set of factors and full value chains. For energy generation and storage, this includes the energy efficiency achievable in the different conversion steps from source to use, and the carbon abatement potential including its dependence on time through the mix of technologies used to produce electricity as well as economic and energy security factors. In any analysis of fuel sources used in transport, a well-to-wheel approach accounting for fuel production, distribution, and end-use is necessary, with freight transport measured in $kgCO_2$/tonne.km. For approaches to greenhouse gas removal, an intricate set of trade-offs and impacts must be considered along with ethical and governance issues.

1 | Energy generation and storage

Most of the technologies needed for providing zero-carbon electricity are proven, ready for scale-up, and economically viable – in the case of wind and solar, even without a carbon price. This has been brought about by technological innovation bringing down the cost of wind, solar, and battery storage by factors of 3, 7, and 5, respectively, over the last 10 years.

However, there remains significant headroom for improving performance and reducing cost further. The scale-up of these technologies will need to be accompanied by an ambitious, joint industry/academic R&D programme across the whole value chain from energy materials to systems which can underpin the competitiveness of the UK's zero-carbon industry. Listed below are some illustrative examples to capture the scale of the opportunities and highlight specific challenges that require attention:

- *Wind*: The UK should capitalise on its global lead in offshore wind deployment. This will require continuous innovation in design of turbines with >10 MW output, lifetime of components, as well as technologies for lower-cost installation and maintenance installation of new/existing systems, including systems installed in deeper seas.

- *Solar*: Opportunities exist for building off the UK's global lead in new solar cell technologies. The Oxford breakthroughs in lead halide perovskites[5] now allow tandem solar cells (perovskite + silicon) that demonstrate towards 30% efficiency, significantly higher than what is achieved in standard silicon modules (23%).[6] The UK has several key industry players that supply the solar cell industry, e.g. Pilkington/NSG glass, who are well-placed to capture opportunities for integrating these new technologies with silicon cells.

- *Nuclear*: Fission and fusion both offer non-intermittent zero-carbon electricity generation – a very important component to overall electricity generation. The challenges for fission reactors are primarily around cost, regulatory approval, and private sector financing, rather than technology per se. Comparison needs to be made to costs of other non-intermittent options, such as battery/hydrogen/hydroelectric storage. Proponents for small modular reactors claim they offer faster manufacturing, assembly, and installation. It is important that public sector initiatives are designed to draw in private sector investment. Fusion retains its promise but

5 Lee et al. (2012) *Efficient Hybrid Solar Cells Based on Meso-Superstructured Organometal Halide Perovskites*.
6 Extance (2019) *Perovskites on Trial*.

is still a long way from practical electricity generation. For example, timescales for the full operation of ITER are measured over decades, with first fusion now scheduled for 2035 – and it is unlikely that fusion can contribute before 2050.[7] Beyond the demonstration of plasma confinement and fusion, breakthroughs are needed to find long-term stable materials for heat extraction and sustainable production of tritium.

- *Carbon capture and storage (CCS)*: Reaching net zero by 2050 will likely require the establishment of significant infrastructure and capacity for CCS,[8] especially if direct air capture (DACCS) or bioenergy (BECCS) greenhouse gas removal technologies were to be deployed at scale (see section below on greenhouse gas removal for discussion of these technologies). The limited CO_2 capture rate and energy efficiency of present chemical, amine-based CCS technology remains a concern and will need to be addressed. UK universities are at the forefront of developing improved CCS technologies, such as electrochemical carbon capture, for which theory predicts higher capture rates and significantly better energy efficiency.

- *Energy storage*: The UK should capitalize on its investments in vehicle electrification and broaden the UK's role in battery storage. The Faraday Institution is currently restricted in its scope to vehicle electrification, but Li-ion battery technology is becoming cheap enough for hourly/daily grid-scale storage and UK groups are also leading efforts to develop technologies for monthly/seasonal electricity storage, such as redox flow batteries, compressed air, liquid air (cryogenic), or chemical storage. Further advances in storage capacity, reliability, and cost – and approaches for reducing the environmental impact of battery production through more effective recycling – will be needed.[9]

- *Hydrogen*: There is a need for developing a clearer UK strategy for the hydrogen economy.[10] Hydrogen could be important as a transport fuel (maybe in the form of a hydrogen-rich chemical such as ammonia), as a feedstock for the chemicals industry, and as one of the energy storage options to be used with intermittent renewable electricity. There are opportunities yet also significant challenges. For example, 'blue' hydrogen from steam reforming of methane will require CCS, and 'green' hydrogen from water electrolysis or hydrogen fuel cells currently operate well below thermodynamic efficiency.

- *Waste heat harvesting*: Currently only about one third of primary energy is converted into useful energy services while the remaining two thirds are wasted as heat in inefficient energy conversion processes. This could be addressed through widespread use of waste heat harvesting based on heat engines, caloric, or thermoelectric devices; however, this requires materials and devices with higher efficiencies, particularly for processes that operate at relatively low heat source temperatures (<400°C). There are opportunities to use low-grade heat in conjunction with liquid air electricity storage technologies which should be explored.

We encourage an urgent debate on how best to use the surplus electricity generated by renewables in sunny/windy periods. Options include energy storage in batteries or other storage media, the electrolytic production of hydrogen or other fuels for peak electricity generation, transportation, or as a chemical feedstock. A consensus on this will need to be achieved soon as most options require significant infrastructure investments.

2 | Construction and operation of buildings

Over 20% of UK greenhouse gas emissions are attributed to the construction and operation of buildings, with around one quarter of that embedded in new construction and the rest arising from

7 ITER (2020) *What is ITER?*
8 Royal Society, Royal Academy of Engineering (2018) *Greenhouse Gas Removal*.
9 Harper et al. (2019) *Recycling lithium-ion batteries from electric vehicles*.
10 CCC (2019) *Net Zero: the UK's contribution to stopping global warming*.

operational energy use, in particular heating.[11] Figure 3.1 provides a summary of the benefits and barriers for different solutions to decarbonisation of heating, with heat pumps showing the most promise in most circumstances.

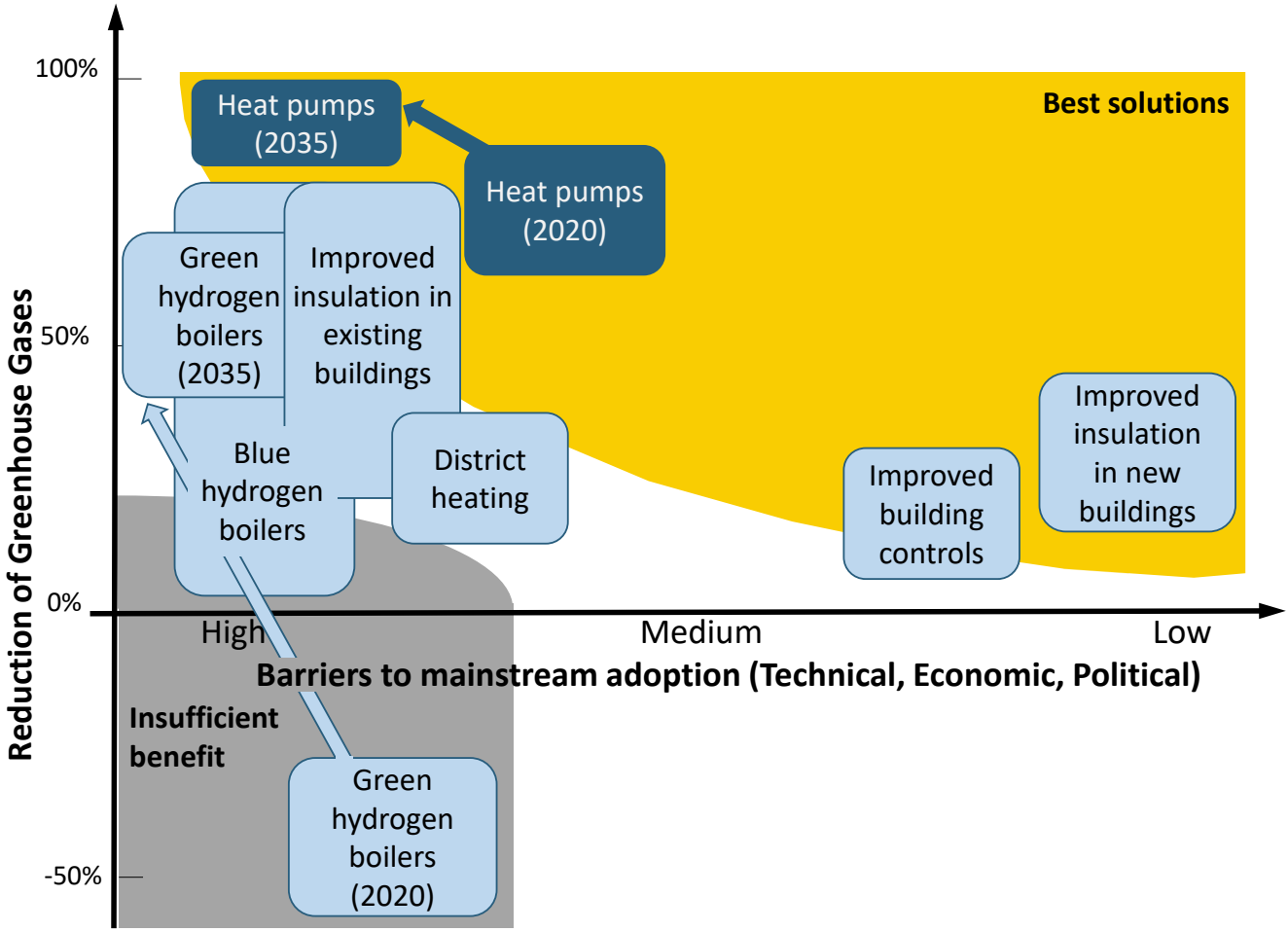

Figure 3.1: Technologies for reducing greenhouse gas emissions from heating buildings. The 'benefits' (potential emissions saving compared with benchmark of a natural gas boiler in 2020) vs 'barriers' to widespread adoption of technologies. The yellow shaded region shows the best targets for research and development; the grey region indicates insufficient benefits. Included are solutions that improve efficiency (dark blue) and alternative energy sources (light blue). Where dates are shown this indicates the year at which the solution is implemented, which is relevant for solutions based on electricity because of decarbonisation of the electricity grid.

Opportunities for reducing construction emissions include (see also Chapter 4: Infrastructure):

- *Efficient use and recycling of materials*: Advances in building design have encouraged greater focus on reduction in materials per square metre, re-use of key components (e.g. structural steel), and greater degrees of recycling of building materials. However, the extent to which buildings really adopt these practices is limited by the current economic framework for contracting whereby it can still be cheaper and easier to use virgin materials, and to design for destruction and landfill rather than dismantling at the end of life. The changes which are needed to effect a transformation in construction practice require engagement with all relevant stakeholders including procurers of buildings, contractors, designers, and component manufacturers.

11 UK Green Building Council (2020) *Climate Change*.

- *Increased use of timber*: The embodied carbon of buildings can also be reduced through changing the material for structural support from concrete or steel to timber. Timber has a high strength-to-weight ratio, and if sourced from sustainable forests, the structural components of a building could be a carbon sink. However, even though there have been significant advances in timber design with glulam beams and similar products, the current building codes are not well-suited to adoption of these materials in taller buildings. Investment to support appropriate testing and changes in codes could accelerate adoption in a wider range of building types.

- *New insulation material*: There is a pressing need for much improved insulation material for the refurbishment of existing buildings that is affordable, durable, and fire retardant, and research into this should be promoted. The catastrophe at Grenfell has highlighted the issue of safety for building materials and implementation of appropriate codes.

- *Building control standard compliance*: Compliance with building control standards is variable, and the lack of resource in this function at a local government level should be addressed. Post-occupancy metering of energy usage and other devices are used for rating buildings, but could also be used as a means of demonstrating compliance with building standards in areas such as airtightness and insulation. This issue is particularly important given that building contractors rarely have to pay for the energy costs of the building in use, and hence do not usually have a financial incentive to go above and beyond the scheme that is proposed by the design team.

