Rebuilding a Resilient Britain: Supporting Lower-Carbon Local Economies

Report from Areas of Research Interest (ARI) Working Group 5

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Foreword

The COVID-19 pandemic presents a fundamental challenge to our society, economy, and ways of living. We need to ensure that our response to these challenges is informed by the best possible evidence, by engaging with the right stakeholders. As a first step toward this goal, the 'Rebuilding a Resilient Britain' programme of work was launched in July 2020 to bring together researchers, funding bodies and policy makers to identify evidence and uncover research gaps around a set of cross-cutting Areas of Research Interest.

ARIs were initially developed in response to the recommendations of the *2014 Nurse Review of Research Councils*, which called on government departments to communicate clearly where their research objectives lie. The ARIs take the form of an annually updated list of priority research questions, which invite the academic community to engage with government departments to inform robust evidence-based policy making.

With the advent of the COVID-19 pandemic, however, it became clear that the societal issues affecting Britain's recovery over the medium- to long-term cut across departments. The ESRC/GOS ARI Fellows therefore worked with the CSAs and Council for Science and Technology to identify a set of ARIs relevant across all departments and sectors. Under the meta-themes of **Rebuilding Communities**, **Environment and Place**, and **Local and Global Productivity,** each led by two CSAs, nine Working Groups were formed:

Rebuilding Communities led by Robin Grimes (MoD Nuclear CSA) and Osama Rahman (DfE CSA)	**Environment and Place** led by Robin May (FSA CSA) and Andrew Curran (HSE CSA)	**Local and Global Productivity** led by Paul Monks (BEIS CSA) and Mike Short (DIT CSA)
1. Vulnerable Communities	5. Supporting Lower-Carbon Local Economies	8. Local and National Growth
2. Supporting Services	6. Land Use	9. Trade and Aid
3. Trust in Public Institutions	7. Future of Work	
4. Crime Prevention		

With input from the Universities Policy Engagement Network, UKRI, the What Works Centres, and the National Academies, each Working Group was populated with subject experts and representatives from funding bodies and government departments.

The working groups met several times over the summer and used their networks to:

a. identify a diverse range of existing or ongoing research,

b. synthesise evidence which can be quickly brought to bear on the issues facing departments
c. identify research gaps in need of future investment.

This report represents the culmination of the work of one of these Working Groups. The expedited timeframe of this work, along with their specific areas of expertise, led to some variation in how each group approached the task. It should be noted that this document represents the views of the Working Group members and is not indicative of government policy.

As well as providing deep expert reflection on the cross-cutting ARIs, it is hoped that these reports, and the work that led to it, will prompt further collaboration between government, academia, and funders. Working across government and drawing from the extensive expertise of our academic community will be essential in the recovery from the COVID-19 pandemic, to rebuild a resilient Britain.

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List of acronyms

AI	Artificial Intelligence
ARI	Area of Research Interest
AHRC	Arts and Humanities Research Council
BAME	Black, Asian and Minority Ethnic
BBSRC	Biotechnology and Biological Sciences Research Council
BEIS	Department for Business, Energy and Industrial Strategy
CBI	Confederation of British Industry
CJS	Criminal Justice System
CO	Cabinet Office
COVID-19	Coronavirus Disease 19
CSA	Chief Scientific Advisor
DCMS	Department for Digital, Culture, Media and Sport
Defra	Department for Environment, Food and Rural Affairs
DfE	Department for Education
DfT	Department for Transport
DH	Department of Health
DHSC	Department of Health and Social Care
DIT	Department for International Trade
DWP	Department for Work and Pensions
EPSRC	Engineering and Physical Sciences Research Council
ESRC	Economic and Social Research Council
FCDO	Foreign, Commonwealth and Development Office
FSA	Food Standards Agency
GCSA	Government Chief Scientific Advisor
GOS	Government Office for Science
HMRC	Her Majesty's Revenue and Customs
HMT	Her Majesty's Treasury
HO	Home Office
HSE	Health and Safety Executive
MHCLG	Ministry of Housing, Communities and Local Government
MoD	Ministry of Defence
MoJ	Ministry for Justice
MRC	Medical Research Council
NERC	Natural Environment Research Council
NGO	Non-Governmental Organisations
NICE	The National Institute for Health and Care Excellence
ONS	Office for National Statistics
PHE	Public Health England
R&D	Research and Development
SAGE	Scientific Advisory Group for Emergencies
SME	Small and Medium-sized Enterprises
STEM	Science, Technology, Engineering, and Mathematics
STFC	Science and Technology Facilities Council
UKRI	UK Research and Innovation

Contents

1. Chair's introduction

Previous recoveries from crises have included growth and investment in high-carbon industries such as construction and infrastructure. The recovery from the COVID-19 pandemic will take place during a period when the relationship between economic development and the global environment attracts high levels of scrutiny.

The UK will face major short-term economic and social pressures over the coming years, including risks of high unemployment, not least among young people; the mental health of the population; and the financial stability of families across the country. Attempts to mitigate these pressures will inevitably focus on policy interventions that deliver short-term impact.

But this is also a time of opportunity. The pervasive adoption of new technology in the workplace, heightened sensitivity to environmental concerns and a time of accelerated change in economic markets and societal behaviour create opportunities to shape a different type of post-COVID society. Recovery does not have to mean a return to the same pre-COVID world; we can aim to rebuild better. The question is how we can better articulate visions of that new world including the potential for radical shifts in conventions, expectations, and practices. Routes out of this crisis can help meet key challenges around net-zero, levelling up, and a more equal society without dampening opportunities for talented and energetic people.

This adds up to a challenging area of policy development. Government needs a range of new data and other evidence to inform policy debates that have the potential to affect the lives of millions of people across the UK.

Against that background, the objective of this working group was to broaden the set of choices which policymakers could consider; to enable a more imaginative universe of policy options; and the development of a wider network of policy officials and academic researchers who could work together to explore these options.

2. How the evidence was identified and collated

ARIs were identified by departments and prioritised by CSAs. The ARI Fellows presented a set of priority areas to the CSA network and the GCSA who identified which topics would be of most use to take forward. These ARIs were divided into 9 themes, for each of which a working group was established. Working groups were populated with colleagues from UKRI, academia, government, and relevant stakeholder organisations.

Our working group on Supporting Lower-Carbon Local Economies divided the initial 13, later 17 (following late additions from Defra), ARIs into 5 thematic subgroups, each of which was chaired by a member of the Working Group. Chairs were tasked with reaching out to their networks to maximise access to diverse expertise and evidence. Each subgroup collated resources and evidence, synthesised key messages and identified evidence gaps through virtual meetings and via email exchanges. The working group then came together virtually three times in order to share subgroup findings and identify cross-cutting key messages for the working group.

The cross-cutting issues and subgroup key messages are summarised below. For a full report on each subgroups' key messages please refer to Annex 4.

Tensions that working group members noticed during this process included:

- The balance between evidence and judgement - Working group members brought in their expertise to review existing evidence and resources against the ARIs and identify key messages and evidence gaps. In doing so, they did not just rely on evidence alone, but also used their judgement as to which evidence to bring in, interpretation of evidence and key messages, which other colleagues to consult and involve in the process, etc. With a shorter timeframe the role of judgement became more important as working group members relied on instinctive responses and what is already known to them.
- Formulation of ARIs - The working group was tasked with responding to the given 13, later 17, ARIs. Whilst some working group and sub-group members struggled to accept the ARIs as they were formulated, the group did not suggest alternative framing, language or focus of the ARIs. However, an important set of questions emerged: What evidence have government departments previously used to answer these questions? What existing evidence around these ARIs is there already within government departments? What is the actual question, government departments need help with from academics?

3. Key messages

3.1. Cross-cutting themes

There must be a balance between **recovering** the old normal and **rebuilding** a new normal. Previous crises have been addressed through short-term, high-carbon investments, which are no longer a viable option. We need to find ways to broaden the set of possibilities in front of policymakers, through creative and diverse engagement activities, if we are to resolve the tension between economic growth and low-carbon agendas.

In addition, what happens at a national policy level will have critical implications for local level green/recovery, and vice versa.

Sustainability should therefore be viewed as a key feature of new investment and disinvestment decisions. Rather than maximising growth and development, we need to minimise the negative impact on the environment while delivering key services.

Risk and uncertainty are key features of this new environment and cannot be entirely reduced through the existing evidence base. Environmental, financial, economic risks will operate differently with stakeholders. We need to maximise what we can learn from natural experiments at the urban level, such as the effects of local lockdowns and other locally implemented schemes. This will allow us to reduce uncertainty with relatively little political or capital outlay.

Regional and other inequalities must be considered when choosing to invest or disinvest in schemes likely to influence local economies. There are costs as well as benefits to policies and investment strategies (To Transition! Governance), which are likely to operate differently due to regional differences in need and capacity around economic rebuilding.

There is a need to ensure **clear, locally determined processes** to develop, select and implement policies. COVID-19 – amongst other challenges such as climate change and economic upheaval – has created a set of new conditions which cannot be shoehorned into old frameworks and ways of working. We are likely to need new parameters and targets to guide planning, investment, and other decisions. This will involve in-depth conversations with local communities and stakeholders to determine local need and capacity; to close the gap between policy intent and implementation; and to decide together what will be considered investable assets and how to make policy a reality. What will now be seen as an asset, and what as a risk or burden? However, we must be mindful to focus on drawing on robust evidence where available, and producing evidence where required, to inform local choices. Some processes that could be harnessed are based on principles that can transcend particular places but there are challenging issues here about how to balance local/national/global priorities and the 'locally determined' view privileges some interests over others.

In our view, this implies a need for **a cross-government set of ARIs** which specifically identify complex and cross-cutting challenges of this kind. GOS should consider how to facilitate and enact these.

3.2. Subgroup 1: transport

Transport is now the largest contributor of greenhouse gas emissions in the UK accounting for 27% of the total. Electrification of transportation - including marine, rail and aviation - will help reduce local pollution and achievement of the overall net zero carbon ambitions set by the government. It is important to understand the potential impact of large-scale penetration of electric vehicles, and the implication for the electricity and renewable energy network.[1]

The main power source for transport electrification is still battery. Battery treatment after service life poses substantial challenges for ecological protection and sustainable development. There is an urgent need to develop industrialised methods, update environmental regulations, build up sustainable business models, and introduce new mechanism to promote the recycling of retired batteries.[2,3]

There is a widespread utilisation of alternating current (AC) based systems for electrified marine vessels. However, there is an active interest in a transition to direct current (DC) based electrical distribution system which can potentially improves the electrical performance and fuel consumption. Comparison and evaluation of these two systems should be undertaken for further development.[4]

Current models of electric aviation do not demonstrate significant reduction in fuel consumption and emission generation. Full electric or hybrid propulsion promise essential emission reduction. Research into electric propulsion of commercial aircraft to reduce emissions should be a priority.

With increased electrification, there is need to consider the development and operationalisation of charging infrastructure. The decisions necessary to successfully roll out charging infrastructure are multi-dimensional. Decision makers play an important role in addressing and overcoming the challenges to electric vehicle proliferation and provides charging infrastructure utilization data to support such strategies.[5]

The recent pandemic has significantly changed transportation in UK, including modes of travel, travel choices, and subsequent carbon emissions. By looking at where carbon emissions mainly occur (multi-mode transport hubs, charging infrastructure via renewable energy sources such as hydrogen and subsidy schemes, and new techno-economic and environmental policies to implement new decarbonising transportation), there are promising avenues for exploration.

