policy connect

All-Party Parliamentary climatechange Group

NET ZERO EXCHANGES:

CONNECTING POLICY & RESEARCH FOR CLIMATE ACTION

Durham University

UNIVERSITY OF LEEDS

Imperial College London

Manchester Metropolitan University

The University Of Sheffield.

WARWICK THE UNIVERSITY OF WARWICK

UKRI Natural Environment Research Council

September 2021

This essay collection was compiled by Dr Jake Ainscough, formerly Policy Connect, now University of Lancaster, and Dr Jo Hale, UCL.

Policy Connect
7-14 Great Dover Street
London
SE1 4YR

www.policyconnect.org.uk

Contents

> **There has never been a more urgent need to work together for net zero than as the world comes together for COP26. In rising to the challenge we need solutions that work for everyone in our societies.**

Dr Jo Hale, UCL

Foreword

With the UK hosting COP26 in November, the climate emergency has risen up the political agenda like never before. The Government urgently needs to align domestic policy with our global climate commitments, and the urgent need for a clean, green recovery in the aftermath of Covid-19 offers a vital opportunity to do so.

As Greta Thunberg reminds us, when it comes to the climate crisis we must listen to the science. This essay collection is an example of that - of politicians working with academics to understand not just climate science but the science of the solutions.

The collection details the many areas where work is still needed on climate policy, but also demonstrates how readily to hand many solutions are. These solutions are being researched and developed in universities across the UK. It is clear the strength of UK science and research is an important asset in our fight against the climate crisis.

The collection showcases not just the quality of research in the UK, but also the level of cross-party support for climate action. Essays have been contributed by parliamentarians from across the parties and from both Houses. The APPG on Climate Change was founded to coincide with the passing of the 2008 Climate Change Act – a vote that achieved almost unanimous support from across the political spectrum. As current Chair of the APPG on Climate Change, I see great value in striving to maintain and build upon this cross-party consensus where possible.

We won't all agree on the necessary course of action in each sector. And we may not even agree on the speed or scale with which it is necessary to reduce emissions. But we share a common conviction that the climate crisis is a challenge that can and must be surmounted. Deeper engagement between parliamentarians and the scientific community is a vital step in ensuring that we do. It is in that spirit that I fully endorse the work that has gone into producing this collection of essays.

Caroline Lucas MP

Chair of the All-Party Parliamentary Group on Climate Change

Introduction: Achieving Net Zero

Dr Jo Hale

What have we committed to?

The UK passed the net zero target into law in June 2019. It requires us to reduce net greenhouse gas emissions (GHGs) by at least 100% by 2050 compared to 1990 levels. The current target only applies to territorial emissions within UK borders. It does not include the roughly equal level of emissions embodied in what we import (consumption emissions), or emissions from international aviation and shipping. We will achieve territorial net zero when emissions are balanced by removal of GHGs from the atmosphere using tree planting or other methods of carbon capture and storage. This balance is needed because we expect it will be too expensive or complex to remove all emissions from some sectors such as construction and aviation. However the 'net' does not disguise the fact that large absolute emission reductions are needed this decade.

As well as reaching net zero by 2050, the UK is also committed to meeting five-yearly carbon budgets which place a legal cap on total GHG emissions. This requirement to government was set out in the Climate Change Act 2008. The first six carbon budgets have been set, taking us up to 2037. The sixth carbon budget was the first one set in line with the new net zero target – it effectively brings the previous 80% emissions deadline 15 years closer.[1] The carbon budgets are not just stepping stones on the way to reaching net zero, but are also crucial for limiting the cumulative emissions over the intervening period. So far the UK has outperformed the first two carbon budgets and is on course to meet the third, but we will overshoot the fourth, fifth and sixth budgets unless steeper emissions reductions are made.

The UK was the first G7 nation to make such an ambitious commitment to reducing emissions, and continues to be seen as a global leader on climate action. This leadership will be scrutinised in November when the COP26 UN climate conference is held in Glasgow, co-hosted by the UK and Italy. Ahead of the conference the UK and all other Parties to the United Nations Framework Convention on Climate Change (UNFCCC) will put forward nationally determined contributions (NDCs) to global climate action, as a requirement of the Paris Agreement. The UK's NDC sets us a near-term target to reduce carbon emissions by at least 68% by 2030, compared to 1990 levels.[2]

Where are we on the journey to achieving net zero?