Emissions from operational energy use could be reduced by use of heat pumps or hydrogen boilers:

- *Heat pumps* are a well-developed technology and, importantly, are relatively common in many countries. However, in the UK even many new buildings do not have heat pumps installed as a standard feature. This needs to change.

- *'Blue' hydrogen* (hydrogen formed from methane) is an alternative technology for heating. This option might be attractive for existing buildings on the gas network, especially for building owners, since this technology isn't as reliant as heat pumps on improvements to building insulation. Since boilers have a working life of 10 to 15 years, these could be phased in with 'hydrogen-ready' boilers at little additional cost. The investment required for hydrogen-based heating lies primarily in the infrastructure of the gas network, both in terms of upfront cost and ongoing maintenance – much of the UK's iron mains gas networks would need replacing or upgrading with hydrogen-safe polyethylene pipes of higher capacity. The maintenance of the gas network would then need to be considered very carefully, since the effects of leakage of hydrogen which would undoubtedly occur will need to be factored into the overall lifecycle analysis when comparing the alternative heat pump option for decarbonising; it may transpire that hydrogen should be focused on industrial processes where the gas network is much less extensive and hence easier to not only install but maintain.

Heat pumps offer significantly better energy efficiency than hydrogen boilers, as illustrated by Figure 3.2 which shows that 100kWh of chemical energy in natural gas (methane) could deliver 173kWh of heat if converted into electricity used to run a heat pump, but only 58kWh of heat if it is converted into blue hydrogen. Note that both routes require CCS if they are to be carbon neutral. However, heat pumps are currently considerably more expensive, and only really viable once building energy efficiency has been improved. The alternative route of generating 'green' hydrogen by electrolysis of water and using this to power hydrogen boilers uses approximately 6 times more energy than heat pumps.

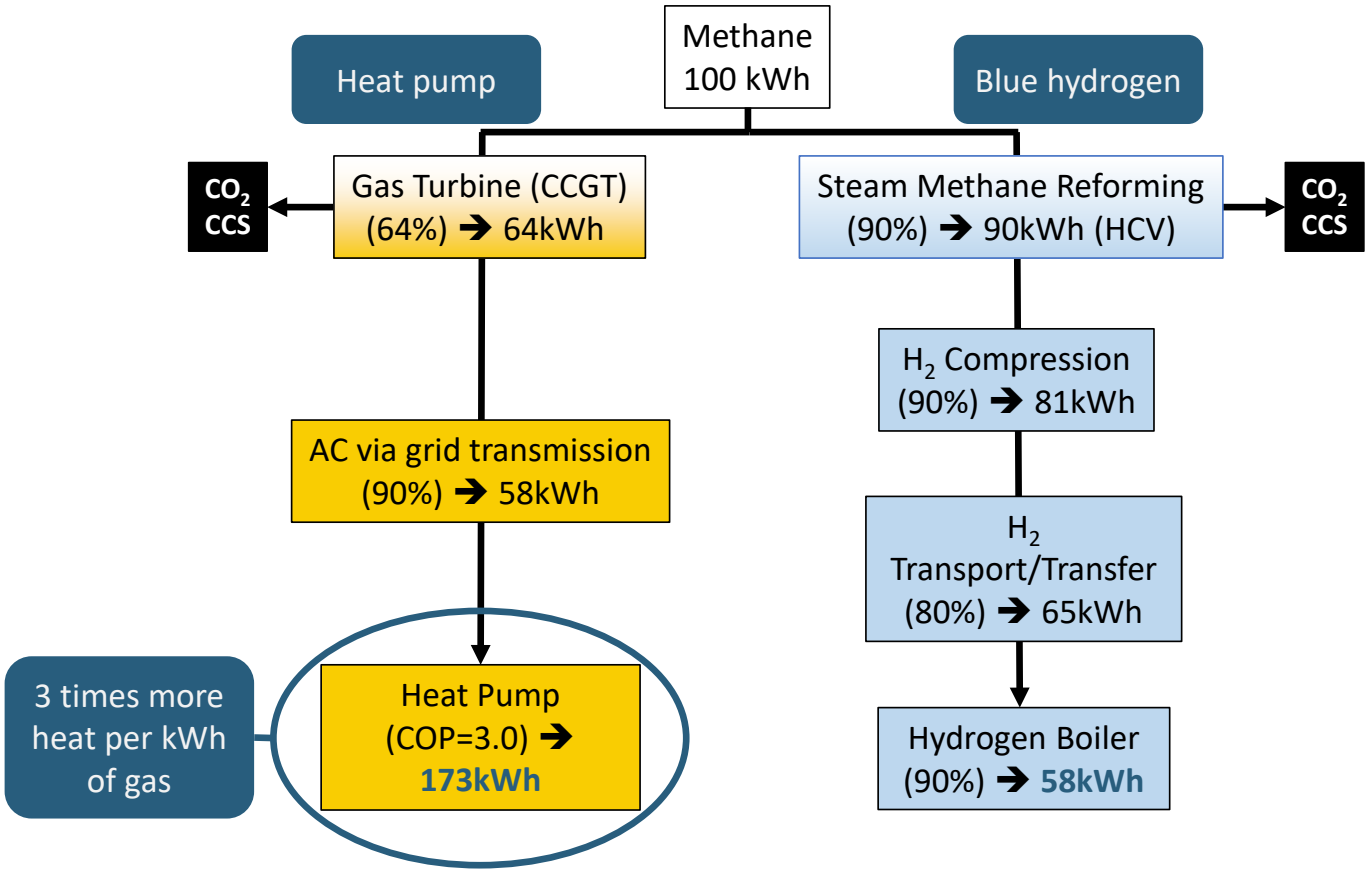

Figure 3.2: Two routes for providing low-carbon heat from natural gas (methane). The efficiency of a heat pump is given by its coefficient of performance (COP).

3 | Transport

While the nation's energy supply has seen dramatic reductions in carbon intensity since 1990, surface transport has remained relatively constant and is currently the largest-emitting sector – accounting for 28% of greenhouse gas emissions in the UK in 2018.[12]

- *Light duty vehicles (passenger and freight)*: Electrification improves air quality in urban areas and, as the electricity grid is decarbonised, yields increasing reductions in greenhouse gas emissions. For passenger transport, electric vehicles (EVs) can now offer ranges of 200km to 300km, sufficient for a large proportion of journeys in the UK. For the majority of light-duty freight vehicles that operate in urban areas, deliveries occur in a small geographic area near to the origin (store, depot, etc.), so the vehicles can charge their batteries when loading with freight and perform deliveries to multiple destinations on a single charge. From an energy supply perspective, the additional load on the electricity grid from the increased number of EVs is likely to increase electricity consumption by 30% in 2050 from today, demanding more renewable energy generation. Smart charging should be widely adopted as it can reduce peak electricity demand and benefit the stability of the electricity grid.[13]

- *Inland freight transport*: Most inland freight in the UK is carried by diesel lorries. Long-haul heavy goods vehicles (HGVs) carry 90% of goods lifted[14] and represent 5% of the UK's total greenhouse gas emissions.[15] Reductions in the carbon emissions could be achieved through energy and logistics efficiency measures and switching to a lower-carbon propulsion energy

12 BEIS (2020) *Final UK greenhouse gas emissions national statistics 1990-2018*.
13 LowCVP (2020) *Energising Our Electric Vehicle Transition*.
14 DfT (2018) *Freight Statistics, TSGB0401: Domestic freight transport by mode*.
15 BEIS (2020) *Final UK greenhouse gas emissions national statistics 1990-2018*.

source. Figure 3.3 summarises the benefits and barriers for technologies that can be used to decarbonise HGVs. High capacity vehicles provide a good solution, and measures such as low rolling-resistance tyres, improved aerodynamics, and light-weighting could be implemented now; further R&D (e.g. aerodynamic improvements) could increase their impact. Options such as platooning have high barriers and offer only small carbon reduction potential.[16] Electrification with large battery packs and fast chargers would reduce payload capacity, increase vehicle prices, require large amounts of materials for battery manufacture, and need expensive charging infrastructure.[17] Hydrogen power would be costly, requiring considerable renewable energy under a 'green' hydrogen route (3.3 times more electricity compared to direct electrification), or increased natural gas imports and large-scale CCS infrastructure for a 'blue' hydrogen route.[18] The best option may be a nationwide Electric Road System (ERS) – this would use mature technology to provide charging in-motion for lorries on the major road network, with small on-board batteries to travel from the electrified network to nearby depots.[19] Although significant infrastructure investment would be needed for this, the costs are within the range of normal motorway projects. To deploy ERS at scale, the economic and political barriers need to be reduced, for instance by running a large-scale demonstration project.

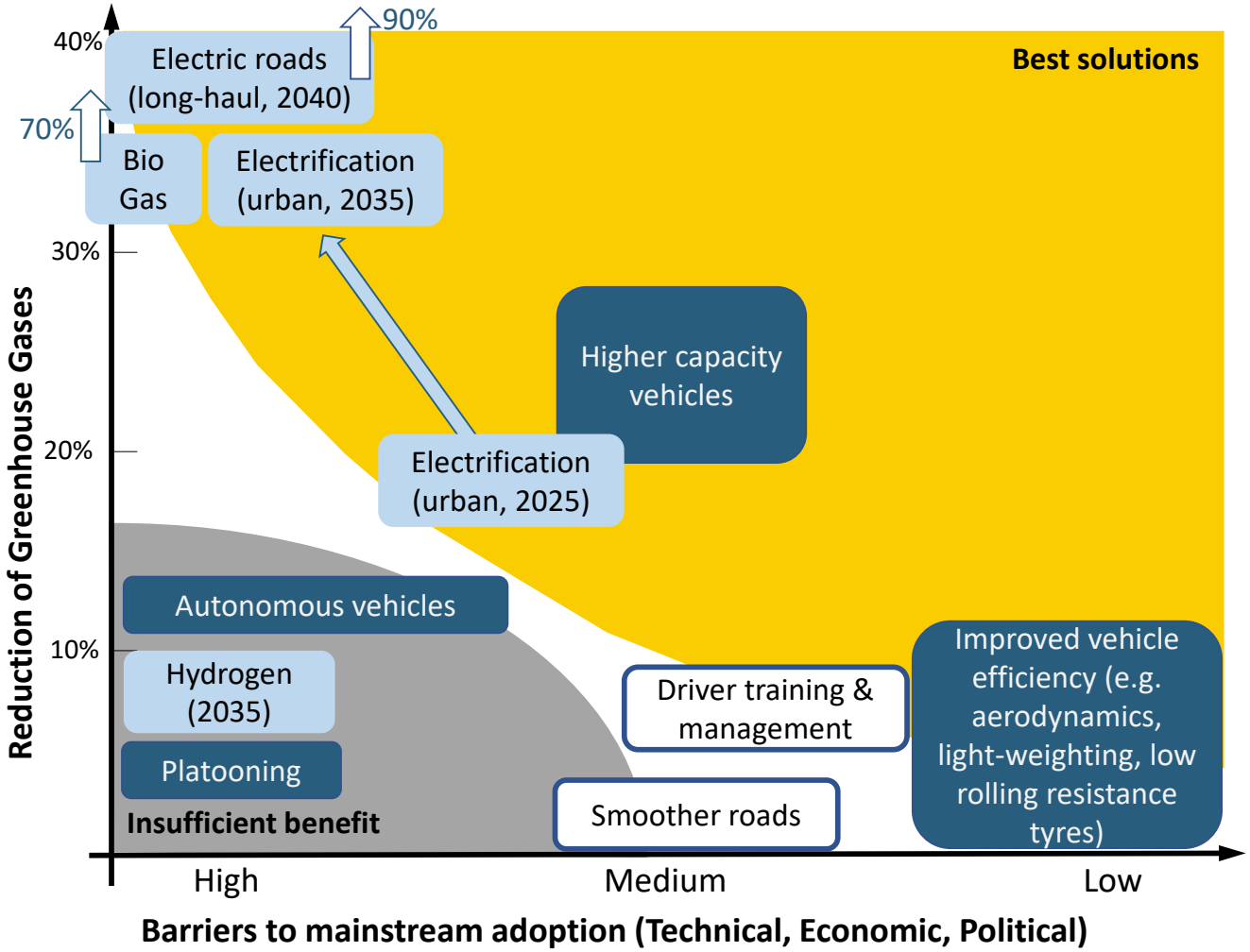

Figure 3.3: Technologies for reducing greenhouse gas emissions from heavy goods vehicles. The 'benefits' (potential emissions saving for an individual vehicle compared with benchmark of a diesel lorry in 2020) vs 'barriers' to widespread adoption of technologies for decarbonising road freight vehicles. Included are solutions that improve efficiency (dark blue), alternative energy sources (light blue), and others (white).