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3.3. Subgroup 2: emerging technologies

Emerging technology, particularly Digital Technologies are pivotal to move to lower carbon economies. The 2019 Gartner Hype Cycle identified key emerging technologies. Together these form Cyber-Physical systems, combining physical monitoring and intervention with large-scale intelligent computing.

AI, visualisation, and simulation is central to the automation and identification of new knowledge from data resources and offers carbon reduction by better coordination of resources. Advanced visualisation with high-resolution simulation offers a new materials design process (e.g. photo-voltaics or batteries). AI can identify candidates to be designed virtually, enabling quicker adoption of low carbon technologies.

Sensor Technology and Edge Computing. Low cost sensors utilising 5G deliver Smart Environments, which can be used for example to improve traffic flow within cities or to assess the impact of climate on crops. Computing on the sensor allows processing “at the edge”, reducing data transfer to central processors, and with greater automation and responsiveness of infrastructure, reduces the carbon footprint. Combining edge and cloud processing deliver rapid local action with high-capacity services to analyse data.

Decentralised applications enabled by Blockchain can build trustless value ecosystems, allowing the automation of the movement of goods and services between entities with no prior relationship. For example, decentralised smart transport has the potential to revolutionise the way people move around, reducing for example the carbon used in single person car journeys or underutilisation of buses.

Digital Twins combine the above into cyber-physical systems and are being developed from automotive design to Buildings Information Management. Twins can reduce carbon by better planning and management of infrastructure. For research councils such as NERC, Twins are a key focus for direct environmental applications, for sites like the Thwaites Glacier, or for optimising infrastructure, like the Attenborough research vessel. Further, the Data & Analytics Facility for National Infrastructure (DAFNI) forms a foundation of a platform to support digital twins.

Quantum Computing may offer a step change in the way data is processed, solving complex routing problems for more carbon efficient logistics.

Effective use of Environmental Data. On 14 July 2020, the Royal Society held a workshop on using digital technology for climate science, including the development of a roadmap for data infrastructures. Key findings included:

- **A need for more effective use of data:** Existing data could be repurposed for carbon monitoring, by releasing it from the public sector and elsewhere such as Smart Meters.
- **Characterise the need for further data:** further data collection could help develop new reporting systems. Efforts to create datasets cost and must be balanced by the emissions generated in the process.
- **Combine multiple sources of data:** Combining data from multiple sources can inform our understanding of emissions, for example, satellite data, on-the-ground measurements, "smart asset" data, and potentially via crowdsourcing.
- **Build capacity in existing data infrastructures:** The UK has established high-quality data repositories, such as the Met Office Informatics Lab, and the JASMIN facility. These can be exploited by researchers collaborating on models alongside curated data.

3.4. Subgroup 3: housing and construction

Housing and Construction affords huge opportunities for decarbonising the UK Economy, being highly energy intensive and accounting for 40% of UK Carbon emissions yet offers the most affordable way of cutting emissions relative to other sectors of the economy.

While enforcing new measures to decarbonise new builds, the real mileage is in decarbonising existing housing stock, about 23.4 million UK homes were built before 1980 and over one million of these are currently vacant. Upgrading or retrofitting existing housing stocks to sustainable standards presents the UK with the greatest opportunities to achieve significant reductions in building energy consumption and carbon emissions.

Effective decarbonising strategy is likely to emerge through combinations of long-term policy mixes drawn under different scenarios and reflective of local peculiarities. A one-fit-for-all policies will not deliver decarbonisation at the rate and speed required.

Decarbonisation ambitions in strategies and policies must reflect capacity to deliver. Massive investments in upskilling is necessary for an effective decarbonisation of UK housing and construction, hence the wider economy.

While the role of government at all levels is central to effective housing and construction sector decarbonisation, construction stakeholders – developers, contractors, professional bodies, financial institutions and households should be incentivised to encourage uptake and investments in new and emerging technology and innovations.

Transition to sustainable housing and construction industry is a process that involves several stages and intermediary actors. Holistic supports with operative structures to deliver them should be established.

Transition to sustainable housing and construction can involve indivisible capital investments and risks. Establishing a platform of some form, physical or digital, is necessary to encourage interaction and dialogue amongst all stakeholders. This will facilitate awareness of current and innovative technologies, support good practice, and mitigate investment risks.

3.5. Subgroup 4: economic development

Economic development offers an opportunity to explore new thinking rather than a more conservative 'what works' approach.[1] National strategic aims toward a greener and cleaner economy, under current economic pressures and the growing embrace of our climate and biodiversity emergency, require a concerted commitment to the questions of equity through investment in a ‘just transition’.[2] There is a large research literature on the contested concept of a ‘green climate economy’, which dates back to the linked concept of ‘ecological modernisation’ – a techno-centric, innovation-oriented approach to working our way out of unsustainable economic development. This has been accompanied by the view that economic growth can be de-coupled from environmental degradation. However, while there are merits to these notions, there is a dearth of understanding with regard to the social and economic implications of shifting from ‘dirty’ jobs to cleaner ones, for example.[3] The societal divergence of interests has become more pronounced with the growing inequalities within/between our cities, towns and regions.[4] Industry transitions toward new, just forms of economic development require an equity-centred approach to new industrial strategic thinking. This will require attention to the following policy considerations:

- An industrial policy that is fit for purpose needs to be commensurate with the immediacy, acuteness and existential nature of the climate crisis, recognising and building on the innovative nature of human intervention and the market economy when well managed by the state, while properly resourced at a range of scales.
- Action needs to take place at a range of scales from the planetary to individual choices (e.g. what food to eat, car to drive, jet to not get on); the city-region is a particularly powerful scale: small enough to act, big enough to resource.[5] However, city-regional growth management and infrastructure planning for a transition to a ‘clean’ economy must factor in the consequential effects on inter-city flows of labour/goods/services from restructured business networks (important for innovation and agglomeration positive spill overs), which have been found to be associated with high emissions from motorised vehicles and the horizontal transportation of those emissions across functional regions, with *uneven* spatial and environmental impacts.[6],[7] This will require cross-sectoral coordination and cross-institutional policies in England between Local Industrial Strategies (LISs) and other policies - especially where a common spatial strategy

is not in place or is subject to conflicting local interests and short political timescales.

- The challenge of planning a 'just transition' is not altogether a technical one; it is the political will to act at a scale that is necessary, such as integrating the 'circular economy' with a net zero strategy through 'Energy Innovation Zones'.[8],[9] Might Brexit be a chance to press the reset button? Might COVID mean some economic activities should be invested in, and others divested from, and those affected by such investment strategies helped though a 'just transition' to new greener, cleaner economic activity? This requires an attention to the economic alternatives versus an attention to savings that then risk re-igniting 'more of the same'.
- *Urban density* is a particularly important consideration of such 'energy innovation zones', namely the correlation between low carbon emissions, density indicators, and investment flows and returns.[10] However, this must be considered alongside a principle of mitigating against socio-economic exclusion and the off-setting of ecological assets that reduce urban green space and the opportunity to benefit from the eco-system services of these assets – including the support of economic livelihoods (see 'Urban Tensions' section of Policy Governance/Climate Change in appendix). Fields in Trust[11] reinforces previous research (Chartered Association of Building Engineers) that has highlighted the loss of urban green in our cities, including a clear divide between North/South (England) and East/West London; Natural England's recent work[12] reinforces this view, highlighting a concentration of overall green space per capital in London.
- Place matters. The impacts of a just economic transition require attention to the distribution of economic areas of investment *and* divestment, its implications for job growth as well as job loss and the need for upskilling or shifting to new economic activities.[13] This requires the embedding of 'equity planning' principles in ongoing national discussions over the reform of the English planning system, and related cases for the value of urban design or well-designed places.[14],[15],[16],[17] Equity planning "*tries to provide more choices for those who have few and to redistribute resources, political power, and participation toward the lower-income, disadvantaged residents of their cities*".[18] The future post-COVID city calls for a new paradigm of sustainable cities, such as that embodied in the concept of the '15 minute city' which provides a framework for fundamental city redesign and the chance to overcome path-dependent development, and *undesirable* forms of resilience.[19]
- Recognise the creativity of the private sector, and the ability of the private sector as autonomous change agent.
- Recognise the capacity of civil society to act as grassroots innovation.[20],[21]

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3.6. Subgroup 5: policy and governance

Over the past five years, calls from the scientific community for urgent action on the twin challenges of climate and biodiversity have grown in strength and urgency. In response, there has been a significant increase in the ambitions expressed by most governments, including the UK, most notably with the growth of commitments to deliver 'net zero' carbon emissions by 2050 and to reverse the decline in biodiversity. The policy and governance challenges of reaching these ambitions are complex. Here we suggest four key points that the UK government needs to consider if they wish to realise this ambition at the national scale whilst driving ambition forward internationally.

Governing for net zero inevitably raises the challenge of how to manage and change demand for high carbon goods and services (e.g. steel, meat, airborne mobility). Approaches which have in the past sought to govern demand as a matter of individual choice are unlikely to be sufficient when seeking to shift complex social practices that are shaped by systems of production and consumption and cultural/social norms.

Many actors will need to be involved in the pursuit of net zero. However, not all of whom see it as in their best interests to do so. For example, the Climate Change Committee note that significant changes are needed in how we use land, but patterns of UK land ownership means there are often powerful interests who have not yet come to embrace their responsibilities for a low carbon transition. There will inevitably be trade-offs and conflicts between actors/economic sectors who will gain from transitions and those who will lose. A robust and strategic approach centred on the idea a 'just transition' and how and by whom it should be managed is needed to manage these conflicts and overcome opposition.

It is critical to remember that such interests are not fixed and may be particularly in flux in the wake of COVID-19. Property owners in central urban districts whose commercial tenants are no longer seeking to renew contracts may be interested in new opportunities to provide housing, which could enable the provision of highly energy efficiency homes while reducing land-take at the urban fringe, and provide employment in renovating these buildings. The value of urban green space has been newly recognised such that new initiatives could be developed. Critically, consumption of coal has declined, suggesting that there is a window of opportunity to accelerate the phase out of this fossil fuel.

Levels of ambition at the global level are likely to be affected by this shifting landscape of interests regarding fossil fuels and the possibility of achieving net zero targets. Globally, various dynamics – the US election, Brazilian recalcitrance, China's declaration of a 60% target – are important contexts for understanding the impact of choices made regarding the COVID-19 crisis. How different states decide between retrenching fossil fuel economies or engaging in green recovery programmes that seriously tackle decarbonisation in the face of the deep recession emerging from COVID-19 is likely to shape renewal of commitments for the Paris Agreement and beyond.

3.7. Subgroup 6: climate change context

Despite the significant direct impact that COVID-19 has had on the global economy, most notably in terms of the reduction in the use of coal across different national contexts and the decrease in both air and car transport during the height of restrictions, the long-term effect on climate change of the pandemic will be shaped by how governments decide to respond to the crisis. COVID-19 sharpens the focus on a choice between a 'green recovery' that accelerates the pursuit of net zero emissions, and a 'high carbon protectionism', that seeks to protect existing high carbon economic sectors and activities.