During the first year after introducing net zero, the Prime Minister established a Cabinet Committee to deliver this goal and the government took initial steps towards creating a net zero policy package, although these actions fell short of calls from the CCC. Then in 2020 coronavirus took hold of the UK. The government outlined its commitment to a green recovery from the pandemic, accompanied by £350 million to reduce emissions from industry, and agreed to jointly lead a UN sustainable recovery workstream.[3,4] In November 2020, the Prime Minister announced a ten-point plan for green recovery which aimed to align the missions of 'levelling up' and reaching net zero.[5] Described by the Prime Minister as "only the start" of government's net zero plans,[6] it sets out target milestones rather than the steps needed to achieve them.

As it stands, we are approaching half-way to net zero in terms of emissions reductions, but we are nowhere near to making all the actions that will be needed for the second half of the journey. There are pathways of actions set out by the CCC, IPCC and other scientific bodies, which, if we follow them, can reduce emissions at the pace needed.[2,7] These tell us steps that can be taken to reach our emissions milestones, but they are only a pathway. We still need to make the national journey to net zero, and this comes with at least three sets of interrelated challenges.

[1] www.theccc.org.uk/publication/sixth-carbon-budget/
[2] www.gov.uk/government/publications/the-uks-nationally-determined-contribution-communication-to-the-unfccc
[3] www.gov.uk/government/speeches/the-sustainable-recovery-investor-collaboration-on-covid-19-recovery-and-the-climate-emergency
[4] www.gov.uk/government/news/pm-commits-350-million-to-fuel-green-recovery
[5] www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution

What are the challenges?

One set of challenges is made up of the particular technological, financial and practical hurdles to decarbonisation within particular sectors. For example: What is needed to scale up proven **carbon capture and storage** technology in the UK, in line with other nations? What will it take to ensure **buildings** use near-zero energy? Why are we not mining **geothermal heat** to supply our heating needs? How can we balance the need for technological advances and reduced demand to curb **aviation** emissions? How can we achieve widespread roll-out of **electric vehicle** and **hydrogen fuel cell** infrastructures? What support should be put in place to facilitate shifts to regenerative practices in **agriculture**? How can we plant the tens of thousands of **trees** per day that are needed to meet net zero? These types of challenges require detailed planning, coordination and investment from government to remove barriers and put in place support for each sector to decarbonise.

A second set of challenges emerge when we step back to look at the bigger picture and consider whole systems. How should we consider and address **consumption emissions** alongside territorial emissions in the UK's global contribution to climate change? How can we increase **circularity** across the whole of the UK economy, including our role in global systems such as **fashion** consumption? How can **industries** shift from a focus on individual technologies to holistic decarbonisation strategies? These challenges require government to examine the UK's national responsibilities, consider unintended consequences and co-benefits of net zero plans, and to support the trialling of new modes and mechanisms of working.

A third set of challenges is about how we – the individuals, households, organisations, local, national and international bodies that shape the UK – can coordinate action across these different levels. What is needed to make sure that national policy strategies are translated into local delivery of net zero on the ground? How can we ensure that underserved groups are given a platform to engage in developing national climate strategies that go beyond 2050, recognising the value of **arts-based** approaches? These challenges require government to move away from one-size-fits-all approaches and to leverage the strengths of local authorities, so that decarbonisation strategies work for everyone as part of the levelling-up agenda.

How can we rise to the challenge?

To rise to net zero challenge, it is important that all stakeholders are involved in developing action plans together. This approach is practiced and preached by leading climate organisations and embodied in the UN Sustainable Development Goals. It can help to ensure that strategies are fair for all groups in society, with benefits that are widely shared and costs that do not burden those who are already disadvantaged. This core principle has been emphasised by the CCC and Climate Assembly UK. Listening to the voices of multiple stakeholders is also important to creating action plans that will be implemented effectively. When plans are linked to people's concerns and values and have tangible benefits tailored to them, they are more likely to lead to action.

A wide range of stakeholders have come together to contribute to the essays in this collection. In the essays, thirteen parliamentarians from five political parties set out their policy recommendations for rising to the net zero challenge. These recommendations have been shaped through a series of roundtable discussions held under the auspices of the All Party Parliamentary Climate Change Group, and developed in partnership with leading academic experts. The essay collection addresses thirteen key climate topics spanning the **UK's carbon footprint, decarbonising industry, heat and the built environment, greening transport, land use change** and **public engagement.** Together, they point to key evidence on the decisions and actions needed to achieve net zero by 2050.