16 Cebon (2018) *Are lorry platoons worth the trouble?*
17 Cebon (2017) *Tesla electric truck – too good to be true?*
18 Cebon (2020) Long-haul lorries powered by hydrogen or electricity?
19 Ainalis et al. (2020) *Decarbonising the UK's Long-Haul Road Freight at Minimum Economic Cost*.

Where dates are shown this indicates the year at which the solution is implemented, which is relevant for solutions based on electricity because of decarbonisation of the electricity grid.

- *Active Travel and Public Transport*: Figure 3.4 compares new technologies that can be used to address passenger mobility needs. Electric taxis and rideshares, e-bikes, and e-scooters are effective methods of reducing carbon emissions. Electric buses offer the best option to decarbonise public passenger transport; electrified rail and light rail/trams all require expensive infrastructure. The use of 'opportunity charging', by which the buses are charged for (say) 10 minutes at each end of the route, when they typically stop to catch-up the timetable, means the vehicles require much smaller, lighter batteries, have lower capital and running costs, lower carbon emissions, can carry more passengers, and distribute the electric charging load.[20] Demand Responsive Transport (human driven or autonomous) offers convenience which can help shift journeys from cars to higher-capacity/better-filled passenger vehicles. Buses and trains powered by 'blue' hydrogen are an option, however the vehicles are currently very expensive, requiring fuel cells, CCS, hydrogen storage, and substantial batteries.

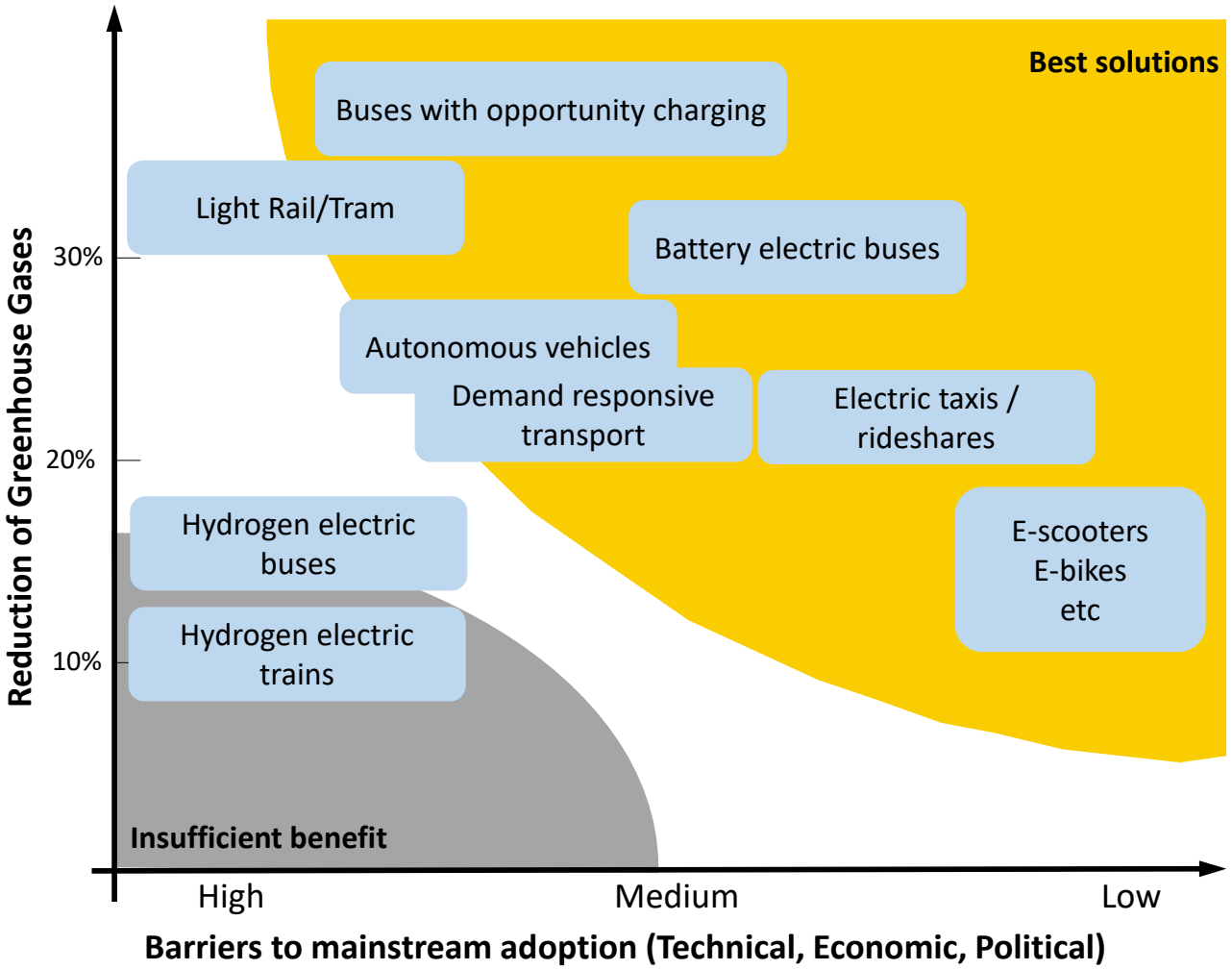

Figure 3.4: Technologies for reducing greenhouse gas emissions from passenger transport. The benchmarks for all technologies are conventional vehicles performing a similar passenger mobility task.

- *Maritime*: Electrification is suitable for smaller marine vessels (e.g. tugs and passenger ships/ ferries) – around one quarter of the global commercial fleet.[21] It is not possible to electrify larger vessels, although hybrid solutions can be attractive under some circumstances. One

20 Nicolaides et al. (2019) *Techno-economic Analysis of Charging and Heating Options for an Electric Bus Service in London*.
21 Wu and Bucknall (2016) *Marine propulsion using battery power*.

alternative fuel is ammonia, manufactured from hydrogen, but the process of making and storing it and then converting it back into electricity is very inefficient. Another option is biofuels, of which biodiesel and biomethane may be reasonable choices for ship propulsion. However, it is questionable whether there will be sufficient biofuel available to fuel all shipping, particularly when most biofuel is currently used for land transport and there are broader land-use concerns.

- *Air*: Decarbonisation of flight is possible. However, there is no silver bullet, and the scale of the problem is immense. Focus is required if the problem is to be solved in the required time frame. The problem is not simply technical; it requires an optimisation of the broader system-of-systems problem, including technology, behaviour, economics, infrastructure, and policy. Three possible pathways exist for decarbonisation. It should be noted that all of these are likely to introduce extra cost and therefore to lead to reduced demand:

  1. *Battery electric* offers the opportunity to reduce both carbon emissions and the substantial non-carbon emissions, such as contrails,[22] to zero. The problem is that the range of such technologies limit it to regional and sub-regional markets.
  2. *Hydrogen* offers the opportunity to reduce carbon emissions to zero but currently is thought to be limited in operating range. The Airbus ZEROe project plans to have a hydrogen aircraft on the market by 2035, with an operating range of above 2,000 nautical miles and carrying 200 people.
  3. *Sustainable Aviation Fuels* offer the possibility of switching fuels into existing aircraft. The problem with this solution is that it requires at least twice the amount of renewable energy as the other two solutions, and is also limited by the sustainable sourcing of feed-stock or the energy required for direct air capture of CO_2.

  To have a hope of decarbonising flight by 2050, investment in all three solutions and robust roadmaps for the decarbonisation of flight – which include the technology, delivery, scale-up, infrastructure, investment, and policy – are urgently required.

4 | Industry

The contribution of the manufacturing industry to global CO_2 emissions is dominated by steel and cement.[23] Both industries are well-established in the UK and there are opportunities for carbon reduction. It is worth noting that both industries are energy-intensive and the progress that the UK is making in decarbonising its electricity grid is a key factor in reducing emissions.

The cement industry is generally regarded as being responsible for around 5% of greenhouse gas emissions. Alternative materials are being investigated and trialled as low-carbon alternatives, but volumes are currently small and building regulations can impede the introduction of non-standard materials and cement blends. Carbon reduction measures being considered in conjunction with existing industry feature the use of alternative fuels and the introduction of CCS as a longer-term goal.[24] However, as a short-term and medium-term mitigation measure, the environmental impact of existing operations could be reduced significantly. For example, it is estimated that carbon emissions could be reduced by nearly 20% using only operational performance management with no significant investment costs.[25]

The steel industry accounts for 25% of global industrial emissions. The primary steel industry has already made great progress in optimising production efficiencies and is working closer than any other industry to the theoretical performance limit. Development work continues to drive further

22 Lee et al. (2020) *The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018*.
23 Fischedick et al. (2014) *Industry in IPCC Working Group III: Mitigation of Climate Change*.
24 Fraunhofer Institute (2019) *Industrial Innovation: Pathways to deep decarbonisation of industry*.
25 Summerbell et al. (2016) *Potential reduction of carbon emissions by performance improvement: A cement industry case study*.

optimisation, e.g. through the COREX and FINEX processes,[23] but all are currently limited in scale. The mainstream opportunities for carbon reduction come from the energy-intensive processes of CCS, and use of CO_2 in the chemical industry such as a pre-cursor for plastics in Carbon Capture and Utilisation (CCU). Both these approaches are being explored globally; CCS in particular is seen as a long-term, capital-intensive solution.[26]

Steel is already extensively recycled. The amount of scrap available for recycling is projected to increase significantly over the next 30 years, and scrap in the UK is nearing comparable volumes to the final demand for steel. Steel produced from scrap using electric arc furnaces allows reduction in CO_2 emissions of at least 70%, and can be 90% (or more) if the electricity comes from renewable sources.[27] Currently 65% of UK scrap steel is exported. The UK steel industry has relatively low CO_2 emissions because the carbon intensity of domestic electricity generation is low, so global emissions could be reduced if the UK were to process its scrap steel domestically. However, building the UK domestic recycling industry is only economically attractive if the quality of the recycled steel is high. This could be achieved by developing improved collection, sorting, and purification technologies.[23,28]

5 | Greenhouse gas removal

It is widely accepted that some form of greenhouse gas removal will be needed in order to reach a position of net zero by 2050,[29] and currently the UK does not have a strategy as to which approaches are going to be most appropriate. In large part, this is because there are still significant uncertainties surrounding many of these. The approaches can be broadly divided into two: nature-based solutions and more engineering-based technologies.

Nature-based solutions are discussed in Chapter 5: Nature. These include: restoring peatland; re-establishing and managing forests; creating, protecting, and restoring freshwater and coastal wetlands; and managing farmland more sustainably. These can be associated with a number of co-benefits including: increased crop yield; increased biodiversity; increased resilience to floods; increased tourism; and associated employment. However, there are challenges which require investment and research including: policy and incentives for current agriculture stakeholders to transition to greenhouse gas removal; how to measure and monitor on-going carbon sequestration; impact of changes in land use and process on food production, biodiversity, and potential contaminants. There also needs to be research undertaken as to how societal changes such as diet will impact the value-chain for the food industry, and hence land use in agriculture and farming.