There is much talk of a Green Deal as a means of 'building back better' – significant investment being placed in green deals in various parts of the world. But it will matter what this looks like, whether it is largely window dressing or a serious attempt to decarbonise the economy. This will depend on whether such green deals are led by initiatives on *infrastructure* and *investment,* on *consumption*, or on *employment.* The first will tend to lock in considerable amounts of fossil-intensive materials even if it might enable broader low-carbon transformations in some contexts. The second would depend in part on the types of consumption being stimulated but could generally hamper transitions focused for example on housing, meat consumption or other high carbon activities. The third, however, focused for example on repair, renovation, insulation, small scale infrastructures for electric charging, tree planting, or peat restoration, could have significant benefits for both economic recovery and decarbonisation without significant up-front high carbon costs.

An alternative scenario however entails the entrenchment of the fossil fuel sector. Some of these (manufacturing, coal, airlines) have been hit hard by the pandemic and the lockdown and have been proposed for significant policy support. Threats to these sectors could lead to significant unemployment which will be regionally highly concentrated. Simple efforts to revive these sectors will work heavily against achieving net zero emissions. While COVID-19 therefore creates significant potential to transform these sectors, principles of just transition become particularly important both to compensate workers for losses and to protect the transition from political backlash.

The success of any initiative in the UK will depend upon the availability of finance in a number of contexts, notably: finance within the United Nations Framework Convention on Climate Change/Convention on Biological Diversity; finance within the development banks for green transition; finance within the private investment communities; and finance within corporations themselves. While the COVID-19 crisis has meant that a huge amount of public finance has been made available to pursue short-term economic stabilisation, this may come at the risk of longer-term financial retrenchment that might undermine the pursuit of net zero and reversing biodiversity loss.

Annex 1: List of participants and contributors

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Annex 2: List of ARIs considered by this group

1. Capturing and maintaining sustainable changes to travel behaviour, including locking-in good practice
2. How will public attitudes be affected? Are individuals, cities or communities motivated by the drop in emission levels resulting from reduced travel? Are they more/less fearful of ambitious decision making to protect the climate? What opportunities does this present in the UK?
3. Future of travel in terms of systems and choices, reflecting decarbonisation goals, reduced aviation opportunities and changing working practices
4. Charging infrastructure – understand the requirements for Electric Vehicle charging, and how effective the policies are to support this, including the Electric Vehicle Homecharge Scheme, the Workplace Charge Scheme, and the On-street Residential Scheme.
5. Scope for digital platforms to support commercial activity
6. What are the benefits of investment in innovative technologies such as AI, automation and decarbonisation, and how best can we unlock these benefits? What role does international collaboration have to play?
7. Changes to housing stock to support lower-carbon future
8. How to encourage the uptake of smart construction and support the use of robotic, off-site, and modular construction
9. Supporting regional diversity and industrial growth while contributing to net-zero
10. How can we best stimulate/maximise the green jobs market to combine economic recovery with a green and just transition?
11. Role of investment in emerging technologies to support economic regeneration
12. How will the economic impact of COVID-19 affect governments' ambitions for climate change targets and biodiversity?
13. What is the impact of COVID-19 on the multilateral and international alignments on climate change consensus?
14. What are the competing pressures, trade-offs and synergies of different land-use in relation to climate change in a post-COVID world?
15. How to protect new low-carbon infrastructure from damages caused by increased climate variability. How can we measure resilience to identify when further action needs to be taken?
16. How can we predict the potential impacts of a changing climate on actions and strategies to mitigate climate change (e.g. how will future climate change impact the delivery of carbons sequestration by different habitats)? What tools are available to allow for effective planning of climate change mitigation strategies that are resilient to a changing climate?
17. What are the positive and negative environmental impacts of increasing renewable energy production (wind, solar, geothermal, etc.) and other actions taken to decarbonise the economy

Annex 3: Evidence and resources relevant to ARIs

ARI	Resource	Key Messages
ARI 8: Changes to housing stock to support lower-carbon future	Holmes, G., Hay, R., Davies, E., Hill, J., Barrett, J., Style, D., & Vause, E. (2019). UK Housing: Fit for the Future? ***Committee on Climate Change***.	Houses in the UK are not fit for the future and attempts at adapting UK housing stock to fit the challenges of climate change have not been very effective. The government needs to address this with several interventions (e.g. designing and building new homes, retrofitting existing ones and ensuring performance and compliance). House holders can effect changes too (e.g. by increasing insulation, installing shading and boiler upgrades). ***The message here is that there is often much more UK government has to do to decarbonise its housing stock. While enforcing new measures for new builds, the real opportunity lies in decarbonising existing stocks that are neither fit for the present and the future. Strategies and policies must realise that the government cannot go it alone, efforts must be made to bring in all stakeholders, particularly homeowners using command and control instruments together with economic incentives***.
ARI 8: Changes to housing stock to support lower-carbon future	Patterson, J. L. (2016). Evaluation of a regional retrofit programme to upgrade existing housing stock to reduce carbon emissions, fuel poverty and support the local supply chain. ***Sustainability, 8(12), 1261.***	This study evaluated the Welsh Government's £9.6 million regional scale housing retrofit programme to reduce fuel poverty, carbon emissions and support energy efficiency and renewable energy supply chain. It reaffirmed government retrofitting strategy as affording huge opportunity reducing housing energy demand, cutting carbon emissions, and enhance energy efficiency. To achieve its goal, a suggestion that while legislation is necessary policy instrument to drive lower-carbon housing, it needs to be complimented with other policy instruments throughout the built environment sector. Measures to cut energy demands, enhance energy efficiency, reduce carbon emissions, facilitate employment and training are critical to the overall success of the strategy implemented.

		The message here is that it will require a combination of strategies, policy instruments, and commitment to decarbonise UK housing stocks.
ARI 8: Changes to housing stock to support lower-carbon future	Rosenow, J., Guertler, P., Sorrell, S., & Eyre, N. (2018). The remaining potential for energy savings in UK households. ***Energy Policy, 121, 542-552.***	***The message here is that upgrading or retrofitting existing housing stocks to sustainable standards presents the UK with huge opportunities to achieve significant reductions in building energy consumption, hence reductions in carbon emissions***.
ARI 8: Changes to housing stock to support lower-carbon future	Jan Rosenow, Tina Fawcett, Nick Eyre & Vlasis Oikonomou (2016) Energy efficiency and the policy mix***, Building Research & Information, 44:5-6, 562-574,*** DOI:10.1080/09613218.2016.1138803	Energy efficiency policy is expected to play a key role in helping to reduce energy demands and attended CO_2 emissions. The experience of 14 European Union countries revealed this to be the case. Energy consumption and CO_2 emissions reductions are unlikely to effectively succeed using single policy instruments. ***The message here is that effectiveness is likely to come through combinations of policy mixes targeted at different scenarios. In other words, success is unlikely with a one-fit-all policies. The challenge is finding how these policies combine and under which scenarios they are most effective. This is particularly the case with financial incentives under different under different scenarios.***
ARI 8: Changes to housing stock to support lower-carbon future	Gillich, A, Sunikka-Blank, M., Ford, A. (2016), Lessons for the UK Green Deal from the US BBNP. ***Journal of Building Research and Information.http://www.tandfonline.com/doi/abs/10.1080/09613218.2016.1159500?journalCode=rbri20***	The message here is that no matter how good a policy may be, poor implementation can lead to the ultimate failures of policies. In comparing the performance of the US Better Buildings Neighbourhood Program (BBNP) with the Green Deal in the UK, BBNP was found to be relatively more successful than the Green Deal in converting energy assessments to actual retrofits, and this was attributed to policy implementation. The UK Green Deal could have benefitted from proactive marketing and outreach, there was no sufficient engagement with the workforce and neither was there concerted effort to develop the technical and non-technical skills and competences necessary to actualise the

		programme and render the policies implementable. ***The key message here is that it is not sufficient to formulate policies, what it will take in capacity to implement must also be ascertained***.
ARI 8: Changes to housing stock to support lower-carbon future	Arif, M, Gillich, A, Ford, A and Wang, Y (2018). Overcoming Practical Challenges and Implementing Low-Carbon Heat in the UK: Lessons from the Balanced Energy Network (BEN) at LSBU. ***CIBSE Technical Symposium.*** **London 12 - 13 Apr 2018**.	The commitment to decarbonise UK heating energy by 2050, highlights the need for efficient electric heating and wider adoption of heat networks. While the possibility of low-carbon heat has always been conceptualised at a theoretical level, creating a gap in knowledge, understanding the challenges to implementation, particularly for existing stock is necessary prerequisite to effective decarbonisation of UK housing stock. Electrified heat can be integrated into existing building distribution systems and Balanced Energy Network BEN system demonstrates how the practical challenges to achieving retrofit low carbon heat to existing building distribution systems can be achieved. ***The message here, once again, is that the requirements to implement policies must be articulated during the time of policy implementation, this is seen as critical in driving a lower-carbon housing stock in the UK.***
ARI 8: Changes to housing stock to support lower-carbon future	Mirzania, P, Andrews, D, Ford, A and Maidment, G (2019). The Impact of Policy Changes: The Opportunities of Community Renewable Energy Projects in the UK and the Barriers they Face. ***Energy Policy.*** **129, pp. 1282-1296**	UK's energy system is majorly centralised and reliant on fossil fuels. The dilemma of successfully delivering energy security, equity, and environmental sustainability, whilst dealing with an ageing energy infrastructure, demands an overhaul of the entire energy system in the UK. In recent years, Community Renewable Energy (CRE) projects have played a significant role in the transition of the UK's energy system, but since 2016 government support for them has been less robust. The message from this study is that certainty and policy stability, particularly government policies is critical to creating the enabling environment for support and successful implementation of policies such as the Community Renewable Energy project. In other words, longer term rather than shorter term policies are critical to driving initiatives such as CRE. The decision by majority of CRE organisations to focus on managing their existing assets rather than expand on their assets is a

		testament to the fall outs of government not following through with its policy. ***For the future, lessons from past initiatives must be learnt and challenges likely to be faced by those venturing into projects such as CRE must be articulated.***
ARI 8: Changes to housing stock to support lower-carbon future	Kaluarachchi, Y. and Jones, K (2013). Promoting low-carbon home adaptations and behavioural change in the older community. ***Architectural Engineering and Design Management. 10 (1-2), pp. 131-145.***	Ambitious target to cut the UK's carbon emissions by 80% by year 2050 exist, to meet this target, action is needed in the residential sector with 27% of the UK's CO_2 emissions coming from energy use in homes. While working towards zero carbon new homes, refurbishment of the existing housing stock to advanced, low-carbon standards is essential. The involvement of all stakeholders and behavioural change of occupants to low carbon lifestyles are necessary. Findings of an EPSRC Public Engagement project (2009-2010) carried out to promote low carbon home adaptations and behaviour change among the elderly. Findings show that promotion exercise of this nature can be very effective in the number of the elderly who have made changes in their lives since attending the events, and others planning to change, or have encouraged someone else they know to make a change in their lives to be more sustainable. ***The key message here is the need to promote policies to groups or sectors that are the target of implemented policies.***
ARI 8: Changes to housing stock to support lower-carbon future	Urge-Vorsatz, D., Eyre, N., et. al. (2012). Towards Sustainable Energy End Use: Buildings, ***in Global Energy Assessment. Chapter 10 in, Global Energy Assessment: Toward a Sustainable Future. Cambridge University Press, Cambridge. 1888***	Buildings and attendant activities account for about 31% of global final energy demand and about one-third of energy-related CO_2 emissions and other pollutants. Efficient energy and energy efficient materials are critical to environmental sustainability. Technological and process innovations coming through have demonstratively resulted in reduced building energy consumption and CO_2 emissions in existing housing stock and also new builds. Huge scope exists to further enhance efficiency in building energy use through on-site and community-scale renewable energy strategy hence zero-greenhouse gas emissions can be achieved. ***The message here is that technological and process innovation affords huge opportunity to decouple the building industry and energy***