[6] www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution/title
[7] www.ipcc.ch/sr15/

SECTION 1: Sector Specific Challenges

1. THE UK'S UNTAPPED RESOURCE: GEOTHERMAL HEAT

Cherilyn Mackrory MP and Professor Jon Gluyas

Cherilyn Mackrory MP

Prof. Jon Gluyas

The UK has a proud history of mineral mining and energy extraction – coal from 23,000 mines scattered from Fife to Kent, tin and copper from Cornwall, lead and zinc from the Pennines and more, oil and gas from the North Sea, Irish Sea and Atlantic Margin. Exploitation of these fuels and minerals allowed us to create the industrial revolution and have helped drive our economy ever since. As we move beyond a fossil fuel based economy, the ground below our feet may still hold the answer to our energy needs.

Over the last few decades, scientists have quantified the vast geothermal potential of the UK. Usually associated with hot water geysers in places like Iceland, geothermal energy harnesses heat from within the Earth. Though the UK lacks significant geothermally heated surface water, below the surface a huge zero-carbon energy source awaits to be unlocked.

Space heating accounts for half of the UKs non-transport energy use, with around two thirds of this associated with the domestic sector and accounting for more than 30% of the UK's greenhouse gas emissions from 21 million gas boilers and other fossil fuel powered heating systems. Finding ways to decarbonise heating is a number one priority for government. In other parts of the world, zero-carbon geothermal heat has successfully been used to meet domestic and industrial demand. Some geothermal schemes, such as the Southampton District Energy Scheme, are also capable of producing energy and cooling services, alongside heating.

Geothermal schemes come in two basic varieties - those designed to produce electricity for which superheated steam is needed and those which produce heat alone.

THE DEEP GEOTHERMAL POTENTIAL OF CORNWALL AND NORTH EAST ENGLAND

The deep geothermal resource in Cornwall represents a significant opportunity for renewable heat and power generation. In the 1970's and 80's the 'Hot dry rocks project' at Rosemanowes Quarry in Penryn, led by Camborne School of Mines, confirmed the high temperatures deep underground in Cornwall's granite. This resource could meet all of Cornwall's demand for electricity and 20% of the UK's demand. Cornwall could lead the way in this new energy sector with a greener, cleaner way of tapping into our incredible geological treasures. A possibly by-product of the geothermal power production in Cornwall is lithium, an element critical for electric vehicle batteries. Similarly high heat flows and lithium rich fluids have also been proven by wells drilled into the Weardale Granite in Durham by Durham and Newcastle Universities in 2000s-2010s.

Cornwall now has two active geothermal drilling sites. One at United Downs and one at the Eden Project in St Blazey, with drilling about to commenced at the latter. The United Downs project was established by Geothermal Engineering Ltd (GEL) to demonstrate the potential of the UKs deep geothermal resource to produce both zero carbon electricity and heat. Once fully operational, the project will supply enough energy to power 6,000 homes.

Conventional geothermal power generation requires a natural source of circulating water at depth and at a high temperature. The granite of Cornwall lacks natural circulating water, but has the high temperatures. The technology proposed in Cornwall is known as engineered or enhanced geothermal systems (EGS). With EGS technology it is possible to increase the circulation of water between wells, at depths of 4-5km, to capture the natural heat source within the rock. The extracted hot water is at a sufficiently high temperature to drive an electricity generating turbine. EGS is a relatively innovative technology but there are generating projects in Europe, the US, and Australia, with many more in construction.

MINE GEOTHERMAL

The schemes being developed in Cornwall are enabled by the specific geology of the region. Other regions in the UK have different but equally important geothermal potential. Many of our major cities and towns could be heated using geothermal energy extracted from deep saline aquifers or flooded and abandoned mines.

The UK built many of its towns where it mined its coal and thus over 25% of the UK's built environment is situated above one or other of the 23,000 former coal mines. As we transition to a zero-carbon economy, these flooded mines may have a second life as part of the UKs low carbon energy mix; a delightful example of the circular economy in action.

Although the mine water is much cooler than can be obtained from great depth, flow rates are reliable and sustainable. The level of knowledge and understanding we have of UK mine systems significantly de-risks the development of mine geothermal heat capacity. By coupling mine geothermal with a heat pump, it is possible to harness the necessary energy to run a district heat networks.

District heat networks are effectively large, insulated pipes that supply heated water to housing and other buildings. Waste heat from industrial processes and from Energy from Waste plants has been successfully linked to district heat networks to provide cheap, low carbon heating to local infrastructure. The Government's Clean Growth Strategy suggests that for a cost-effective path to the UK's 2050 net zero target, 17% of heat demand in homes and 24% of demand in industry and public-sector buildings will need to be met with heat networks.