Engineering-based technologies include construction with wood or carbonated waste ('biomass'); direct air capture with carbon storage (DACCS); and bioenergy with carbon capture and storage (BECCS). Construction with biomass is already widely adopted in a number of other countries, but is more limited in the UK. Increased incentives to account for the embodied carbon of buildings would help accelerate the adoption of more timber. In addition, research and subsequent revisions of current codes and practices would enable a wider range of buildings to be considered for use of timber.[30] DACCS and BECCS have potential for engineering-based carbon sequestration, however they are currently unproven at scale and there are significant concerns with issues such as impacts on water and land use, biodiversity, and their energy use,[31] as well as questions regarding the negative emissions potential of BECCS (see also Chapter 5: Nature).[32] These technologies would require significant investment and support in order to test the scalability of the approach; to determine whether, and if so how, they could be part of a suite of approaches which are acceptable to wider

26 McKinsey (2020) *Driving CO2 emissions to zero (and beyond) with carbon capture, use and storage*.
27 Fraunhofer Institute (2019) *Industrial Innovation: Pathways to deep decarbonisation of industry*.
28 Allwood et al. (2019) *Steel arising: opportunities for the UK in a transforming global steel industry*.
29 The Royal Society and Royal Academy of Engineering report (2018) *Greenhouse gas removal*.
30 Fleming et al. (2014) *Measuring-Up in Timber: a Critical Perspective on Mid-and High-Rise Timber Building Design*.
31 Fuhrman et al. (2020) *Food–energy–water implications of negative emissions technologies in a +1.5 °C future*.
32 Hanssen et al. (2020) *The climate change mitigation potential of bioenergy with carbon capture and storage*.

society; and to reduce the barriers that would be associated with large-scale deployment, and hence reduce the costs.

A framework needs to be established to govern the use of greenhouse gas technologies that addresses sustainability and engages the public. Serious consideration needs to be given as to how greenhouse gas approaches could be established as viable businesses in their own right, ideally independent of funding from government. This will require research and engagement with all stakeholders in the near future, in order that the right suite of approaches can be developed further.

Chapter 3: Investing in Zero-Carbon Technology and a Zero-Carbon Industrial Transition

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Chapter 4: *Infrastructure*
Investing in Resilient and Sustainable Infrastructure

- **Adopt a whole-system, whole-life view** of infrastructure and the built environment.
- **Require all new infrastructure assets to quantify their embodied and lifetime emissions, and develop a sustainable construction protocol** to calculate and optimise carbon in design; calibrate design models against real performance; control processes on construction sites; develop and apply sustainability standards for all major building materials and require 3rd party certification; assess, declare, and manage/reduce waste, embodied carbon, and carbon fuel use; and invest in innovation.
- **Incentivise retrofitting of existing homes** through programmes such as a 'Help to Fix' interest-free loan scheme and similar support for housing associations.
- **Reconsider renewable energy proposals such as the Swansea Tidal Lagoon** as part of a broader strategy to fully decarbonise the power sector and effect the full electrification of transport and heating.
- **Accelerate the decarbonisation of transport** through a combination of measures including demand reduction, shared and integrated transport modes, electrification or use of carbon-free fuels, and policy instruments such as road pricing.

The built environment accounts for over 40% of the UK's greenhouse gas emissions.[1] About half of these emissions come from buildings – including the embodied energy of construction and materials, and the energy needed to heat, cool, and light the buildings. The other half of emissions is accounted for by everything else that happens in buildings (e.g. computers and kettles) and civil infrastructure. As buildings become more efficient, the embodied energy of materials becomes dominant. Embodied emissions during construction are also significant: concrete use in construction accounts for more than 8% of global carbon emissions.[2]

Three different categories of physical assets make up the built environment:

1. Economic infrastructure supports the operation of cities and buildings – energy, water and waste water, transport, flood defences, waste, and communications infrastructure
2. Social infrastructure consists of buildings which are owned and operated for the public good, including health and social care facilities, schools, prisons, the defence estate, and social housing
3. Commercial, domestic, and other buildings including housing, retail, leisure facilities, offices, warehousing, and manufacturing facilities

Approaches to decarbonising construction and use across these categories typically require different incentive mechanisms and support.

The construction industry can help support a sustainable recovery from the pandemic by providing employment and delivering decarbonisation, as articulated in the UK Construction Leadership Council's post-COVID recovery strategy.[3] However, without government incentives and coordination, a substantial reduction in carbon emissions in construction will be challenging in the short term due to the fragmented nature of the industry and the fact that a large number of

1 UK Green Building Council (2020) *Climate Change*.
2 Monteiro et al. (2017) *Towards sustainable concrete*.
3 CLC (2020a) *Construction Leadership Council 'Roadmap to Recovery'*,

substantial, long-term projects are already planned or underway, for example the Highways England Road Investment Strategy,[4] and the water industry's Asset Management Plan.

Reducing operational carbon for existing and planned assets is a more substantial challenge due to the complex and ageing nature of most of these assets. It is also more urgent – we add only 0.5% by value to the existing asset portfolio per year, while much of our housing and infrastructure is over 100 years old,[5] so existing assets make up by far the largest proportion of the built environment. Any programme to decarbonise infrastructure needs to treat the built environment as a system-of-systems, and address existing buildings and infrastructure.

Here we outline a number of opportunities for the COVID-19 recovery strategy to contribute to and accelerate the decarbonisation of the UK's built environment.

The built environment system-of-systems

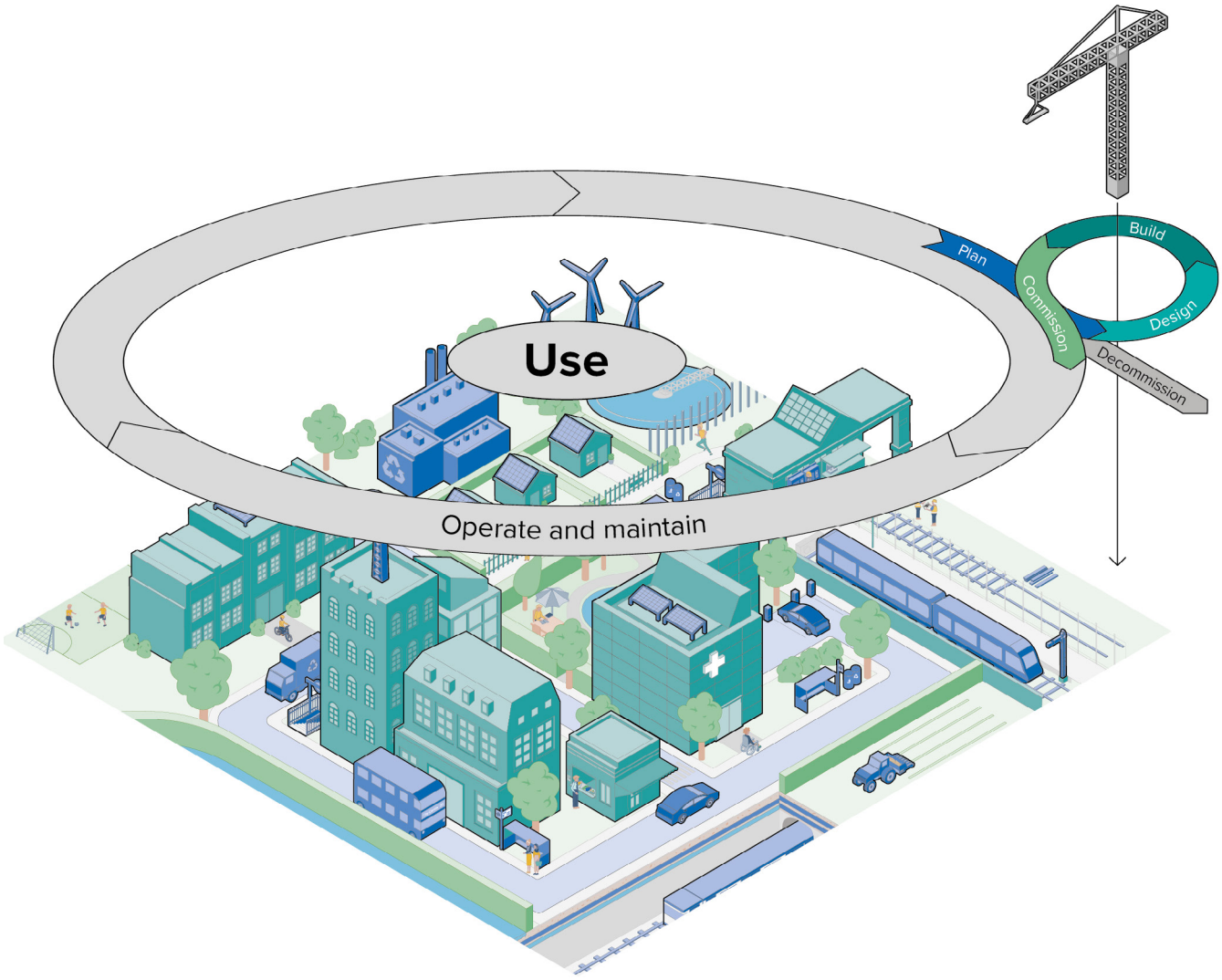

Figure 4.1: The built environment as a system-of-systems[6]

The built environment is a complex system-of-systems, interlinked within cities and towns, and which underpins society and enables it to flourish (see Figure 4.1). This system-of-systems has been sustained over several centuries, and must continue to be so while driving towards the net-zero

4 Highways England (2020) *Road Investment Strategy 2 (RIS2): 2020 to 2025*.
5 Bowers et al. (2016) *Smart Infrastructure, getting more from strategic assets*.
6 Schooling et al. (2020) *Flourishing systems: Re-envisioning infrastructure as a platform for human flourishing*.

ambition. This means that achieving net zero by 2050 is a system transformation challenge,[7] and addressing carbon emissions from existing infrastructure and buildings is critical. Investments in new assets must be seen as interventions on the existing system – hence, not only must the embodied emissions of new assets be considered, but also their own operational carbon over their life, and their impact on the operational emissions of the system as a whole.

Tackling operational emissions is a complex issue, but significant impact can be made by reducing energy consumption – indeed, as more industries and infrastructures transition to electrical power, this will be necessary in order for clean energy solutions to meet demand.

Reducing embodied, or 'capital', carbon is also critical. This is especially true because the climate responds to cumulative emissions and hence cutting emissions as early as possible is important. This is one reason to focus on embodied carbon rather than embodied energy for current metrics. Embodied carbon includes the sequestration of carbon within building materials such as timber and the emission of carbon dioxide through chemical reactions during the production of materials such as cement. Interventions that save operational carbon during the lifetime of an asset by increasing up-front the embodied carbon (for example, increasing thermal mass by using more concrete) need to be carefully assessed, as they may not be justified if the predicted lifetime of the asset is overestimated.[8]

Energy generation and storage

Decarbonising energy requires a systems view of infrastructure. The full electrification of transport, and heating and cooling within a decarbonised power sector could be achieved with a clear strategy based on providing the increased electricity demand through all of the following (see Chapter 3: Technology for further discussion):

- An expanded use of renewables, in particular offshore wind, solar, and onshore wind
- Reconsidering renewable energy proposals such as the Swansea Tidal Lagoon and the Mersey Barrage – the Swansea Tidal Lagoon could be ready to start quickly and would provide jobs in an area of high unemployment[9]; the Mersey Barrage could use water wheels and avoid barrage difficulties while providing employment in the North of England[10]
- A modest increase in generation from nuclear power including small modular reactors
- Providing the remaining electricity with natural gas equipped with carbon capture and storage (CCS)
- Achieving the flexibility needed for a high percentage of renewables (>65%) through peak power generation using sustainably developed battery, hydrogen, or pump hydropower storage, together with demand management and a more interconnected electricity grid
- The considered use of bioenergy coupled with carbon capture and storage (BECCS) for carbon sequestration

We support the strategy presented in the Committee on Climate Change 2019 Net Zero report[11] which would allow the UK to establish itself as a world-leader in zero-carbon technologies with potential for many new, highly skilled jobs (see chapters on Economy and Just Transition).

Reduce energy demand and increase efficiency

There is a major opportunity to improve the energy efficiency of buildings through adopting passive

7 Prime Minister's Council for Science and Technology (CST) (2020) *A systems approach to delivering net zero: recommendations*.
8 Material Economics (2018) *The Circular Economy: A Powerful Force for Climate Mitigation*.
9 Rainey (2018) *Lightweight steel tidal power barrages with minimal environmental impact: application to the Severn Barrage*.
10 Maritime Journal (2007) *Renewables Power from Mersey Waterwheel*.
11 CCC (2019) *Net Zero: the UK's contribution to stopping global warming*.

measures such as high levels of insulation, design for solar gain in winter, measures for preventing overheating in summer, and the use of direct solar for water heating. Many commercial and industrial properties exhibit a 'performance gap' between the anticipated energy use when designed and the actual energy consumed post-occupancy. This performance gap can be closed through performance feedback loops to designers and contractors, and through requiring post-occupancy measurement and certification of energy use. This should be combined with a programme of surveying existing buildings to understand where heat losses are occurring, and carrying out targeted retrofits – while monitoring the performance of these measures, as emissions reductions from many retrofit activities to date are much less than anticipated.