	pp. ISBN: 9781107005198.	***consumption intensity, hence green-house gas emissions. The key message here is that while several policy instruments may be available, they need to be tailored or adapted to specificities or socio-economic and political realities of the country.***
ARI 8: Changes to housing stock to support lower-carbon future	Janda, K.B., Killip, G. and Fawcett, T. (2014) Reducing Carbon from the "Middle-Out": The Role of Builders in Domestic Refurbishment. ***Buildings, 4(4): 911-936.***	This study explored how builders respond to low-carbon housing refurbishment in both UK and France with the focus on how building expertise in low-carbon housing refurbishment is manifesting. While the two countries were found to have comparable long-term CO2 emissions reduction strategy on the one hand, and on the other, they both have decided to drive CO2 emissions through retrofitting or refurbishment. The building trade is comprised of general to specialist builders, each with different capacity to effect change and bring about low-carbon housing stock. The significance of this is in showing that top-down and bottom-up intermediaries should not be the only change actors to be the focus of policy. Building professionals are categorised as "middle actors" while policy makers are seen as "top down" actors, and homeowners and clients are seen as bottom-up change actors. While policy drive often concentrate on "top down" and "bottom up" actors to effect desired policy outcome, professionals are seen as having the capacity not only to mediate or effect change upwards, downward, and sideways along low-carbon retrofit supply chain. While in the UK, low-carbon retrofits were targeted at housing associations and those on low-income or receiving income support, those on income transfers, attracting non-professional building trade, the was different in France hence the involvement of building professionals and technological and process innovations attracted to the sector. It was found that the retrofit housing supply chain experience change effects from all directions, and the middle actors had the most accelerating effects. Rather than displace other change actors, the recommendation is for a mediating platform to be created. ***The message is that all stakeholders have a role to play in the lower-carbon housing strategy drive. This is particularly the case with building professionals who has the capacity to effect both technological and process innovations and deliver quality at all***

		***levels output, including physical work, design, and communication into policy*.**
ARI 8: Changes to housing stock to support lower-carbon future	NFB (2019). Transforming Construction for a Low Carbon Future. ***https://www.builders.org.uk/documents/transforming-construction-for-a-low-carbon-future/***	Construction, however, has a greater role than most other sectors of the economy to play in reducing building energy consumption and Carbon emissions. The industry accounts for 10% of total UK carbon emissions and directly impacts 47% of all national emissions. The sector critical to UK government carbon reduction efforts, which justifies the particular focus it is receiving from policy makers. This study focuses on 'main contractors' as essential gatekeepers to a low-carbon future. Main contractors are seen as change drivers and when in partnership with the supply chain and their forward-thinking clients, they are best placed to affect the transition to a lower-carbon future a reality. The UK government reportedly spend £15 billion yearly on domestic housing sector and £5 - £10 billion on industrial and commercial sectors annually. ***The message here is that the UK government has tremendous powers to leverage lower-carbon housing stock and must not hesitate to use existing measures such as the certification scheme to effects, and at the same time, take proactive action to develop tools for accurate measure of carbon use to enable companies understand their carbon footprints and adopt carbon reduction measures.***
ARI 8: Changes to housing stock to support lower-carbon future	Currie & Brown (2018). Cost of carbon reduction in new buildings.***https://www.cse.org.uk/downloads/file/cost-of-carbon-reduction-in-new-buildings.pdf***	UK has a legal commitment to reduce carbon emissions by 80% by 2050. Different options explored in new housing and non-domestic buildings together with associated costs and other factors relevant to the development of local planning policies. However, emphasis was placed on policy options that are specific and reflective of local priorities, viable as well as other considerations such as capacity to implement and deliver projects to policy. Attention to cost information as well as other relevant policy considerations must are critical to policy effectiveness in delivering carbon savings whilst protecting housing supply and reducing costs to household. Costs of scenarios involving a variety of policy options were considered looking at minimum levels of energy efficiency, onsite carbon savings

		and then the achievement of net zero carbon standards considering regulated energy or both regulated and unregulated energy. Results suggests that for an additional capital costs of 5-7%, it is possible to achieve a net zero regulated carbon emissions from a combination of energy efficiency and on-site carbon reductions. ***Key message here is that it is feasible to reduce energy demands and cut carbon emissions by decarbonising existing housing stocks using strategies and policies specific and reflective of local priorities. Policies must be well costed under different scenarios and informed by local peculiarities.***
ARI 9: How to encourage the uptake of smart construction and support the use of robotic, off-site, and modular construction	Woodhead, R., Stephenson, P., & Morrey, D. (2018). Digital construction: From point solutions to IoT ecosystem. Automation in Construction, 93, 35-46.	The construction industry is in a transformational stage brought about by the emergence of disruptive technology and innovation.UK construction companies are not engaging with the transition with the speed witnessed in other advanced and emerging economies. The UK construction industry must appreciate the current transformational process brought about by disruptive technologies and stand the risks of becoming uncompetitive nationally and internationally. A stronger drive for Research and Development is advocated but a collaborative research is needed to understand the combination of policy-mix that will incentivise and encourage the uptake of smart innovative technologies as well as processes for efficient delivery of quality and sustainable built assets. ***Key message here is that it is feasible to reduce energy demands and cut carbon emissions by decarbonising existing housing stocks using strategies and policies specific and reflective of local priorities. Policies must be well costed under different scenarios and informed by local peculiarities.***
ARI 9: How to encourage the uptake of smart construction and support the use of robotic, off-site, and modular construction	Kivimaa, P., Hyysalo, S., Boon, W., Klerkx, L., Martiskainen, M., & Schot, J. (2019). Passing the baton: How intermediaries advance	Intermediary actors (e.g. innovation funders, energy agencies, NGOs, membership organisations, or internet discussion forums) operate at many levels to advance transitions. Integrating existing conceptual models on transition dynamics and phases and a typology of transition intermediaries to examine how intermediaries advance transitions in different phases, intermediary actors were found to be critical from predevelopment to stabilisation

	sustainability transitions in different phases. *Environmental Innovation and Societal Transitions, 31*, 110-125.	stage of transition. This was found to be particularly relevant to encouraging transition to heat pumps and low-energy housing. Intermediary functions change at various levels of transitions from “supporting experimentation and articulation of needs in predevelopment, to the aggregation of knowledge, pooling resources, network building and stronger institutional support and capacity building in acceleration”. ***The message here is that encouraging transition, as being expected of UK construction industry to transit to sustainability do involve many intermediary actors and several stages of the transition process. This requires a holistic support and structures in place for delivering the support.***
ARI 9: How to encourage the uptake of smart construction and support the use of robotic, off-site, and modular construction	Housing, Communities and Local Government Committee, (24 June 2019) Modern methods of construction, HC 1831 2017–19.	The UK lacks adequate homes and meeting the government target necessitates using Modern Methods of Construction (MMC) in addition to the traditional methods of housing delivery. This involves innovating smart technologies and processes such digitalising designs, 3D printing, IoT as well as onsite construction processes thereby delivering faster and smarter housing and other infrastructure and services. The role of the government in speeding uptake of new technological innovation is clearly articulated. While new strategies and policies are necessary, there is scope within existing measures in currently in place move house building firms to embrace MMC, and these include the Home Builders’ Fund; partnering with lenders, valuers, and developers to ensure mortgages are available for MMC buildings. ***The message here is that what it will take to effective move housing building firms to adopting prevailing technological and process innovations transcends the conventional form of support. All construction stakeholders must play their roles, including professional bodies as well as financial institutions to facilitate the market for MMC homes.***
ARI 9: How to encourage the uptake of smart construction and	Fifeld, L. J., (2018). Hospital wards and off-site modular	Modula construction are off-site manufactured and assembled on site, affording opportunities for purposed design and built incorporating several energy demand reductions. A modular

support the use of robotic, off-site, and modular construction	construction: Summertime overheating and energy efficiency. ***Building and Environment, 141, pp. 28-44.***	thermally lightweight, well insulated, naturally ventilated hospital building was constructed and found to consume 31% less energy and 21% less CO_2 emissions respectively. However, some risks were identified, and these relates to overheating risks in relatively cool summer months. The recommendation was that the overheating risks should be resolved before wider adoption in other hospital schemes. ***The message here is that modern methods of constructions can deliver reduced energy and CO_2 emissions but there are other sustainability attributes that should be actively sort, including thermal comfort and wellbeing.***
ARI 9: How to encourage the uptake of smart construction and support the use of robotic, off-site, and modular construction	Piroozfar et al. (2012). Design for sustainability: A comparative study of a customized modern method of construction versus conventional methods of construction. ***Architectural Engineering and Design Management, Volume 8, Number 1, 2012, pp. 55-75(21)***	Investigation of an offsite construction method offering customization against its conventional counterpart in a fairly controlled context using two educational buildings with customization strategy. The data was collected, collated, and analysed, and the environmental impact of two buildings was measured using two different open-source applications. The result shows that despite the higher standards required by law, which in return increases the environmental impacts, the new school building performed significantly better with a slightly lower environmental impact compared to conventional buildings. ***The message here is that even with conventional methods of construction, buildings consciously designed to sustainability attributes, irrespective of standards will out-perform conventional buildings in terms of natural resource consumption intensity and wider environmental impacts. Sustainable construction is a necessity in delivering low-carbon housing.***
ARI 9: How to encourage the uptake of smart construction and support the use of robotic, off-site, and modular construction	Mantesi E, Hopfe C, Konstantinos M, Glass J, Cook M. (201). Empirical and Computational Evidence for Thermal Mass Assessment: The Example of	Insulated Concrete Formwork (ICF) is a site-based Modern Method of Construction (MMC). As an MMC, ICF has several advantages: increased speed of construction, cost and defect reduction, safety, among others. Moreover, the ICF wall construction method has similar benefits to any other heavyweight structure (such as strength, durability, noise attenuation). However, its thermal performance is not yet well-researched and understood. Using