Other countries are already moving ahead in utilising water from old mine systems for district heating. The municipality of Heerlen in Netherlands opened a mine water geothermal scheme in 2008 and now supplies zero carbon heat to 500,000 square meters of commercial and residential buildings. At a smaller scale, the UK actually already boasts a functioning mine geothermal system. Lanchester Wines in Gateshead, working together with the Coal Authority and the Environment Agency, became the first UK business to heat one of their sites with a mine water fed heat pump. Other schemes are moving towards completion with many occurring in North East England, South Tyneside Council are leading the way. There are no technological barriers to expanding this approach across the UK.

The amount of mine water available in the UK could meet our heating needs for many decades. If we choose to store heat in the mine water (from solar thermal collection and waste heat from industry) the system can be indefinitely sustainable as has been shown in Heerlen. Developing the resource could see approximately one million jobs created - once again placing the UK's mines at the centre of thriving local industries. With huge disruptions from Covid-19, investing in the UK's geothermal potential could see jobs and growth brought to areas hardest hit by the pandemic.

CAPTURING THE OPPORTUNITY

Geothermal power is the only renewable energy resource not affected by the weather; it is ‘on’ 24 hours a day, with plants typically running over 90% of the time. The surface area of the plants is the smallest of any power source, and with buildings no higher than 10m, geothermal energy has a low impact on the landscape. With the right policy support, and enterprising local authorities, geothermal energy can make a substantial contribution to the UK’s future low-carbon energy mix. At the same time, developing this natural resource would help to level up parts of the country with proud histories of contributing to the UK’s energy security.

UK industry now awaits the policy to bring the pieces of the puzzle together. We need to take positive action including; improving building standards on heat insulation and provision of underfloor heating systems for all new houses with external connections available for technology agnostic heat sources including mine water heat, legislation such that any deep wells drilled for petroleum must also be evaluated for geothermal energy delivery (as in the Netherlands) and support for infrastructure for developing mine water heat which is heavily front end loaded on cost.

Geothermal projects are by their nature localised and require the coordination of a number of actors (producers and consumers) to make them a success. A report from Frontier Economics and Imperial College London highlighted that if geothermal heat is to be brought online, there will need to be a conscious local effort to ensure that policy incentives are not pulling in different directions – they will have to be aligned towards geothermal heat. Without proper coordination, national level policy incentives risk undermining local efforts to develop mine geothermal heat.

The need for strong coordination makes the role of local authorities crucial in the development of geothermal heat projects. In Southampton, where a deep geothermal system provides heat, cooling and electricity to a range of public and private sector users, it took a local authority to recognise the potential, take ownership of the project and make it a success.

As the Government looks to level up the country, places like Cornwall are showing they have the natural resources to once again play host to a thriving industry that can provide power to the economy of the 21st Century.

2. TO NET ZERO & BEYOND: THE ROLE OF CARBON CAPTURE AND STORAGE

Professor Jon Gluyas
and Theo Clarke MP

The idea seems so simple. If one of the main causes of climate change is pumping too much carbon dioxide into the atmosphere, why not just take it back out again? The beguilingly simple logic behind carbon capture technologies has earnt them many ardent supporters.

Prof. Jon Gluyas

Forests of mechanical trees removing carbon dioxide like their Amazonian real tree cousins seems fanciful. However, such an approach, known as 'direct air carbon capture' coupled with geostorage (DACCS), is just one potential technology for carbon capture technology albeit one which leads to an increase in energy demand. Other technologies are essential for tackling the climate crisis.

Theo Clarke MP

Here we discuss the essential role of carbon capture and storage (CCS) in helping the UK meet our net zero target. We also make the case that the UK is well positioned to become the centre of an emerging global CCS industry.

WHAT IS CCS AND WHY DO WE NEED IT?

Whilst not a silver bullet, carbon capture and storage technologies will be essential in sectors that cannot be decarbonised any other way, in the timeframes required in order to achieve the target of net zero by 2050. For example, CCS will be needed in industry and manufacturing to ensure UK businesses remain competitive while simultaneous reducing emissions. The paradigmatic cases here are the production of steel and concrete – making both of these produces huge amounts of unwanted carbon dioxide because the chemical breakdown of limestone (calcium carbonate) is a key process in cement and steel manufacture. Yet if we are to build the infrastructure for a low carbon economy, we are going to need lots of both steel and concrete.