Where buildings are commercially or publicly owned, retrofit can be incentivised through regulation. However, other approaches are required for owner-occupied domestic properties. A long-term plan for a net-zero carbon retrofit programme for existing homes[12] would have the additional benefit of providing new employment for those losing jobs elsewhere in the economy while safeguarding existing employment. For properties not covered by the programme, the UK Construction Leadership Council's suggestion of a 'Help to Fix' interest-free loan scheme, predicated on energy efficiency, would be one way to encourage homeowners and improve the quality of the nation's housing stock.

Transition to zero carbon heating and cooling

Heat accounts for about one third of the UK's greenhouse gas emissions, and half of that is from the residential sector. The vast majority of properties currently rely on gas boilers for water and space heating, with a small percentage using oil. Passive measures such as those described above will reduce gas/oil use to some extent, however much of the UK's housing stock is very old and difficult to fully retrofit.

Therefore, it is vital that a systematic approach is taken to reducing dependency on gas/oil. There must be a rapid move to renewables both at local (house or district) and national level. Measures should include exploiting rooftops for PV, using ground source and air source heat pumps where appropriate, and adapting gas-fired central heating radiator systems to run on electrically heated water. The installation of gas boilers in new buildings should be phased out as soon as practically possible, a switch to heat pumps should be encouraged for the 15% of homes not currently connected to the gas network, and retrofitting of existing buildings for maximum energy efficiency should be accelerated to increase the feasibility of switching to heat pumps for these buildings. For a detailed discussion, see Chapter 3: Technology.

Tools now exist to assess the potential for renewable energy solutions for heating and cooling at the building and district level,[13] enabling maximum exploitation for heating and cooling at the local level and hence reducing demand on the national network. This surplus supply can then be put to other uses such as electric vehicle charging.

One short-term measure which should not be ignored is to require all methane leaks from the gas supply system to be eliminated. Methane is a powerful greenhouse gas that is increasing rapidly in the atmosphere.[14] Detectable, low-level (non safety-critical) leaks are estimated to be 1-5% of total methane production.[15]

Minimise carbon in new buildings and infrastructure

When making decisions about construction of new buildings or infrastructure, it is important to

12 Construction Leadership Council (2020) *Letter to the Chancellor of the Exchequer*.
13 Pickering and Choudhary (2019) *District energy system optimisation under uncertain demand: Handling data-driven stochastic profiles*.
14 Nisbett et al. (2019) *Very Strong Atmospheric Methane Growth in the 4 Years 2014–2017: Implications for the Paris Agreement*.
15 Balcombe et al. (2018) *Characterising the distribution of methane and carbon dioxide emissions from the natural gas supply chain*.

use early-stage discussions of options to prioritise no-build and low-build solutions, which optimise existing assets, systems, and processes before new build is considered – as shown in the carbon reduction curve.[16] This may include considering alternative 'build nothing' ways of delivering the same service using existing assets through challenging the root cause of the need, and 'build less' options including repurposing existing assets, for example converting old warehouses into apartments, with careful consideration of conversions to ensure they are suitable for people and communities.

Material resource efficiency needs to be at the forefront of design and construction where new build is required. Choosing materials with a low carbon footprint must be a priority (see Chapter 3: Technology). This includes reducing cement content, scaling up the use of low carbon cements, and increasing the use of reused steel.[17] There is an opportunity to replace cement and steel construction with engineered timber – which naturally leads to draft-proof buildings due to the construction method and is a long-term store of carbon.[18] Engineering and construction organisations must become versed in material and carbon analysis, and understand the impact of materials specified.

Using data to understand sustainability and carbon efficiency across the entire lifecycle of a project from the beginning of the design stage will establish mitigation of climate change as an essential aspect of design and construction to be considered alongside health and safety. The construction process must minimise material waste through using digital tools to monitor and manage material flows, and using quality control methods to avoid rework.

Delivering major carbon reductions in this way requires procurement to prioritise low carbon solutions. The criteria by which projects are measured determines outcomes. When the key criterion is lowest cost, that measure will drive decisions and outcomes and strip projects of innovation.[19] Traditional transactional contracting arrangements resulting in low profit margins make carbon-reducing innovation less feasible. Moving away from delivering projects in a transactional manner to new approaches, such as those outlined by Project 13,[20] facilitates solutions that take carbon reduction into account. A whole-life approach is essential to identify costs of design innovations at the capital expenditure stage which can be more than made up for through cost saving at the operational phase.

Public sector and regulated companies should be required to include carbon reduction targets and reporting commitments explicitly in their procurement documents, as a deliverable of the procurement process, to move the 'cost-carbon' balance towards zero-carbon choices. This should include embodied carbon (from materials) and operational carbon used during construction. Relevant standards (such as PAS 2080, a global standard for managing infrastructure carbon) should be used to achieve this. Construction projects should also be required to be net zero – with emissions reductions against 'business-as-usual baseline' planned in as part of each project at every stage, and all residual emissions offset using gold-standard offsetting schemes.

The construction industry has historically responded best to regulation on the basis that the 'level playing field' of regulatory control allows all parties to compete on an equal basis. Investment in skills, policies, and training for better construction requires structural change (see Chapter 2: Just Transition). Government subsidies, when well-planned and executed, can have a significant impact; for example, the feed-in tariff for solar panels stimulated the solar panel market and drove down the price to a point where subsidies could be withdrawn.

16 HM Treasury (2013) *Infrastructure Carbon Review*.
17 Allwood et al. (2019) *Absolute Zero*.
18 Ramage et al. (2017) *The wood from the trees: The use of timber in construction*.
19 CSIC (2019) *Smart Sustainability – Exploiting data in engineering to mitigate climate change*.
20 Institution of Civil Engineers (2020) *Project 13*.

Measure, measure, measure

A zero-carbon transformation will require a rapid digitalisation of the infrastructure and construction sector, with widespread and coherent adoption of digital technologies and data to enable industry to measure performance and improve on it.[21] These digital technologies need to be used to measure and learn from real performance in order to make radical changes to the way infrastructure assets are designed, built, operated, maintained, and integrated. To improve infrastructure systems performance and industry productivity while reducing carbon (embedded and operational), ongoing measurement and monitoring must be consistently implemented. Sensing technologies and data analytics should be used not just to measure carbon, but to reduce waste, reduce materials and resource use, design for resilience and adaptability, and create whole-life models of value. This could (and should) impact design codes, construction methods, and asset management approaches, resulting in more productive and efficient outcomes.

Decarbonise transport

Transport-related carbon emissions can be reduced through a combination of measures including demand reduction, shared transport modes, and a move to electrification or carbon-free fuels. In addition, transport project appraisal needs to include all external effects, both positive and negative, as set out in the Government's Appraisal Manuals.[22] The choice of investments must then be guided by that proper investment appraisal.

- *Demand reduction*: The response to COVID-19 has demonstrated that far more work can be done at home without having to travel. There is a unique opportunity, therefore, to build upon this change and incentivise more extensive home/local working. This will require a rethink around what constitutes the workplace – evolving from a space for production to become a space for constructive interaction and positive networking – rather than allowing these to happen as a by-product of the working environment. The 15-minute city concept in which everyone is able to meet most, if not all, of their needs within a short walk or bike ride from their home has emerged as a response to such ambitions. Dublin Chamber has recently launched a vision and proposal for a 15-Minute City[23] focused on planning, housing, and transport provision. This highlights the fact that transport cannot be considered on its own – it is a fundamental part of the wider urban plan, which it influences and is influenced by.

- *Active travel and shared use of mobility options*: The drive for increased patronage on public transport is challenged by the COVID-19 pandemic. However, the focus on localisation opens the opportunity for increased use of active transport modes (walking and cycling) and shared micro-mobility schemes (e-scooters and e-bikes) which will both help to reduce congestion and emissions, and have knock-on health benefits. Several local authorities sought to encourage uptake of active travel in response to COVID-19 through trial pedestrianisation of city centre areas, thereby creating safe spaces for cycling and walking. In Manchester, these trials have now influenced proposals for the local transport strategy. This approach has already been recognised by government, with investments in cycling and walking during 2020, and needs to continue to be a fundamental part of transport planning, as part of a 'mobility as a service' (MAAS) approach. MAAS is essentially an integrated approach to public transport, with end-to-end journey planning and ticketing covering combined modes including 'last mile' solutions which may include micro-mobility solutions and, in future, connected autonomous vehicles. This combination of traditional public transport with new approaches offers the opportunity to manage the (temporary) issues of capacity in shared public transport.

- *Cycling and walking infrastructure*: Transport (and other) investment decisions must be made with a fully social (i.e. with all impacts priced) cost-benefit appraisal. The benefit-cost ratio of

21 CDBB (2020) *The approach to delivering a National Digital Twin for the United Kingdom*.
22 HM Treasury (2018) *The Green Book: Central Government Guidance on Appraisal and Evaluation*.
23 Dublin Chamber (2020) *Dublin: The 15 Minute City*.

cycle investment is 13:1, which would be increased if health benefits were included. This is already higher than that of road investment – and much higher than for rail.[24]

- *Electrification*: The electrification of road freight could be achieved cost-effectively and with low technical risk with an Electric Road System (ERS), consisting of an overhead catenary system on major roads. This could be deployed across the strategic road network within 10 years and would address the majority of emissions from long-haul freight (see Chapter 3: Technology). The mass electrification of personal and public transport will require substantial, coordinated investment in charging infrastructure, and in some areas an upgrade to the electricity grid to support the additional charging load. The specific requirements will depend on local development plans for housing, job locations, etc., as this will influence where vehicles will need to be charged and the load on the grid (see Chapter 3: Technology for more details of electrification and low carbon fuels).

- *Road pricing and fuel duty*: Under current road taxation, electric vehicles (EVs) are heavily subsidized as they do not pay fuel excise duty and hence do not contribute to the cost of the road network. If the switch to EVs is successful, that lost tax revenue will need to be replaced, logically with road pricing. Fuel duty would be reduced to levels justified by carbon prices, charges for other externalities (air pollutants such as NOx, particulates, etc.), and the residual cost of the road network, with the rest collected through road pricing. In the current circumstances, and until road pricing can be introduced, there is a strong case for raising the road fuel duty.[23]

- *Other measures*: In the short term, reducing the national speed limit from 70mph to 60mph could also help reduce emissions by over 10% where the limit applies. When the US reduced its national speed limit to 55 MPH in 1973, as an energy-saving measure in response to the oil embargo, it is estimated that approximately 3.4 billion gallons of fuel were saved and some 5,000 fatalities avoided in 1974.[25] This has the advantage that it could be imposed immediately. However, it would need careful messaging to be acceptable to the public – including, for example, estimations of the changes to journey time and clear information on how much carbon (and fuel) will be saved.

Chapter 4: Investing in Resilient and Sustainable Infrastructure

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24 Newbery (2020) *Transport policy for a post-Covid UK*.
25 Clotfelter and Hahn (1978) *Assessing the national 55 mph speed limit*.

Chapter 5: *Nature*
Investing in Nature-based Solutions and Supporting Agriculture and Rural Affairs

- **Deploy carefully designed nature-based solutions to climate change.** These approaches have strong public support, provide employment and recreational space, and have benefits for physical and mental health. Options to remove greenhouse gases and avoid further emissions include better management, protection, and restoration of peatlands, wetlands, forests, and some types of grasslands. Some measures can provide resilience to climate change impacts such as flooding; the creation of monoculture plantations of fast-growing tree species should be avoided.
- **Create a new National Nature Service** to employ many tens of thousands of people and restore our land, coastlines, oceans, and economy for a greener, more prosperous future.
- **Overhaul policies and incentives in agriculture and rural development, including subsidies and taxation schemes** to reward landowners for benefits provided to society, and tailored support and training to help farmers adopt sustainable practices and invest in innovation.
- **Support sustainable food production, reduce food-system waste, and promote healthier diets.** This can help to cut costs in agriculture, public health, and the food industry, as well as bringing down consumer expenses.