	Insulating Concrete Formwork. ***Energy and Buildings 188-189 DOI: 10.1016/j.enbuild.2019.02.021***	computational analysis and empirical evaluation, the thermal performance of an existing ICF building and develop evidence about its transient thermal behaviour. The results demonstrate that the ICF fabric showed a slow response to changes in boundary conditions, providing a stable internal environment. The concrete core of ICF was found to act as a buffer to the heat flow, reducing transmission losses by 37% in contrast to a lightweight wall of equivalent insulation. This demonstrates environmental attributes inherent in MMC regarding its energy saving and carbon emissions reduction. ***The message here is that innovative modern methods of construction delivers more than the inherent direct sustainability qualities, the product quality elements ensure minimum wastes as incidents of defects are reduced to avoid huge post-construction correctional expenditure.***
ARI 9: How to encourage the uptake of smart construction and support the use of robotic, off-site, and modular construction	Mosca L, Jones K, Davies AC, Whyte J, Glass J. (2020). Platform Thinking for Construction. ***Transforming Construction Network Plus Digests – Series 2. Publisher URL: http://bit.ly/Platform-Thinking-for-Construction***	This offers clarification on the ongoing conversation around platform thinking in construction and reveals the benefits of adopting a platform as a strategy for driving technological and process innovations in the construction industry. The need for a platform to host '***… a digital process where a designer seeks to provide an optimum functional and aesthetic solution whilst being cognizant of and […]adhering to the rule set of an appropriate construction platform***' – is considered a necessary prerequisite for driving innovation in the construction industry. However, creating an appropriate platform is critical, as variations of platforms exist between, organisations, product, ecosystems, and market intermediary platforms. Suggestion was that a 'Platform Approach to Design for Manufacture and Assembly (P-DfMA)' be created to promote and embed MMC in UK construction. ***The message is that a platform of some form where likeminded individuals and businesses can interact and exchange ideas is essential for incubating and sustaining transition of the kind we are suggesting here where all stakeholders in MMC can effectively interact and exchange good practice.***
ARI 9: How to encourage the	Oti-Sarpong, K., (2019). Offsite	Digitally enabled construction industry affords huge opportunities for national and international

uptake of smart construction and support the use of robotic, off-site, and modular construction	manufacturing, construction, and digitalisation in the UK construction industry – state of the nation report. ***Cambridge Centre for Housing & Planning Research.*** ***https://pdfs.semanticscholar.org/43b2/bb6b983a639fe43d5a01132b3951090c1dd8.pdf***	growth, and this will enable market advantages. Despite the obvious benefits, the uptake of digital technologies and modern methods of construction such as offsite manufacturing (OSM), remains low. Several factors are held to account for this, including the state of the economy, market dynamics, lack of business case, unclear policies, lack of incentives, non-adaptive regulatory frameworks, poor demand, organisational inertia, lack of capabilities and socio-cultural interpretations of value explain low uptake of MMC. The conclusion is that for MMC or OSM to take off in UK construction, the identified factors must be addressed. ***The message here is that it will take a concerted effort to encourage uptake of new and innovative technology by UK construction firms despite the obvious benefits of doing so. Market conditions and demands for MMC housing coupled with incentives and cultural shifts for this to happen***.

Annex 4: Key messages submitted from each subgroup

Subgroup 1: transport

No submission.

Subgroup 2: emerging technologies

Introduction

Shifting to lower carbon economies requires step changes in the way existing technology is both supported within infrastructure and accessed by end users. For example, the shift from large, centralised carbon-centric power generation (coal/gas) to more decentralised local power networks (solar / wind) requires greater knowledge of local demand and generation as well as determining future needs. Emerging technology has a pivotal role to play in this move to lower carbon economies for both power supply and generation along with the technologies that consume it.

This document aims to give an overview of some of these emerging technologies alongside examples of work that are being applied to deliver lower carbon economies. Toward the end the Royal Society Digital Technology and the Plant project finds are summarised with respect to emerging technologies and reducing carbon. Two platforms are introduced: Data & Analytics Facility for National Infrastructure (DAFNI) as a UK leading project linking emerging technologies to improve the performance and carbon use within national critical infrastructure but also to support infrastructure analysis in the form of sector digital twins investigating and understanding the impacts of policy decisions; the Example Natural Capital Valuation (NEVO) tool. The document concludes with a benefits summary of emerging technology.

Emerging technologies

In order to scope this document, it is important to capture what are emerging technologies. Looking at the Gartner Hype Cycle from 2019 a first step at identifying some scope of the technologies can be done.

With reference to the hype curve categories (which often overlap) of emerging technology can be identified. The first of these can be seen as Artificial Intelligence related technologies, Sensor Technologies, Edge Processing, Advanced Computing Platforms, Visualisation and Simulation, Trustless / Decentralised and Convergence Applications such as the driverless car (sensors, AI). In combination, these provide a Cyber-Physical system, combining physical systems monitoring and intervention with large-scale intelligent computing.

Artificial intelligence

The domain of Artificial intelligence is wide ranging incorporating (for example) areas of language automation under the domain of Natural Language Processing (NLP) to automation of data analysis using Machine Learning Models. Techniques and methods within the area of AI can be combined into data processing pipelines harnessing different elements of the technology.

Central to the attraction of AI is the ability to both automate and also identify new knowledge and value from data resources with the help of machines. Automation and the utilisation of this knowledge has significant potential to reduce the amount of carbon currently used in the economy by better co-ordination of resources.
A significant concern regarding the adoption of AI is the role of the human. Threats to jobs, privacy and also in some cases safety of AI automation is a significant concern to the research and industrial community in the AI domain. These issues have to be addressed in a way the future economy can benefit by the use of AI and automate in a way new jobs and processes are created that improve people's lives and the environment.

The recent acceleration in the use of data science techniques in the environmental sciences demonstrates the enormous potential to support complex system science and to better understand our natural environment. For example, data on the environment is often spatially sparse, and at a resolution that is not immediately useful for decision makers. AI and data science can be used to fill in the data gaps, bring in new information from other sources, and produce a higher resolution picture of the environment. Examples of this approach include the use of Machine Learning to predict PM2.5 levels hours in advance, using public historical data on air pollution in Beijing to train and test the algorithms and to also utilize this information for carbon credit trading. Such an approach makes use of advanced technology in wireless sensor system, IoT, intelligent multi-sensor fusion, and AI solutions for big data processing. Similarly, the World Resources Institute and Microsoft's 'AI for Earth' programme are working collaboratively to use aerosol optical depth information from satellites to improve local air quality forecasting in Sao Paulo. Within India, Deep Neural Networks have been employed for predicting the occurrence of flood based on temperature and rainfall intensity.

Sensing technology

The rapid growth of the Internet of Things (IoT) bringing concepts such as the Smart City to general discourse has relied on the rapid expansion of cheap sensor technology and improved connectivity utilising 4G and 5G networks. Outside of cities sensors from personal health devices to improved imaging technology on satellites have produced significant amounts of quality data that can be processed.

With respect to carbon reduction this data often relates to activity of a device, person, or current state of the natural environment i.e. air pollution. Utilising this data within cities to improve traffic flow to reduce carbon and pollution or in agriculture to examine the impact of climate on African crops has the potential to better inform planners and policy makers.

Edge processing

IoT consists not only of sensors but increasingly powerful computing capabilities located on the same board as the sensor. This innovation is increasing the possibility of edge processing of data. This enables complex decisions and calculations to be made at the point at which the data is sensed.

Edge capability prevents large volumes of data being transferred across networks and processed at central storage points and can reduce the carbon footprint of traditional data sensors. It also has the capability to bring greater levels or automation and response to critical national infrastructure to reduce energy wastage and save carbon.

A good example here is the use of Edge Processing on pipelines. Gas, Oil and Water pipelines traditionally are monitored in relation to output and pressure at certain points. Leaks are often hard to pinpoint and can lead to significant loss of resource. Using edge sensing within the pipelines research and commercial organisations have demonstrated how this waste of resources can be reduced by the edge devices detecting and processing data at source to identify more exactly where leaks have occurred.

The combination of Edge processing with cloud services provides a powerful infrastructure for monitoring and intervening in the carbon economy, combining rapid local action with the wider range available for cloud services combing large data source. Using edge devices also encourages the active participation of the citizen, to contribute and react with their own behaviour; in such systems, user value and sensitivity needs to be designed in. Effective and equitable architectures for combining these need to be further explored.

Advanced computing platforms/visualisation

Advances in computing power lead to the ability to process data on more local devices and reduce the need for centralised energy intensive data centres to reduce their carbon footprint. Centralised points of data processing are able to handle more data and processing better utilising energy that is used.

Quantum Computing looks to offer a significant step change in the way data is processed in the future. Current computing infrastructures are either too costly to solve complex but low value routing problems or in some cases these problems are beyond the capacity of computing.

For example, the management of logistics within and organisation such as Ocado has the possibility to optimise the routing of logistics to better utilise the energy used https://www.hartree.stfc.ac.uk/Pages/Quantum-Simulation-capabilities.aspx. In the future using such advanced platforms and communication infrastructure such as 5G such advanced routing capacity will expand to the co-ordination and management of networks of traffic via vehicle to vehicle communication.

Visualisation and simulation

With respect to visualisation the domains of Augmented Reality and Virtual Reality combined with modelling and simulation enabled by materials analysis using High Performance Computing has the ability to change the design process. For example, new materials for photo-voltaics or batteries can be proposed by using machine learning to propose candidates from properties and tested and deployed into designs virtually and tested using simulations. This can reduce time to market, reduce the need for physical testing to enable quicker adoption of low carbon technologies and also reduction in them during development.

Decentralised and converged applications

Decentralised applications embrace technology enabled by Blockchain to build trustless value ecosystems. These are important in the domain of automation for the movement of goods and services between entities with no prior relationship. For example, the automated negotiation between parties to pool resources such as energy within a local power supply network. Working with Siemens the Hartree Centre used Blockchain to automatically trade energy between neighbour's solar panels according to demand logging use and negotiating the best price.

Thus, decentralised technology is needed to build smaller networks of value that can reduce the need for extra centralised resources. Other examples of autonomous networks can be seen within emerging driverless cars where they have the ability to sense and negotiate with each other over space. Using automated transport has the potential to revolutionise the way people move around. This can therefore reduce the amount of carbon used in one-person car journeys to underutilisation of buses.

Drones also can merge technology such as AI image recognition with sensor technology. A common use of drones can be within agriculture to inspect areas of land to complex buildings inspection. This technology saves human and machine resource, helps optimise business operations and reduces carbon.

Digital twins

An approach which combines the above in a combined cyber-physical system is Digital Twinning. The Digital Twin design process is currently being deployed in a wide range of domains from automotive design to Buildings Information Management. The DAFNI project is good example of such an approach and how it can be used to better plan and maintain critical infrastructure reducing carbon by better design and management (see next section).

For research councils such as NERC the use of Digital Twinning is a key focus with respect to direct environmental applications. NERC have identified that the approach could be focused on heavily instrumented sites like the Thwaites Glacier, or for optimising the performance of large infrastructure (for example, a digital twin of the Attenborough research vessel).