There are four parts to the CCS chain; capture of the carbon dioxide, compression of the carbon dioxide, transportation to the storage site, and finally injection deep underground (> 1km) into a porous and permeable reservoir. All parts of this chain have been shown to work at scale in different parts of the world.

Carbon capture technologies can be integrated into power plants, directly into industrial processes, or into the production of hydrogen. This latter use is especially important. Hydrogen is a possible substitute for natural gas (methane) in many industrial processes, such as concrete production, and can also be used as a fuel in cars, trucks, planes, and ships. Unlike natural gas, the combustion of hydrogen alone produces no greenhouse gases.

The most common method for making hydrogen, involves reacting methane with water at high temperatures, producing hydrogen and carbon dioxide. Unabated, the carbon emissions from this process would defeat the point of switching to hydrogen in the first place. In the absence of CCS, a hydrogen economy is likely to have a larger carbon footprint than the present fossil fuel-based economy. By removing the carbon dioxide from hydrogen production through CCS and you can produce 'blue hydrogen' – a low carbon fuel source with endless applications.

Hopefully there will come a time when we can produce 'green hydrogen' directly from water at sufficient scale using low carbon electricity but CCS is important as a 'transition technology' – allowing sectors to decarbonise sooner via blue hydrogen, than would otherwise be possible. This 'transition' feature of CCS extends to its potential use in fossil fuel power plants, helping in the short term to reduce their negative impact on the environment by allowing these plants to contribute to a low-carbon energy mix whilst renewables continue to be scaled up to enable renewables to produce 'green hydrogen' in the long term. Yet even as these transition uses are wound down, demand for CCS will not disappear. Processes like cement manufacture will continue to need CCS to decarbonise. Demand for storage capacity as CCS expands globally will continue for many decades, with the UK uniquely positioned to cater to this demand.

Not only could the UK benefit by using CCS to decarbonise our own economy but as the geology of the UK's offshore areas are ideal for the final stage of the process – injecting the carbon deep undergrown for storage, the UK is ideally placed to provide storage capacity to a growing international CCS industry. This will provide more green jobs for UK workers and enable Britain to increase its role in helping to tackle global climate change.

PROGRESS TO DATE

The need to scale up CCS is recognised across the world. Yet the total quantity of carbon dioxide captured and stored globally each year is only around 40 million tonnes – around 0.1% of the carbon dioxide released to the atmosphere. The Intergovernmental Panel on Climate Change has for many years been promoting CCS but uptake has still been slow. There are 19 CCS plants operating world-wide with four more under construction. A further 28 are in the early to mid-stages of development and there are 39 demonstration scale plants.   At present the need is to scale up CCS at pace, rather than just focusing on developing new technology.

Closer to home, the UK has been talking about the importance of CCS for the past 15 years. However, we have not yet made it happen. Support for CCS has gone back and forth. This lack of certainty has been a major barrier for wide scale deployment. The UK has had competitions to develop demonstration projects, formed a UK CCS Research Centre and more. But the reality is that hundreds of millions of pounds have been spent without capturing and storing a single molecule of carbon dioxide.

Research in the UK on capture, transport and storage of carbon dioxide, including long term monitoring of the stores, has been extensive and of outstanding quality. Between 2010 and 2015 the Energy Technologies Institute supported research on the total UK offshore storage capacity in depleted oil fields and saline aquifers of the UK continental shelf. The UK was in the vanguard of CCS in 2015 but is now seen by some as being behind Norway, USA, Canada, Australia, China, Abu Dhabi and other nations. We could by now have been selling storage space and exporting expertise and training.

BECOMING A GLOBAL LEADER: HOW THE GOVERNMENT IS SUPPORTING THIS NEW INDUSTRY

We welcome that this (Conservative) Government has finally ended equivocation over support for the CCS industry. Over the last year, the Government has announced significant new funding to ensure that CCS can be ramped up to allow us to meet our world leading decarbonisations targets.

This new funding will help support CCS related projects across the country including Carbon Humber (planned 18.3 M Tonnes per annum carbon dioxide storage and expected to be at capacity operation by 2040), Net Zero Teesside (0.8-6 M tonnes pa, industrial CCUS operational by 2030), and offshore storage projects such as Acorn and Caledonia Clean Energy (storage sites offshore Scotland) and HyNet (NW England with storage in the East Irish Sea depleted gas fields) or indeed any other CCS project.