In this chapter, we discuss the wider environmental dimensions of a recovery from COVID-19, and in particular the options for deploying so-called nature-based solutions along with measures that could be implemented to create a more resilient and sustainable economy with a focus on food, agriculture, and rural affairs. We indicate priorities for cutting agricultural emissions recognising that links between interventions in agriculture/land use and the supply of food and some farmed products need to be considered, including at the international level.

Nature-based solutions are approaches that address societal challenges by protecting ecosystems, restoring them, or managing them sustainably. In the context of climate change, nature-based solutions are interventions that harness the power of nature to reduce net greenhouse gas emissions (e.g. by sequestering carbon) and help people adapt to the impacts of climate change. The concept has received increasing attention in international fora, including the UN Framework Convention on Climate Change (UNFCCC), the Convention on Biological Diversity (CBD), the Sendai Framework for Disaster Risk Reduction, the World Economic Forum, and the UN General Assembly.[1,2,3] The UK government has expressed support for nature-based approaches to climate change in the run-up to UNFCCC COP 26.[4] As such, these approaches are relevant for UK climate policy both nationally and internationally, including with a view to supporting climate adaptation in the developing world. Nature-based solutions inherently connect the interlinked crises of climate, nature, and social inequality and – if well-designed and avoiding risks from approaches that maximize one environmental service at the expense of others – provide an opportunity to simultaneously address

1 IUCN (2020) *Global Standard for Nature-based Solutions. A user-friendly framework for the verification, design and scaling up of NbS*.
2 NbS for Climate Coalition (2019) *The Nature-Based Solutions for Climate Manifesto. Developed for the UN Climate Action Summit 2019*.
3 World Economic Forum (2020) *New Nature Economy Report II: The Future of Nature and Business*.
4 House of Commons Library (2020) *COP 26: the international Climate Change Conference, Glasgow, UK. House of Commons Library Briefing Paper No. 8868*.

these.[5,6,7] In this way, they could play an important role in shaping a resilient and sustainable recovery from COVID-19.

Also central to shaping a more resilient and sustainable economy is the development of agriculture and land management policies that help deliver nature-friendly farming and increase food security while offering enhanced environmental protections and support for rural communities as part of efforts to ensure greater regional equality (see also Chapter 2: Just Transition). Emissions from agriculture in the UK currently represent about one tenth of national greenhouse gas emissions. They are mostly caused by livestock rearing and waste management (methane), fertilizer use (nitrous oxide), and soil management and on-farm machinery (carbon dioxide). A comprehensive national strategy is required to support the agriculture sector to eliminate these emissions through sustainable and innovative solutions. Given the importance of farming as the key land use (72% of land in the UK is farmed), it will be important to ensure that all farming is sustainable and delivers multiple benefits: food production, nature protection, landscape, recreation, good jobs, etc. Interventions should therefore be aligned with the relevant sectoral strategies and plans, such as the Government's plans for a system of Nature Recovery Networks enabling species to move along corridors and spread beyond the boundaries of traditional nature reserves.

Nature-based solutions

As previously stated, nature-based solutions address societal challenges by protecting ecosystems, restoring them, or managing them sustainably while providing an opportunity to simultaneously address two of the major challenges of our time – the interlinked climate and nature crises.[5,6,7]

Nature-based solutions have the potential to generate large returns (including economic ones) because of the co-benefits they deliver in addition to reducing greenhouse gas concentrations or addressing climate risk. These ancillary benefits may include marketable products, jobs, biodiversity conservation, improved health, reduced disaster/hazard risk, and recreation opportunities. Many nature-based solutions also offer the opportunity to address climate change mitigation and adaptation simultaneously. That said, it is important to recognise that there can be trade-offs between different goals associated with the use of nature-based solutions. For example, focusing only on carbon sequestration could lead to the creation of large monoculture plantations of fast-growing tree species. This would contribute to climate change mitigation in the short term but would have little biodiversity or recreational value.[8]

At the global level, a number of recent analyses have highlighted high returns on investment and job creation potential for typical interventions that improve the state of nature and ecosystem services.[9,10,11] For the UK, the interim findings of the Dasgupta Review[12] convey a similarly strong message. Comparisons of different types of interventions included in stimulus packages following past economic shocks, such as the 2008 financial crisis, also point to investments in nature, such as ecosystem restoration, performing well.[13,14] Their short-term potential for job creation (or retention) includes both highly skilled and relatively unskilled jobs across planning, engineering, input supply (e.g. seedlings and other materials), landscaping, care for young plants, etc. Medium-term impacts

5 IPBES (2019) *Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*.
6 IPCC (2019) *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*.
7 WWF (2019) *Climate, Nature and our 1.5°C Future. A synthesis of IPCC and IPBES reports*.
8 Seddon et al. 2019 *Grounding nature-based climate solutions in sound biodiversity science*.
9 Food and Land Use Coalition (2019) *Growing Better: Ten Critical Transitions to Transform Food and Land Use. The Global Consultation Report of the Food and Land Use Coalition*.
10 Nature4Climate (2020) *Nature-positive recovery for people and climate*.
11 World Economic Forum (2020) *New Nature Economy Report II: The Future of Nature and Business*.
12 UK Government (2020) *Interim Report – The Dasgupta Review: Independent Review on the Economics of Biodiversity*.
13 Hepburn et al. (2020) *Will COVID-19 fiscal recovery packages accelerate or retard progress on climate change?*
14 Nature4Climate (2020) *Nature-positive recovery for people and climate*.

can also boost the tourism and outdoor recreation sector, which in some areas will need support to recover from the current crisis. Often, nature-based solutions can be beneficially deployed in regions with weak infrastructure or declining economic activity, helping to address regional inequality.

When assessing the economic effectiveness of investments in a green recovery, interventions that support adaptation to climate change deserve special attention. This is because not only can they deliver direct benefits (such as job and income creation), but they can also produce benefits for societal resilience, i.e. the potential to avoid future losses. In fact, poorly designed investments that increase vulnerability to natural disasters such as flooding or drought impacts could put additional strain on the economy even within relatively short time spans. According to the Global Commission on Adaptation, typical benefit-cost ratios for adaptation investments range from 2:1 to 10:1.[15] For the UK, well-documented figures demonstrating a high potential for cost savings even over the short- to medium-term exist, e.g. in the area of flood management and coastal protection.[16,17]

The opportunity to accelerate delivery against climate policy targets coincides with currently high levels of public support for investments that enhance green space, nature recovery, and recreational value.[18,19] Nature-based solutions may involve the creation of 'bigger, better, more joined-up' networks of protected natural areas that deliver a range of ecosystem services, bringing them in line with recommendations for better management of England's wildlife sites.[20] There is also a possibility to combine some measures with public involvement, thus enhancing their co-benefits for mental and physical health[21,22] (see also Chapter 2: Just Transition). Finally, many of these interventions can be implemented safely even under the conditions of an ongoing pandemic, as they take place outside and social distancing is possible for most aspects of the work.[13]

Opportunities with a climate change mitigation focus (greenhouse gas removal and avoiding further emissions)

There is wide agreement that significant emission savings and carbon sequestration leading to greenhouse gas removal can be achieved in the UK through the following measures [17, 21,23,24,25,,26]:

- Restoring peatlands, many of which are currently degraded and releasing carbon as a consequence of intense management for agriculture, forestry, and grouse moors
- Re-establishing and managing forests, with opportunities for restoration, improved management, and utilisation of wood and timber in durable products such as building materials, although planting forests on peaty soils needs to be avoided because this results in soil carbon loss, thus counteracting carbon sequestration in biomass
- Creating, protecting, and restoring freshwater and coastal wetlands, which have a high potential for carbon sequestration and are currently affected by drainage, development, erosion, and sea level rise
- Managing farmland more sustainably, where carbon storage can be enhanced through improving soil carbon management and increasing the share of trees and hedgerows

15 Global Commission on Adaptation (2019) *Adapt now: a global call for leadership on climate resilience*.
16 Environment Agency (2020) *National Flood and Coastal Erosion Risk Management Strategy for England*.
17 Natural Capital Committee (2020) *Advice on using nature based interventions to reach net zero greenhouse gas emissions by 2050*.
18 Ipsos (2020) *How do Great Britain and the world view climate change and Covid-19?*
19 RSPB (2020) *Recovering together. A report of public opinion on the role and importance of nature during and in our recovery from the Coronavirus crisis in England*.
20 Lawton et al. (2010) *Making Space for Nature: a review of England's wildlife sites and ecological network*.
21 Natural England (2019) *Monitor of Engagement with the Natural Environment –The national survey on people and the natural environment*.
22 Public Health England (2020) *Improving access to greenspace: A new review for 2020*.
23 Committee on Climate Change (2019) *Net Zero: The UK's contribution to stopping global warming*.
24 Evans et al. (2017) *Implementation of an Emissions Inventory for UK Peatlands*.
25 Field et al. (2020) *The value of habitats of conservation importance to climate change mitigation in the UK*.
26 RSPB (2020) *Nature-Based Solutions in the Green Recovery*.

Interventions need to be planned carefully, and their impacts assessed across multiple dimensions, to ensure they are supporting rather than contravening other policy objectives (such as those on biodiversity, public health, food security, and climate change adaptation), and to prevent displacement of emissions both nationally and internationally (see also Chapter 3: Technology). The latter is particularly important in relation to measures that affect agricultural production and imports of food, feed, and fuels. Strategies to increase the domestic production of bioenergy should only be adopted on the basis of comprehensive lifecycle assessment.

Nature-based climate change mitigation actions also need to be designed for climate resilience, as carbon stored in ecosystems may become vulnerable to climate-related hazards such as drought, wildfires, pest outbreaks, or erosion. Restoration of peatlands and forests to a more natural state is generally thought to increase their resilience and thus provide even stronger benefits in terms of avoided emissions than would be assumed on the basis of current emission factors, but details of methods, species selection, and choice of site can be critical.[27,28]

Opportunities with a climate change adaptation focus

The following types of nature-based interventions have been proposed in the context of climate change adaptation in the UK, but can also contribute to emissions reductions – both through carbon sequestration and storage, and through indirect impacts such as reducing energy use for facilitated drainage, the need for cooling, or the distances travelled for recreation[29,30]:

- Protect and restore coastal ecosystems to control impacts of sea level rise and increases in storm surges
- Manage catchment areas to reduce flood risk and limit damage when floods do happen, and to a lesser degree address risk of drought (e.g. restoration of upper catchment forests, conversion of arable land to grassland in sensitive locations)
- Utilise nature-based approaches for resilient infrastructure planning – protecting roads from mudslides, reducing peak loads on drainage systems, creating windbreaks, etc.
- Increase urban green space such as urban forests, reallocation of land for parks, green walls and roofs, and sustainable urban drainage systems
- Use trees and hedgerows on farms to reduce soil erosion by wind and water (see also the agriculture section below)

Specific opportunities that could be taken up in COVID recovery strategies have been compiled in proposals submitted by a number of bodies and organizations. These include already agreed government interventions that could be scaled up (including by facilitating private investment), and promising ideas that could be piloted.[31,32,33,34] Government subsidies and investments could be re-designed and re-prioritised to deliver more value in light of the current crisis and the continuing nature and climate emergencies. There is a window of opportunity linked to Brexit and the departure from the EU Common Agricultural Policy (CAP) that should not be missed (see agriculture below).

27 Anderegg et al. (2020) *Climate-driven risks to the climate mitigation potential of forests*.
28 Crane (2020) *Woodlands for climate and nature: A review of woodland planting and management approaches in the UK for climate change mitigation and biodiversity conservation*.
29 Environment Agency (2020) *National Flood and Coastal Erosion Risk Management Strategy for England*.
30 RSPB (2020) *Nature-Based Solutions in the Green Recovery*.
31 Committee on Climate Change (2019) *Net Zero: The UK's contribution to stopping global warming*.
32 Rewilding Britain (2019) *Rewilding and Climate Breakdown: how restoring nature can help decarbonise the UK*.
33 RSPB (2020) *Recovering together. A report of public opinion on the role and importance of nature during and in our recovery from the Coronavirus crisis in England*.
34 Wildlife and Countryside Link (2020) *Shovel-ready green recovery projects*.