Royal Society, Digital Technology, and the Planet project

On 14 July 2020, the Society convened a workshop to gather evidence, as part of the Digital Technology and the Planet project, exploring the uses of data and digital technology for climate science and monitoring. This included the development of a roadmap for data infrastructures for net zero. Some of the key findings that emerged included:

- **Support more effective use of existing data:** There already exists datasets that could be repurposed, and made more accessible, to enable more effective carbon monitoring. Public institutions such as schools and universities could release data about the emissions they generate as a means of demonstrating best practice in data collection and use. There are also opportunities to expand resources that catalogue datasets, such as Resource Watch from the World Resources Institute, which helps researchers identify, utilise, and understand the origins of data in an accessible manner. Data from smart meters in particular could be made more accessible for the analysis of trends in household energy consumption. Making data open is not always appropriate, whether for data protection or commercial concerns. In some cases, such concerns might be ameliorated through careful consideration of the level of disaggregation applied to the data. Where data cannot be made open, access mechanisms such as data licensing could help expand its use, avoiding research teams having to build their own pipeline for data access. In the case of satellite data, there is currently no legal framework and increasingly satellites are being launched by commercial companies or by NGOs, with different implications for data access. A protocol or roadmap for data solutions for net zero would be needed to clarify how existing data could be made more accessible, and to set out next steps.
- **Characterise the need for further data:** There are areas where further data collection could help develop new reporting systems. For example, there is already some data available about transport mobility trends that can be useful in calculating emissions, but such analyses would benefit from more frequent releases. Efforts to create new datasets are not, however, without cost, creating trade-offs in data collection strategies. The need to collect and store data for net zero must be balanced with the need to limit the emissions generated in the process.
- **Combine multiple sources of data:** Combining data from multiple sources can create insights that can inform our understanding of emissions from different

sources. For example, satellite data can help measure point emissions from sources such as power plants. If combined with data from on-the-ground measurements, analysis of such point emissions could be made more accurate. There might be a role for crowdsourcing the generation of useful data about emissions, but there are substantial issues with the consistency of reporting of individual activity data. For example, in the UK there is a crowdsourcing model for energy consumption where people provide energy meter readings – but this is now being replaced with data emitted directly by smart meters, considered more reliable. There is a role for events such as hackathons in crowdsourcing data mining and helping uncover a breadth of useful data sources. Patterns of data collection also seem likely to change in future, for example it is possible to imagine a world where each building would broadcast its emissions.

- **Build capacity in existing data infrastructures:** The UK has already established several high-quality data repositories. The Met Office Informatics Lab, for example, plays a role in calibrating data and in the coordination of agreements around the sharing of weather data, at both a national and an international level. These resources enable accurate weather forecasting across the globe, which is critical for example to improve the response to extreme weather events. Similarly, the JASMIN facility provides the UK and European climate and earth-system science communities with an efficient data analysis environment, provides new ways for scientists to collaborate in self-managing group workspaces, enabling models and algorithms to be evaluated alongside curated archive data, and for data to be shared and evaluated before being deposited in the permanent archive.

Incentives to develop computing as infrastructure for net zero

In considering incentives to develop computing as infrastructure for net zero, participants in the Royal Society workshop outlined the following:

- Different types of data come with different types of rights and responsibilities. In considering data use, different companies, communities, and individuals might have different priorities and concerns, and data access solutions that might be acceptable to one group might not be acceptable to another. Creating widespread buy in and support for the collection and use of data for net zero will require a joint understanding of the shared challenge posed by climate change, as well as clarity about the purpose of data collection and computing for the planet. It will be important to communicate progress with the use of data to achieve the net zero target over time.
- At the national level, the UK's presidency of the COP26 United Nations Framework Convention on Climate Change conference offers the opportunity to direct policy attention towards better use of data for net zero. There is a willingness to explore ways to extract information about systems dynamics to inform policy interventions, towards a green digital economy. The COVID-19 crisis also showed how the resilience of systems such as global supply chains

could be affected by unexpected events, which raised awareness of the importance of using data effectively.

- For many businesses, the value in collecting and making available data on carbon emissions is not clear. Different mechanisms could be used to encourage businesses to publish robust carbon emissions data.
- Central banks and supervisory bodies are pushing for disclosures such as those promoted by the Task Force on Climate-related Financial Disclosure to become mandatory. Annual disclosures could be extended to include more granular data about energy use or to include by default data about Scope 3 emissions. Such data would then be used to assess whether a business's activities are compatible with the 1.5°C target. This would encourage companies to adopt best practice to reduce emissions from their operations, energy use and eventually their supply chains. If the largest companies could be encouraged to monitor supply chain emissions, the need to collect robust data on emissions would then trickle through their supply chains.
- Public-private partnerships might have an important part to play too in supporting new models for creating value from data. For example, the Met Office Informatics Lab and most of the European weather centres act as semi-private organisations, providing weather information for different purposes. Access to standardisation systems or and governance frameworks provided by the public sector could provide an incentive for private organisations to provide data, which they might otherwise be reluctant to share on account of commercial concerns. A lot of organisations currently do not provide data free-of-charge because they see the commercial value in it; this will require a shift in mindset and incentives. CERN may provide an interesting alternative business model where any country can take part and access software and data.
- Large scale investment funds could be incentivised via tax breaks to companies that are active in developing digital systems towards net zero – in R&D, reporting and emission reductions.
- Big tech could make a substantial contribution by investing in the maintenance of complex datasets and making these accessible to all. Google Earth is a good example of free data resource provided by a large tech firm, which is a large pool of satellite data available to everybody – and which can be used for example to analyse the resilience of ecosystems. Making large, complex datasets accessible is particularly needed in the developing world.
- If greater carbon monitoring is to become the norm around the globe, there might be a business case for big tech to develop and deliver robust carbon emissions monitoring and reporting systems, working with corporates and investors…"

References

DAFNI: The Scientific Computing Department at the STFC is building DAFNI (Data and Analytics Facility for National Infrastructure). It is a platform to take models developed in Universities, Government, and Industry: scale these up, provide higher level of resolution or wider coverage and allow integrations with other areas of research pertinent within infrastructure planning. DAFNI is a platform working with a wide range of research groups (12 partner Universities supporting the project). Focus is to take the analysis which looks at infrastructure modelling. DAFNI has a role to play in the development and deployment of Digital Twins for infrastructure systems. DAFNI has capability to store and manage large amounts of disparate data, and to provide a legacy host for models, which can be developed independently, yet brought together into one platform. Thus, DAFNI can provide a hub for a Digital Twin infrastructure, supporting the research and development required to explore the most effective ways in which Digital Twins can be deployed within infrastructure systems. DAFNI would work in conjunction with edge suppliers of sensors and local data, and control systems to the local environments.

Subgroup 3: housing and construction

While enforcing new measures to decarbonise new builds, the mileage is in decarbonising existing housing stock. About 23.4 million UK homes were built before 1980 and over one million of these are currently vacant. Upgrading or retrofitting existing housing stocks to sustainable standards presents the UK with the greatest opportunities to achieve significant reductions in building energy consumption and carbon emissions.

With upgrading and retrofitting, as a decarbonisation strategy, the government should definitely take the lead. However, and given the enormity and scale of the challenge on the one hand, and on the other, the speed with which solutions are sought because of the looming climate catastrophe, the government must demonstrate clearly that it ‘***cannot go it alone’***. Other stake holders active in the housing sector must be engaged and empowered to rapidly engage with the strategy. Other stake holders include Housing Association, Local Authorities, Homeowners, and the third sector have pivotal role to play in achieving lower carbon housing stock in the UK.

For effectiveness, successful decarbonisation of UK housing stock is unlikely to happen using a single one-fit-for-all policy, rather a combination of policy mixes contextualised in local specificities or under different scenarios. How these policies may combine and under which scenario to deliver quality lower-carbon housing must be examined and fed back into policy formulation. In other words, a holistic approach to policy formulation must be entrenched in the system.

Capacity to implement policies must be articulated at the same time policies are being contemplated. The key message here is that it is not sufficient to formulate policies, what it will take in capacity and competence to implement must also be ascertained.

While all stakeholders have a role to play in lower-carbon housing strategy drive, This is particularly the case with building professionals who have the capacity to effect both technological and process innovations and deliver quality at all levels of output, including physical work, design, and who are not just able to communicate policies into deliverables but more so, are able to adapt to policy updates.

The message here is that technological and process innovation affords huge opportunity to decouple the building industry and energy consumption intensity, hence green-house gas emissions. The key message here is that while several policy instruments may be available, they need to be tailored or adapted to specificities or socio-economic and political realities on ground.

The UK government has huge powers to leverage lower-carbon housing stock and should not hesitate to use existing measures such as the certification scheme to effects, and at the same time, take proactive action to develop tools for accurate measure of carbon use to enable companies understand their carbon footprints and adopt carbon reduction measures.

Key message here is that it is feasible to reduce energy demands and cut carbon emissions by decarbonising existing housing stocks using strategies and policies specific and reflective of local priorities. Policies must be well costed under different scenarios and informed by local peculiarities.

How to encourage the uptake of smart construction and support the use of robotic, off-site, and modular construction

The message here is that encouraging transition, as being expected of UK construction industry to transit to sustainability do involve many intermediary actors and several stages of the transition process. This requires a holistic support and structures in place for delivering the support.

The message here is that modern methods of constructions can deliver reduced energy demands and CO_2 emissions, but there are other sustainability attributes that should be actively sort and these include thermal comfort and wellbeing. In other words, buildings with efficient energy use and low-carbon emissions must be checked against other sustainability attributes, a holistic approach to sustainable development.

The message here is that even with conventional methods of construction, buildings consciously designed to sustainability attributes, irrespective of standards will out-perform conventional buildings in terms of intensity of resource use and wider environmental impacts. Sustainable construction is a necessary prerequisite to delivering low-carbon housing.

The message here is that innovative modern methods of construction is efficient and eliminates wastes in resource use as well as saving on time leading to project delivery on time and cost.

The message is that a platform of some form, where likeminded individuals and businesses can interact and exchange ideas, is required for incubating and sustaining transition of the kind we are suggesting here where all stakeholders in Modern Methods of Construction (MMC) can effectively interact and exchange good practice.

The message here is that it will take a concerted effort to encourage uptake of new and innovative technology by UK construction firms despite the obvious benefits of doing so. Market conditions and demands for MMC housing coupled with incentives and cultural shifts for this to happen.

Subgroup 4: economic development

As referenced elsewhere, a key question for future deliberations over economic development concerns how to resolve the tensions between economic growth and low carbon agendas, whilst rebuilding the “new normal”. These challenges also highlight the huge new opportunity for realisation of the “win-win” policy co-benefits for low carbon economic recovery driven by the pandemic socio-economic reshaping of cities, demonstrating a radical shift in behaviour, conventions and practice is fully realisable.

Research gap areas include:

1. Assumptions
   - What do we mean by “green” jobs?
   - What are the implications of delivering on ‘green’ and ‘clean’ growth?
   - What are the economic boundaries of these assumptions?
     - Where do we begin to critically reflect on questions of how supply chains are structured geographically to encourage economic diversity locally and regionally, and questions of equity / distribution?
2. Common understandings
   - What are the common interests across economic sectors (e.g. food, energy, and water nexus)?
     - Which areas would be attracting these cross-sector investments?
     - What are the challenges / implications of investing in these sectors or cross-sector areas?
     - How can these cross-sector opportunity areas be resourced?

    - What does this mean for policy coordination, for industrial and infrastructural planning?
3. Innovation
    - How to take into account questions of poverty / inclusion in the push for innovations in, and planning for transition?
        - How do to learn from COVID-19 e.g. our sensitivity to the importance of affordable energy and energy efficient homes when we are spending more time at home; and, more importantly, taking into account the distribution of ecological goods in homes/buildings/neighbourhoods?
        - What is the role of newly proposed planning reforms and their alignment with new design guidance and proposed regulatory measures under the Environment Bill?
        - How to ensure growth areas are not bypassing a duty to green space provision in cities and its health and wellbeing-links to economic productivity?
        - How to ensure a consistency of policy focus, avoiding short term policy measure or experimental initiatives' short term and growing trust and stability in the business community – especially SMEs?
4. Risk
    - Which aspects of the economy are most exposed to the processes of decarbonisation? Some resource-intensive forms of economic activities may no longer be viable, in the wake of re-occurring COVID-19 related restrictions on the movement of people, goods and services. Should we recognise a Schumpeterian opportunity for 'creative destruction' and support those affected to transition to something new and better, which will need a spending-led recovery that incentivises business/industries to let go and build something better? Again, such an approach requires an equity-centred orientation considering existing structural inequalities between the North and South (England), and between industry sectors most likely to be affected by shifts to a 'cleaner' economy. The following points would require attention going forward in this regard:
        - Increased demand of skills.
        - Decreased demand of skills.
        - Sector differences (degree of exposure not sufficiently explored).
        - How to shift jobs in dirty energy to clean energy jobs?
        - How to prioritise those communities at the forefront this change?
        - Empowering communities; resourcing capabilities from local authorities.
        - How to unlock investment that priorities vulnerable communities?
5. Education
    - De-skilling/re-skilling: where to increase financial support of university apprenticeship schemes, and vocational education?
        - Identifying priorities for technical education / vocational apprenticeships.
        - How to link innovation zones to investment in re-/up-skilling?

Evidence and Resources:

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Subgroups 5 and 6: policy and governance, and climate change

How will the economic impact of COVID-19 affect governments' ambitions for climate change targets and biodiversity?

Harriet Bulkeley, Peter Newell, Matthew Paterson, Richard Nunes & Obas Ebohon

Drawing on evidence related to the political economy of national government ambitions for climate action, the ways in which previous economic recession-recovery cycles have shaped climate policy ambitions and current emerging trends, we identified the following issues as those which are likely to affect governments' ambitions for climate change and biodiversity targets.

Impact of COVID-19 on key fossil fuel sectors of the economy

Those economies with a strong reliance on fossil fuels have tended historically to display the least ambition when it comes to climate action. Over the past decade however there has been a growing shift to renewables in many major economies which is changing this landscape by bringing increasing pressure on the viability of the coal economy. As COVID-19 drives down demand for power, and in particular that generated by coal-fired power stations, we could expect to see a further squeeze on coal – this appears to be the case in the UK where the economy ran for a record number of days without coal during the spring/summer of 2020, and may also be shaping political thinking on climate ambitions in countries such as China and India. This could be creating an open door for more ambitious climate policy and an appetite for transition to low carbon energy sources. This raises in turn a number of questions about the nature of a COVID-19 induced energy transition, including its effects on jobs and employment (regionally), what will happen to 'stranded' assets and whether there are sufficient skills and capital to support a rapid transition. These factors will no doubt vary geographically.

The US is perhaps a key case here, where it is increasingly clear that levels of coal consumption are only being sustained by direct political intervention to support it (Stokes 2020), and where the pressure on electricity markets generated coal may thus be expected to increase pressure on those policies, especially in an election year. The US Department of Energy anticipates that coal consumption in electricity will decline by around 20% during 2019 due to COVID-19 and the associated recession (see https://thebreakthrough.org/issues/energy/covid-coal-decline)

The 'energy policy tracker' is a good source of information to consult: https://www.energypolicytracker.org/

The COVID-triggered recession does not seem to have had significant impacts on carbon prices within the European Union Emissions Trading System (ETS). Prices dipped a little during March and April, but only slightly, and have rebounded to pre-crisis levels of around €25 per tCO2e. See https://markets.businessinsider.com/commodities/co2-european-emission-allowances and World Bank 2020. At present these prices seem thus driven by the regulatory improvements to the ETS generated by the Market Stability Reserve (MSR). It is possible a prolonged recession though will drive down prices but for the moment they seem resilient. Whether the MSR can fully compensate for increased allowance sales by reducing further auctions is not clear (Elkerbout & Zetterberg 2020).

Nature and strength of Green Recovery Packages

After the 2008 economic crisis there is evidence that attempts at a green recovery had a notable impact on certain sectors of the economy – particularly commercial buildings where increased capital investments in property were associated with an overall 'greening' of the sector. There is certainly both available capital seeking investment opportunities as well as large-scale public green recovery funding available, most notably in Europe where the Green Deal looks set to be even more ambitious than was originally intended and to come not only with promised capital but with a whole host of measures that will tie the private sector recovery more into green economic (re)development – for example the new requirements for reporting on investment and also the Green Accord which is likely to require cities seeking to access Green Deal funding to have in place ambitious climate and biodiversity plans.

Several countries in Europe – notably Germany and France – are likely to also have their own green recovery packages.

Hence, we can expect to see both public and private investment in Europe at the national, regional, and local scale being increasingly tied to ambitious climate and biodiversity action. At the same time there remain serious uncertainties about how private sector investment can be ‘unlocked’ and directed towards ‘green’ investment – for example, there remain doubts over the possibilities of delivering ‘biodiversity net gain’ through conventional models of financing and delivering urban development, and also about what the implications of increasing housing provision will be on existing natural assets. The potential impact of any Green Deal is also likely to be tied to the nature of the policy packages advanced – evidence suggests that packages of measures and policies are likely to be more successful in generating employment and recovery over the longer term.

Availability of international finance

Ambitious climate and biodiversity action will require financing from public sources such as the Green Climate Fund, International Monetary Fund, World Bank, and other development banks. The European Bank for Reconstruction and Development has already declared that by 2023 50% of its lending will be to green projects, and other development banks are following suit. Indeed, there is concern that there are insufficient ‘bankable’ projects to meet this flow of capital. At the same time, it is not clear whether the finance available can be channelled to ‘recovery’ measures – often the emphasis is on new technology, new development, new infrastructure etc. There may then be a shortage of finance for key ‘green recovery’ measures and a danger that by spending significant amounts of capital without taking such provisions we may further ‘lock-in’ forms of economic and social life that are unsustainable in the long-term.

At the same time, there are increasing concerns about indebtedness and the degree to which countries may start to default on their loans, in turn posing a risk to international financial institutions and their liquidity. Within this context, there are increasing calls for ‘debt for climate’ and ‘debt for nature’ swaps, so that debt is written off against promises for more ambitious climate or biodiversity action. This may appear an attractive option, but there will be concerns raised about both the legitimacy of commercialising nature/climate action in this way, and also whether this will be a means through which countries in the global North will seek to avoid reparations for climate damage as is being called for by several nation-states in the ‘loss and damage’ debate in the United Nations Framework Convention on Climate Change. Overall, the withdrawal of the US from international agreements and continued tensions over the future relationship between the EU and the UK may serve to further erode the availability of international finance.

Waning ambitions in the face of unemployment in key sectors of the economy

There are now some signs of 'foot dragging' in key industry sectors (e.g. car manufacturing) that had previously appeared to be relatively comfortable with timetables for ambitious action (e.g. transition from diesel to electric cars) which may start to place pressure on governments not to 'go too fast' in the face of the economic downturn. At the same time, we can expect that tied into a recognition of the need for 'just transitions' in sectors which are likely to be particularly affected by shifts to a low carbon economy will be calls to avoid added pressures that might create additional unemployment in key economic sectors and regions where unemployment levels may be high as a result of COVID-19. Maintaining levels of ambition in the face of these kinds of pressures is likely to require explicit policies and interventions to deal with both the uneven impact of COVID-19 on the economy and the uneven impacts of climate change measures, particularly in regions where single large employers may be impacted by both dynamics (e.g. steel sector, car manufacturing, coal, offshore oil economy etc.). This could also lead to (more) reluctance to impose what are seen as punitive measures in favour of climate action – such as carbon taxes.

Increasing prominence of questions of risk (and return)
At the same time, it is clear that many businesses are now recalibrating their risk exposure in the wake of the pandemic in ways which could drive ambition for climate and biodiversity action. In particular, some 'assets' that had previously been regarded as necessary for a functioning economy – large commercial office buildings – are now being questioned. Equally, faced with empty high streets and a lack of access to inner city economies on public transport, road infrastructure is now being rethought for other users. This could lead to shifts in where both public and private interests lie in terms of climate and biodiversity, but planning how to make best use of the space vacated by these uses will be critical if the political will for a green recovery is going to be matched by action. Depending on how the idea of a green recovery is imagined and put into practice – whether this is primarily driven by efforts to create employment or to create returns on investment, whether to provide either temporary uses or forms of creative space for example – different kinds of economies could be considered to be viable. There also remains a strong appetite in the financial sector for risk disclosure in terms of the exposure of portfolios both to the direct impacts of climate change and to the risks of 'stranding' as the low carbon transition progresses. There is some evidence that new forms of disclosure with respect to nature/biodiversity are now emerging for both value chains and assets, such that how institutional investors respond to the climate and nature crises are likely to be critical in shaping government ambitions for action.

Brexit impacts
When it comes to biodiversity, government ambitions are perhaps as likely to be shaped by Brexit as by the effects of COVID-19, given that so much is now up in the air when it comes to environmental regulation, standards and policies, especially related to farming and fisheries. This is likely to have an effect not only in the UK but

also in other places around the world as new terms of trade are agreed which may have higher/lower levels of environmental ambition.

In terms of climate change, a particular concern here is the question of the ETS and UK participation. The UK has been a leading actor in the ETS both in terms of the policy process and the market operations. The UK government has announced intentions to introduce a UK ETS, broadly mirroring the design of the European Union ETS, and the intention is to leave open the option of linking back to the European Union ETS. Nevertheless, the detailed implementation remains to be announced and there is thus significant uncertainty both for UK and European Union climate policy.

Research Gaps

While there is a significant body of research to draw upon to inform policy in this area, it remains rather dispersed and further work may be useful in drawing together key elements to inform policy. In particular, we would suggest the following topics provide potentially useful avenues for further inquiry:

- While some work is underway, we lack a systematic mapping of either (a) how far the commitments made by Parties to the United Nations Framework Convention on Climate Change in their Nationally Determined Contributions (NDCs) might be affected by COVID-19 and its economic effects (e.g. on the coal sector or on key economic sectors where ‘foot dragging’ on previous commitments is emerging); or (b) how far commitments being made for a (green) recovery could either support or limit the stated ambitions of NDCs. This review could support further analysis concerning how shifts in domestic economic and environmental priorities may in turn lead to a realignment of commitments towards climate action internationally (and could be coupled with an overview of the implications for Biodiversity commitments at the national level, see also section below).
- There is currently a strong narrative on ‘building back’ the economy, even where this is framed in ‘green’ terms. Radical possibilities for rethinking what ‘recovery’ means – for example in terms of how economies function, how investment might shift as what constitutes an ‘asset’ is recalibrated, and in relation to changing power dynamics between different sectors and regions of the economy – are not yet being bought to the fore in a systematic way or in a manner that makes them amenable for policy and practice (see also section below).
- A systematic mapping of the nature and consequences of different forms of ‘green recovery’ (and which kinds of recovery and what forms of green are involved) would be useful in understanding how far these are likely to drive more ambitions for or conflicts between climate and biodiversity goals.