Principal recommendations:

- *Restore, re-wet, and protect peatlands*: This should be a priority action and should include reversal of drainage and past afforestation where possible. No further afforestation should be encouraged on peat soils of any depth, as the impact on emissions is likely to be detrimental even when considering the carbon sequestration in trees and wood products. Farmers who cultivate arable and horticultural crops on lowland peat should be supported to move towards farming practices that allow groundwater tables to be raised and to manage groundwater levels in a more precise and targeted way, minimising carbon loss from the soil and avoiding long-term loss of productive areas due to subsidence. Finally, production of sustainable alternatives to peat-based horticultural products (much of which are imported from overseas) should be supported.

- *Support the creation of woodland and planting of trees and hedgerows*: Ideally this will be done in synergy with sustainable methods of agricultural production and in ways that will enhance biodiversity. If well planned, increased tree and shrub cover on agricultural land can support adaptation to climate change and protect water and soil quality. The creation of new forestry plantations for bioenergy should be avoided as they consume a large amount of space for very little climate benefit and can be detrimental to biodiversity.

- *Choose afforestation sites and species with climate change adaptation, biodiversity, and public health benefits in mind*: For example, planting mixed native broadleaved species with a broad climatic niche will help stabilise slopes, increase the retention capacity of floodplains, buffer and connect old-growth woodlands, and create urban forests and/or forests within walking or cycling distance from residential areas (see also Chapter 2: Just Transition). To allow forest cover restoration efforts to take place efficiently and at scale, guidance on species selection and restoration/planting methods (including taking account of climate change) need to be made widely available, and access to all required inputs (including suitable seedling material in the quantities needed) should be facilitated.

- *Protect existing species-rich forests alongside reforestation/forest restoration*: While such measures contribute less to short-term job creation, their overall value to society and the economy (through ecosystem service provision) is generally significantly greater than that of newly created forests.

- *Restore species-rich grasslands and change grazing regimes to reduce overgrazing*: This is especially important in areas with high potential for co-benefits such as sensitive locations in floodplains, upland areas affected by or at risk from erosion, or areas important for recreation. Reducing the area grazed may be a more effective way to reduce damage caused by overgrazing than trying to adjust stocking densities, as significant reductions or sustained periods would be necessary in many upland heath or peat bog areas to allow the regeneration of natural woodlands.

- *Create a new National Nature Service, and provide education and training to support the implementation of nature-based solutions*: The idea of a post-COVID National Nature Service[35] should be explored. This could employ tens of thousands of people in countryside management, ranger services, and nature recovery, including in urban and peri-urban areas. More generally, education training programmes need to be developed to support the implementation of the nature-based solutions outlined above (see also Chapter 2: Just Transition).

Food, agriculture, and rural affairs

It is essential that measures to support a green recovery from COVID-19 promote food security,

35 Wildlife and Countryside Link (2020) *National Nature Service Letter to the Chancellor of the Exchequer*.

support climate- and nature-friendly agriculture, and acknowledge the particular needs of rural communities.

Agriculture in the UK accounts for about 10% of greenhouse gas emissions.[36] The government should adopt and support the National Famers' Union (NFU)'s target of achieving net-zero greenhouse gas emissions from agriculture by 2040,[37] but should aim to reach it by focusing on sustainable and innovative solutions. Some promising options for reducing emissions from agriculture include: precision farming and other approaches to reducing fossil fuel and agrochemical inputs; better livestock management; nature-based approaches as mentioned in the preceding section (i.e. enhancing permanent woody vegetation and diversifying production); improving soil carbon management (e.g. through low- and no-till cultivation); reducing overgrazing and restoring upland grasslands; and renewable energy/biomass production only from residual substances (where that is possible without depleting soils) and not from bespoke planting/crops which compete with food for land. Promoting resilient and sustainable farming practices will also help protect employment in the farming sector.

The links between interventions in agriculture/land use and the supply of food and other farmed products need to be considered, including at the international level. Land management practices should be prioritised in terms of their overall performance with regard to climate change mitigation and adaptation, food and energy production, and conservation/enhancement of environmental quality and biodiversity.[38]

The future UK food system will continue to include a mix of home-grown and imported produce, and everything we consume should be produced to high standards. In this context, possible interventions outside the agriculture sector itself are also relevant, such as shifting diets and reducing food waste, alongside measures that reduce waste at all stages of production and processing. To meet the nation's needs for healthy food, a reduction in meat demand should be accompanied by a shift of meat production towards an efficient combination of sustainable and ethically sound farm-based rearing of animals (in particular pigs and poultry), and extensive, grass-fed systems of cattle and sheep production in areas where these can deliver multiple benefits. Sustainable consumer choices should also be supported with regard to plant-based foods (considering factors such as the demand for land, water, and agrochemical inputs), including for imported products where potential impacts on carbon emissions, biodiversity, human health, and food security in the country of origin may be important.

There is an urgent need to replace the EU Common Agricultural Policy with effective support mechanisms that reward overall value provided to society, and thus ensure efficient spending of public funds. The Agriculture Bill's commitment to rewarding farmers for delivering public benefits through the Environmental Land Management Scheme is welcome. But there must be sufficient resources and good sources of advice to farmers to ensure investment in the right places for delivering nature recovery and emissions reductions through sustainable farming systems. Such support needs to be tailored appropriately to match different environmental and economic situations of farmers. Sustainable, nature-friendly farming systems require sustainable management of water resources, crop and animal management systems that do not damage or undermine soil structure, and the protection of habitats and landscapes as an integral part of farm businesses. A lack of training/awareness and need for initial investment have been identified as barriers to uptake of new practices, e.g. improved nutrient and soil carbon management, precision farming, renewable energy, and waste treatment. Farmers also need support to anticipate impacts of climate change and take early adaptation action to avoid the economic consequences of crop failure and stranded investments. Adjustments to functioning and content orientation of advisory services could help with this.

36 BEIS (2020) *Final UK greenhouse gas emissions national statistics: 1990 to 2018*.
37 NFU (2019) *Achieving Net Zero: Farming's 2040*.
38 Finch et al.(2019) *Assessing the utility of land sharing and land sparing for birds, butterflies and ecosystem services in lowland England*.

The NFU should be encouraged to establish 'green' kite mark standards for all forms of food production to allow consumer differentiation of products. Encouragement should also be given to establishing similar standards within catering, a major outlet of food supplied in the UK. Farmers should be incentivised to create and manage habitats specifically for nature enhancement within their farm systems, for example by planting woodland and hedgerows, restoring peat, creating wetland, or managing hay meadows, and sustainable food production should sit alongside these goals. A particular focus area for change should be arable or horticultural production on peat soils, for example in the Fenland area. Farmers should be supported to adopt production methods that are compatible with higher groundwater levels, and to manage groundwater levels in a more precise and targeted way (see recommendations on restoring, re-wetting, and protecting peatlands above).

The support mechanisms provided to farmers in a post-Brexit environment should adhere to rigorous nature-based standards and generate public benefits, but this will be challenged by the reality of international trade agreements and competition for local and international markets. Whilst there have been promising models which suggest that the notion of 'land sparing' and intensification of agricultural production can offset greenhouse gas emissions, others suggest that a broad strategy of sustainability measures should be established across all agricultural landscapes. There also needs to be more recognition of the financial reality faced by many farmers who will be driven to maximise productivity, and the subsequent threat to environmental standards (e.g. localised gaseous emissions and threats to fluvial water quality). Furthermore, sustainable intensification will not be incentivised by UK agencies lowering environmental standards (e.g. water quality) below those that were upheld through European regulations.

Climate change and other environmental pressures are already directly and indirectly impacting UK farming systems. Crop production is under threat in the UK from the increased intensity of climatic extremes (e.g. the likely 30% reduction in UK wheat yields associated with climatic conditions in the UK over 2020). The science associated with crop breeding and improvement will be required to develop resilience in grain crops for heat and drought or changing growing season length. Any increased reliance on the import of food stocks for animal production or human consumption will also trigger greenhouse gas emissions and water use within third party countries, and the impact of their production (e.g. soy) on environmental degradation and removal of natural vegetation should also be factored into the UK carbon budget. The potential emergence and spread of zoonoses and animal pathogens, which can be promoted in some farming systems with poor biosecurity, pose a risk to global food systems as well as health. These can also be associated with lower welfare standards, which should be considered in future trade deals and regulatory frameworks.

Principal recommendations:

- *Develop tailored policies, incentives, and support to limit agricultural greenhouse gas emissions and attain sustainable intensification*: This could include initial investment to promote better carbon management in agriculture on 'mineral' soils, along with regional approaches, e.g. for uplands or intensively farmed peatlands. Launch an advisory service to help with the adoption of sustainable farming systems in support of the Agriculture Bill's commitment to rewarding farmers for delivering public benefits through the Environmental Land Management Scheme.

- *Support sustainable food production and healthier diets*: Recognise the pressure that a changing climate is placing on food production, as well as the impact of environmental degradation and threat of pests and diseases arising in third party countries where welfare and production standards are lower. Invest in promoting healthier and more plant-based diets, reducing or making better use of food waste, and sourcing and consuming local produce where this is the most sustainable option. This can help to cut costs in agriculture, public health, and the food industry, and can bring down consumer expenses (see also Chapter 2: Just Transition).

- *Overhaul subsidies in agriculture and rural development as well as taxation schemes:* Reward landowners appropriately for benefits provided to society, as promised in the Agriculture Bill. This can go hand in hand with consideration of impacts on jobs, aiming to support sustained and satisfying employment. Protected landscapes can lead the way in collaboration with farmers, as they already have staff, plans, and infrastructure to support this. Support diversification for certain rural and agricultural communities which can be coupled with strategies to increase access to the countryside, thereby also delivering health and welfare benefits for urban dwellers.
- *Calculate and cut the carbon footprint of food, animal feed, and biomass imports*: This should include impacts on land demand and agricultural productivity, and possible associated effects on trade, deforestation, and food security in other countries. Investments in biomass production and land use for energy need to be evaluated critically (see Chapter 3: Technology).
- *Ensure post-Brexit international trading agreements are aligned with action on the climate and nature crises*: These agreements must provide incentives for sustainable agriculture and associated supply chains within the UK, and must not lead to the import of food produced to lower welfare and sustainability standards, or to a reduction in environmental regulatory standards for atmospheric pollution or water quality.

Chapter 5: Investing in Nature-based Solutions and Supporting Agriculture and Rural Affairs

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Chapter 6: *International* Global Leadership Opportunities for the UK

- **Demonstrate UK international leadership, building on key global events to respond to the climate, biodiversity, and health crises.** Through the upcoming UN Framework Convention on Climate Change COP26, the Convention on Biodiversity COP, and collaborations in the World Health Organization, mobilise diplomatic channels and all stakeholders to advance a green, just recovery.
- **Help coordinate and deliver a global response to the need for education, awareness, and capacity on climate change and biodiversity conservation** among all stakeholders and at all levels, from global to local, also supporting new career and employment opportunities.
- **Leverage pandemic recovery investments to implement the Paris Agreement and the global Sustainable Development Goals.** Promote new investments, economic stimulus finance, and innovative solutions which align with climate change, species extinction, extreme poverty, and other agreed SDG targets, also fulfilling binding treaty obligations.
- **Promote international green, just recovery cooperation through new economic agreements.** Shape and implement sustainable development commitments from existing and new trade, investment, scientific cooperation, and technology transfer treaties, and leverage economic relationships to more effectively enable a green future.

A green, just recovery provides important opportunities for the UK to assume an international leadership role: leadership by example, leadership by investment, and leadership by enhancing global cooperation. In addition, as the UK looks to reaffirm its international influence following Brexit,[1] climate change, biodiversity conservation, and the green recovery in particular provide opportunities to promote global ambition. Many of the challenges posed by the destruction of nature and climate change, which are inextricably linked to rising poverty rates, are fundamentally global, requiring enhanced global cooperation and for leading countries to take the steps needed from which others can emulate and learn.