What is the impact of COVID-19 on the multilateral and international alignments on climate change consensus?

Peter Newell, Matthew Paterson, Harriet Bulkeley & Richard Nunes

The impact of the COVID-19 crisis (and responses to it) on multilateral and international alignments towards a consensus for the need for climate change action are likely to stem from: (a) domestic economic impacts and how these are distributed across different sectors/regions of the economy; (b) the availability of finance for low carbon transitions, both domestically and from multilateral/international sources; (c) the extent to which COVID-19 recovery plans are tied to (different forms of) a ‘green new deal’.

More specifically, we can say:

- Overall, there is a fear, to some extent backed by historical precedent, that environmental ambition, including at the international level, is reduced in times of economic crises as political attention and state resources are more focussed on boosting the economy.
- This is not withstanding the potential to ensure recoveries from such crises are green and historical evidence, as well as contemporary examples, of how governments can use their power and resources to bring about rapid shifts in the organisation of industry (such as industrial conversion), behaviours and infrastructures (such as with the New Deal on which the Green New Deal is partially modelled).
- There is a prospect of reduced ambition amid a reluctance to impose any policy measures that might impact growth, increase unemployment or prove politically unpopular (carbon taxes for example or floated ideas about frequent flyer levies, meat taxes etc). Likewise, the drive to stimulate recovery through new road building programmes and continued commitments to airport expansion, for example, could lock in a high carbon pathway.
- This fear is often capitalised upon by incumbent industry actors to slow phase outs (of coal for example) or to delay the introduction of measures (phase out of internal combustion engine vehicles) or to lobby for enhanced support. Examples include Occidental's successful lobbying for access to the US Federal Reserve “Main Street Lending Program” or the $28 m given to three coal mining companies with ties to officials in Donald Trump's administration.
- Reduced state revenues (used for furlough schemes, bailouts etc) may lead to calls to reduce funding to climate institutions (Green Climate Fund, Adaptation Fund, World Bank climate funds). There is some evidence of this already happening. Contributions to the United Nations Climate Change secretariat received by the end of March were at a record low compared with those in previous years with a hole of €33 million (£39.5m). As of July this year, United Nations Climate Change had received only 48% of its core contribution for 2020 according to one report.
- The economic shocks induced by COVID-19 might also reduce the availability of funds for alternative infrastructures, subsidies to renewable energy, retrofit programmes, phase out of gas supply to homes etc.
- Many of the impacts on the global climate negotiations flow from domestic politics and the effect on leadership within the negotiations. For example, the outcome of

US election will have a decisive impact on whether the US engages positively with the climate regime. Likewise, accelerated Amazonian deforestation in Brazil during the COVID-19 crisis will affect the shape of the discussions on forests and land use, land-use change, and forestry.

- Increased indebtedness as a result of COVID-19 and the increasing financialisaton of the economy could have a series of direct and indirect effects on the negotiations. Some studies have looked at how financial crises impact on the achievement of the sustainable development goals including in areas relevant to climate progress (energy, forests, land, climate itself). But we also see innovative approaches to linking debt write offs to conservation measures (forests, blue carbon, and nature-based solutions) as well as the financialisaton of climate adaptation.
- Though the Glasgow CoP has the issue of loss and damage on the agenda, we might expect even more entrenched resistance on the part of richer countries to pay compensation at a time of financial crisis.
- Shifting supply and demand for carbon credits in the wake of COVID-19 and the economic downturn affecting some sectors of the economy could impact on carbon trading policies in the climate regime. In particular perhaps, this might apply to discussions about the rules by which future carbon trading should be governed, including under the Paris agreement's Sustainable Development Mechanism, but also with regard to voluntary carbon offset schemes such as the aviation industry's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) scheme. A recent point of contention has been the baseline for the scheme which was to have been 2020, but in light of flights being grounded due to COVID-19, companies have been seeking to take it back to 2019 so as to avoid the costs of having to purchase significant amounts of additional offsets. The sharp decline in 2020 emissions and in baseline emissions, would mean an increase of over 60% in offsetting requirements over the lifetime of CORSIA.

While we can have a degree of confidence in raising these specific issues as of material concern in shaping the possible ways in which alignments for climate change action internationally may come to be reconfigured, it is also important to note that other geopolitical issues are also shaping this dynamic (e.g. cooling in relations between China and Europe, uncertainty over the outcomes of the US election).

In addition, while there is an evidence base to support our suggestion that these issues will be of significance in shaping climate politics at the international level in the short term (up until COP26 and its immediate aftermath), there is more uncertainty about their implications for how any agreements reached in Glasgow will be implemented.

There are a number of remaining knowledge gaps where further evidence gathering and research will be useful to help support policymaking:

- While some work is underway, we lack a systematic mapping of either (a) how far the commitments made by Parties to the United Nations Framework Convention on Climate Change in their Nationally Determined Contributions (NDCs) might be affected by COVID-19; or (b) how far commitments being made for a (green) recovery could either support or limit the stated ambitions of NDCs. This review could support further analysis concerning how shifts in domestic economic and environmental priorities may in turn lead to a realignment of commitments towards climate action internationally (and could be coupled with an overview of the implications for Biodiversity commitments at the national level, see section above).
- Similarly, a review of the evidence concerning the availability of international/multilateral finance for climate action and how this is changing in the light of COVID-19 would add further depth to the initial analysis presented here.
- At the same time, it will be crucial to understand how key economic actors who operate transnationally and are often involved in transnational governance initiatives for climate (and biodiversity) are/not shifting their position and commitments for action, as these actors have come to play a crucial role in building the political momentum for climate action at previous international climate summits. If a cooling can be detected amongst such actors, it may be that this feeds into a waning of political momentum (and public interest) globally.
- There is currently a strong narrative on ‘building back’ the economy, even where this is framed in ‘green’ terms. Radical possibilities for rethinking what ‘recovery’ means – for example in terms of how economies function, how investment might shift as what constitutes an ‘asset’ is recalibrated, and in relation to changing power dynamics between different sectors and regions of the economy – are not yet being bought to the fore in a systematic way or in a manner that makes them amenable for policy and practice (see also section above).

What are the competing pressures, trade-offs, and synergies of different land-uses in relation to climate change in a post-COVID world?

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There are two principal competing sites of such pressure and trade-off. Most of these are fairly well understood at the technical level, we would emphasise the social and political dynamics that are important in shaping how these pressures play out in practice.

Urban tensions

One site in which competing pressures for land-use has been bought into sharp relief by both COVID-19 and climate change is in urban areas. These trade-offs are to be found principally between housing (or land development for commercial/industrial use) and green space. COVID-19 has intensified the importance of green spaces –

parks, paths, and so on – in particular for those without access to private gardens. There is strong evidence that the distribution of green space is far from even and that over time there has been a decline in the amount of green space available in cities. There have been persistent pressures to increase house construction which puts pressure on these spaces in urban areas, and there is evidence the government is seeking to relax planning restrictions as part of economic regeneration initiatives post-COVID. This may affect urban fringe areas especially. Some measures which on the surface may appear to support nature and biodiversity, such as schemes to support biodiversity offsetting, could provide further incentives for urban development and hence the loss of 'natural' spaces in and around cities. A less extensive but nonetheless critical tension lies with the demands for increased infrastructure for non-car-based forms of transport. Increased cycle ways and public transport lanes/routes in particular may often conflict with green spaces. (this is also the case outside urban areas, as evidenced by the trade-offs and conflicts over HS2 in relation to woodlands, for example).

At the same time, reduction in land value for commercial property (perhaps especially in inner city areas) may release land for new purposes. How trade-offs between demand housing and green space are managed in such a way as to enable both economic activity and health and well-being of urban dwellers will be critical. There is growing evidence of the importance of access to green space for health, well-being, educational attainment, and pro-environmental behaviour. Ensuring that alternatives to existing models of housing development are considered which take account of the need to manage trade-offs and tensions of this kind will be crucial for the future of urban places.

There remain overall tensions between urban density, which can reduce energy demand in relation to transport, and providing space in the city for nature, which can both perhaps reduce urban heat islands and also provided spaces for increasing health and well-being. Green spaces are not only a question of public amenity. They should also be understood as parts of urban climate adaptation, through what are often called "nature-based solutions". Tree cover reduces the urban heat island effect and thus reduces pressures for air-conditioning, likely to increase as heatwaves become more frequent. Maintenance of urban waterways – streams and rivers, small wetlands, are important to minimise flood risk as well as enhance urban biodiversity.

Upland management

The other principal site where tensions are emerging is in upland areas. These have been widely recognised as sites with great potential for meeting net zero emissions. This is in particular regarding afforestation and peatland management, but also important for onshore wind energy generation. The tensions here are with existing uses of these environments, notably sheep farming, moorland management (e.g. for grouse hunting) and their use for leisure and aesthetic appreciation. The Committee on Climate Change has documented the potential for land use changes to play a role in achieving net zero emissions. Afforestation is the single most important contributor to such emissions reduction. The Committee is clear on the need for substantial changes in land use to meet these goals – specifically that 22% of existing agricultural land needs to be switched to focus on long-term carbon sequestration (i.e. forestry and peatland management). The technical aspects of these are reasonably well understood. However, two tensions are worth highlighting.

One is that this entails a substantial switch in diets away from meat (especially ruminants) and dairy. Opposition to this switch comes from both the agricultural sectoral lobbies, which have significant investments sunk in this aspect, but also from the cultural dynamics of meat and dairy. There have been significant shifts towards vegetarian/vegan or low-meat consumption diets, but not on the scale envisaged to meet net zero targets.

The other concerns land ownership patterns. The Committee on Climate Change note the varied forms that land ownership takes, and the obstacles this can play in blocking land use change. Of most obvious note, and already made the subject of controversy, is managing uplands for grouse shoots, which entails drying out peatlands and turning them into sources rather than sinks for CO_2. But the problem is more pervasive, preventing for example sustained planning of afforestation measures, with the result that rates of afforestation have been substantially below targets set by government within the context of the Climate Change Act.

Research Gaps

Whilst tensions over land-use identified here have been extensively researched over the past three decades, such that the underlying dynamics, drivers and potential consequences are relatively well understood, there remain gaps in our understanding which could be addressed to support policy-making in this area:

- The extent to which different forms of policy, planning guidance and regulation are either exacerbating or ameliorating tensions and trade-offs between competing land-uses and with what implications for climate (and biodiversity) outcomes. Given that the UK is about to embark on a new chapter of environmental policy-making outside of the European Union it will be critical to understand the potential unintended consequences of well-intentioned policies and their consequent legacy for climate change and other sustainable development goals, notably health and well-being.
- How new models of land ownership, governance and investment can be developed which support forms of land-use which are able to generate multi-functional outcomes (e.g. provide housing and ecosystem services; generate electricity and enable recreation). Some examples exist, but a systematic overview of these approaches and their application to the two critical sites of contestation covered in this note would likely provide a useful resource to inform the future direction of policy in this area.