The UK is in a unique position – taking the Presidency of the G7 in 2021, holding a leadership position in current climate change negotiations with COP26 in 2021, and embarking on the formulation of new economic relationships with critical trading partners – to leverage past experiences, forge new alliances, and galvanise the breadth of actors underpinning an effective post-pandemic recovery. The UK could thereby build back better while gaining a global reputation as a leader in climate action and achievement of the Sustainable Development Goals (SDGs), and at the same time building greater innovation and competitiveness in a new green, just, knowledge-based global economy.

Climate change

One of the many major events that was postponed as a result of the global pandemic is the 26th Conference of the Parties (COP26) to the United Nations Framework Convention on Climate Change (UNFCCC). This was meant to be held in Glasgow in late 2020, and instead will take place in November 2021. The UK holds the Presidency, in partnership with Italy, and thereby will be leading the international climate change negotiations, which currently sit at a critical juncture. Many of the preparatory engagements will need to be undertaken virtually, which poses new challenges. There is need to maintain momentum and enhance ambition towards a robust and unified implementation of

1 Gifkins et al. (2019) *Global Britain in the United Nations*, UNA-UK.

the Paris Agreement. However, at the same time, countries must rebuild their economies following the impacts of the COVID-19 pandemic and the subsequent market disruptions it has caused. Developed countries will need to show solidarity with least developed and other highly vulnerable countries as they look to address the existential challenges posed by the global pandemic, and the economic recovery in the context of continuing impacts of climate change.

The Committee on Climate Change has previously identified several sectors where the UK has the potential to establish a dominant global market share including smart grids, advanced building design, materials and manufacturing systems, low-carbon power, low-carbon services such as finance and consultancy, low-emissions vehicles, and energy storage.[2] In this context, it is crucial to ensure that fiscal, legal, and regulatory programmes created to address economic disruptions caused by COVID-19 also lay the groundwork for an effective shift to a global net-zero economy. Weaving threads of common objectives arising out of the pandemic-induced economic downturn together with advancing a bold climate agenda could provide a unique opportunity to generate collective commitment that is inclusive and responsive to the magnitude of the global climate challenge.

In the lead up to COP26, the UK can play a central role in engaging with observers and a broad array of domestic and international stakeholders across the private and public sectors to galvanise efforts. In 2020, the UK has stressed the importance of enhanced action on adaptation and resilience, promoting nature-based solutions, advancing the energy transition, accelerating zero-carbon road transport, and harnessing finance to advance the Paris Agreement's goals.[3] Each of these could be advanced in such a way that they support green recovery programmes.

Biodiversity conservation

Biodiversity (the variety and variability of life on Earth) is the foundation of a sustainable economy. Water, food, and energy are the building blocks on which human life and economic systems are built and they in turn depend on biodiversity. The resilience of the global economy is intricately linked to the state of the nature. Currently, nature is declining globally at rates unprecedented in human history, and therefore the conservation and restoration of biodiversity is critical to achieving green growth and sustainable development. The UN Summit on Biodiversity in September 2020 concluded that our societies are intimately linked with, and dependent on, biodiversity. Its loss and degradation jeopardize progress towards the SDGs and threaten human health and wellbeing. The COVID-19 pandemic has further highlighted the importance of the relationship between people and nature, and the role that ecosystem conservation and restoration plays in fostering nature-based solutions to preserve natural capital and create buffers to zoonotic transmission of diseases.

The UK has historically been a global leader in the science, policy, and practice of biodiversity conservation. The UK's conservation science and capacity-building initiatives are world renowned for informing and shaping local, national, and international environmental policy and practical action to protect and restore nature. The dependence on nature to achieve sustainable food production, mitigate and adapt to climate change, and create a circular economy is now proven.

With the 15th Conference of the Parties of the UN Convention on Biodiversity scheduled in China for May 2021, it is vital that the strategy, goals, and targets agreed for biodiversity conservation worldwide are informed by evidence, aligned with those to be adopted to address climate change by COP26 of the UNFCCC, and contribute to the SDGs. UK expertise (from government, academia, the private sector, and NGOs) in developing payment for ecosystem services schemes, nature-based solutions, landscape-scale restoration and rewilding, national and international marine protection zones, and an innovative 25-Year Environment Plan can be harnessed to provide international leadership and innovation in biodiversity conservation.

2 Committee on Climate Change (CCC) (2019) *Net Zero: The UK's contribution to stopping global warming*.
3 Priestley (2020) *COP 26: the international Climate Change Conference, Glasgow, UK*.

The 2020 Dasgupta review on the Economics of Biodiversity, commissioned by the UK Treasury, explores "the sustainability of human engagements with nature – what we take from it; how we transform what we take from it and return to it; why we have disrupted nature's processes; and what we must urgently do differently to enhance our collective wealth and well-being, and that of our descendants."[4] This, together with the World Economic Forum's series of reports showing the relevance of nature loss to boardroom discussions,[5] will offer new agendas for action and cooperation to achieve global green growth, and an opportunity for the UK to once again demonstrate global leadership in biodiversity conservation.

Sustainable development cooperation

Fostering enhanced channels for sustainable development cooperation is a central area of opportunity for the UK, advancing both post-pandemic recovery and Paris Agreement goals. Actions should strengthen and build on the UK's past development cooperation success, ensure that budget allocations continue to reach 0.7% of GNI, as committed, and promote green recovery pathways with investment to support the transition to a low-carbon future for least developed countries.

The Green Climate Fund was set up in 2010 with a goal of raising $100 billion per year by 2020. This is still nowhere near sufficient to meet the scale of challenges associated with the Paris Agreement implementation. The scale of the investment needed is in the tens of trillions, according to the World Bank.[6] Indeed, the *total* amount announced to date for the fund is $10 billion and only $8 billion has been confirmed. New leadership in mobilising the investments required would build on the current UK commitments to International Climate Finance, totalling £5.8 billion between 2016 to 2020, and on the £3.87 billion previously spent on climate-related activities from 2011 to 2015.[7] Further effort is needed, and very skillful UK leadership is badly needed, to finalise operationalisation of the market and non-market measures under the Paris Agreement, while mobilising climate finance contributions both bilaterally and through multilateral bodies to enable further cooperation on sustainable development.

Despite decades of slow progress, there remain many gaps in our progress to achieve the world's binding treaty commitments on sustainable development, in alignment with the global SDGs. The UK can support green recovery cooperation which meets binding sustainable development commitments agreed multilaterally relating to climate change, biodiversity, and desertification under the Paris Agreement, the Convention on Biological Diversity, and the United Nations Convention to Combat Desertification. Increased recognition and protection for traditional knowledge, with access governed by the Nagoya Protocol to the Convention on Biological Diversity and ensuring fair and equitable benefit sharing, provides an important pathway to foster both climate- and biodiversity-related priorities, while supporting the broader sustainable development agenda.[8,9] Additional emphasis should be placed on encouraging interlinkages across climate and human rights discourse, including through the Convention on the Elimination of Discrimination Against Women and other binding accords, and through other low-carbon, climate-reliant mechanisms which contribute to achieving the global Sustainable Development Goals (SDGs). Addressing global inequalities should also be urgently prioritised to reduce the drive for global migration and conflict, and is intimately linked to the challenges of sustainability.

The challenges of responding to climate change are particularly acute in climate-vulnerable and

4 UK Government (2020). *Interim Report – The Dasgupta Review: Independent Review on the Economics of Biodiversity*.
5 World Economic Forum (WEF) (2020) *New Nature Economy Report Series*.
6 World Bank (2019) *Climate Finance*.
7 UK Department for International Development (2020) *2020 UK Climate Finance Results*.
8 Cordonier Segger and Phillips (2015) *Indigenous Traditional Knowledge for Sustainable Development: The Biodiversity Convention and Plant Treaty Regimes*.
9 Phillips (2016) *Intellectual Property Rights in Traditional Knowledge: Enabler of Sustainable Development*.

resource-constrained jurisdictions. In particular, a capacity chasm has opened across all disciplines in relation to climate change solutions. There exists a crucial need for increased education, awareness, and capacity building on climate change among all critical stakeholders. The UK could help to coordinate and deliver a global response, which would also help support post-pandemic employment opportunities.

Trade, investment, and diplomacy

International trade and investment are critical catalysts to enable a green future, including through: (i) general references such as linkages with direct and indirect land-use changes, as well as timber products, (ii) enabling resilience through investment, (iii) prioritisation of green economy and green growth, (iv) taxation aspects, such as carbon tax or border tax adjustments, and (v) interlinkages with carbon sinks and sequestration.[10]

The UK can promote green recovery cooperation which synergistically achieves sustainable development commitments agreed in existing trade, investment, scientific cooperation, and technology transfer treaties, mobilising the newly merged Foreign, Commonwealth, and Development Office, and updating and modernising existing relationships to more effectively enable a zero-carbon future.

A survey of innovative 'good practice' processes and provisions on sustainability adopted in regional and bilateral trade and investment agreements identifies a range of options for the UK, including: (i) enhanced cooperation provisions (i.e. Comprehensive and Economic Trade Agreement (CETA) 2016), (ii) promotion of low-carbon technologies (i.e. EU-Singapore Economic Partnership Agreement (EPA) 2018), (iii) non-regression of environmental provisions (i.e. CETA, Trans-Pacific Partnership agreement (TPP)), and (iv) advancement of a progressive trade agenda (i.e. joining negotiations for the Agreement on Climate Change, Trade, and Sustainability (ACCTS) with Norway, Iceland, New Zealand, Costa Rica, and Fiji).[11]

The UK's net-zero commitment is, by accounting convention, measured based on production rather than consumption and, as such, does not account for the emissions associated with imports. In addition to losing industry and jobs associated with the offshoring of energy-intensive industries, this can lead to higher overall emissions (so-called 'carbon leakage'). One part of the solution has seen the UK take a lead through its Industrial Decarbonisation Challenge,[12] which aims to accelerate the cost-effective decarbonisation of industry by developing and deploying low-carbon technologies at scale in the UK – with the first low-carbon industrial cluster by 2030, and the first net-zero cluster by 2040. In so doing, the UK can demonstrate that traditional energy-intensive industries need not also be carbon-intensive.

The other side of the equation is addressing the carbon-intensive imports themselves, and there is also growing interest in exploring the potential for WTO-compliant border tax adjustments (BTAs). No one country can do this by itself, so the UK should continue to work with like-minded countries to explore options for implementing such BTAs if necessary.

Government has and should continue to take a global leadership role in demonstrating innovative technology and funding topical climate research and technologies. A good example of this is the UK's funding for greenhouse gas removal (GGR), first through £8.6 million investment from the research councils over 2017-21, which has now been significantly extended under the current £31.5 million Strategic Priority Fund call to support up to five individual GGR Demonstrators as well as a central Directorate Hub. In addition, the UK Chancellor has committed £100 million to a new innovation

10 Phillips (2020) *Briefing 2: Trade-Climate Interlinkages Approaches Taken in Nationally Determined Contributions*.
11 Gehring and Morison (2020) *Briefing 1: The UK's Trade-Climate Agenda - How can the UK take quick advantage of existing opportunities to boost climate-friendly trade flows?*
12 UK Government (2020) *Decarbonising the UK's industry*.

programme to develop and demonstrate direct air capture of CO_2 and other GGR technologies with the aim of projects starting by mid-2021.[13]

Although there may be differences over the specific details of where to invest, this is the sort of scale of research and demonstration funding that will be needed to gain global attention. Also, importantly, acting promptly can help the UK research and business communities gain first mover advantage.

Leadership need not solely come from government. Another example of effective use of British soft power, the Global Apollo programme was initiated in 2015 by leading British scientists, economists, and industrialists.[14] This eventually helped inspire Mission Innovation,[15] whereby 24 large economies committed to double their clean energy RD&D investments by 2020/21.

Most countries had been on track to meet this commitment, however the International Energy Agency's recent World Energy Investment flagship report has highlighted that budgetary pressures precipitated by the pandemic may lead to significant reductions in energy R&D.[16] There is therefore a need for the UK government to not just continue to maintain its own commitments, but to work with others to ensure momentum towards meeting these targets.

Chapter 6: Global Leadership Opportunities for the UK

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