These projects, and new ones like them, received a major boost in the Prime Minister's Ten Point Plan for a green industrial revolution. This plan, designed to build back better from the Covid-19 pandemic, will support up to 250,000 jobs across the country. The plan includes £1 billion of funding to support CCS, £200 million more than had already been committed in the 2020 Spring Budget. This funding will allow for the establishment of four CCS clusters across the country by the end of the 2020s. Support for CCS is also central to the Government's recent Industrial Decarbonisation Strategy and their National Infrastructure Strategy. This new support, backed by world leading research into CCS technology, will put the UK back at the forefront of creating and delivering innovative solutions to tackling climate change.

This large Government investment into CCS demonstrates the Government's commitment to levelling up our county as crucially, this new support for CCS will provide good, stable jobs across the whole of the UK: from Wales to Teesside and from Merseyside to Aberdeen. Jobs will be created directly in the sector, as well as across the whole country up and down supply chains. Developing a world class CCS industry will allow us to decarbonise the UK economy whilst redeploying skills and workers from the oil and gas sector. The Government's commitment to underwriting the birth of this new industry is a key part of its plans to level up the whole of the UK.

AN INDUSTRY OF THE FUTURE

CCS is not a replacement for rapid decarbonisation of the energy sector and widespread electrification of the economy. Addressing climate change will require action on all fronts. But it is clear that in the UK and around the world, there is a desperate need to rapidly scale up CCS capacity. The UK's research prowess and our stable, well studied geology make us a natural hub for driving this expansion. In decades to come we can be exporting knowledge and expertise, and importing carbon for storage from around the world. With support from Government, there is a great potential for CCS to become an industry of the future that the UK can be proud of, enabling us to create green jobs and reach net zero by 2050.

3. ARE BUILDINGS EVIL?: RETHINKING RESPONSIBILITY IN THE CONSTRUCTION INDUSTRY

John Cryer MP and Prof. David Coley

John Cryer MP

Prof. David Coley

In industrialised nations, buildings are typically responsible for 40% of carbon emissions. There have been attempts for decades to reduce their energy use, with only modest success. In general, these efforts have been based on logical augments backed by quantitative analysis. Given the small progress made, it would seem this is an unsuccessful tactic. In this essay, we suggest a different approach. We are aware of the damage climate change is already doing to the infrastructure and livelihoods of those in the poorest nations. Given we know how to build, and have built, exemplary low energy buildings, our failure to make this the norm might be viewed as an almost deliberate stance. Our inability to inculcate change appears to have overruled moral concerns. We know from other deep changes in society that the trigger is often a popular movement, or demand. Such demands are often aided by being able to classify the object or behaviour as lying one or other side of a line separating the acceptable from the unacceptable. We hence suggest an alternative way to accelerate change in the construction industry is to view buildings, or elements of buildings that increase the energy consumption beyond the minimum, as not just unfortunate - but as simply unacceptable and or even ugly. This moves the agenda from an unsuccessful quantitative one based on U-values and kgCO2, to a moral and aesthetic one.

The dictionary definition of evil is generally configured as the opposite of good. Our purpose here is urgent in the asking – are buildings evil? We suggest it might be useful to view buildings differently – to consider them from a moral rather than purely aesthetic or functional perspective. We ask, what would happen if we saw poorly performing buildings or elements of buildings as morally unacceptable and by definition, ugly, rather than just inefficient? In short, we want to foster a link between aesthetic, ecological and moral values.

DEFORNOCERE AND THE ASYMMETRIES OF CLIMATE IMPACTS

Buildings tend to be designed, then others are asked to tweak the design in order to mitigate to some minor degree the damage to the world the building will do. We have much evidence that this does not work. , , It is also clear the main focus is the immediate health and safety of those in or near the building, not those that will be most impacted by a changing climate. Those impacted can be thought of as a hidden population.

The western world has a history of hiding populations—women, ethnic minorities, etc. , , and there is a risk we do the same with respect to climate change. , , In order to make sure this population is included (along with the rest of humanity) right from the start of a project or when we analyse existing buildings, we introduce the notion of defornocere. We use this term to describe buildings, or elements of buildings, that are harming others and that we believe should be seen as unacceptable or even ugly due to this harm.

There is something deeply asymmetric about whom climate change will most impact, and who has caused the problem. It is unquestionably true that those who live in wealthy, energy intensive societies will be safe from the worst impacts of climate change for a while, and those who emit the least will suffer the most, and suffer first. Yet asymmetries also play out within nations, where the wealthiest in society are responsible for the most emissions but the costs are placed on communities that are more vulnerable.

Such injustices can be too easily forgotten in technocratic or aesthetic discussions about the size and shape of building glazing. It is worth wondering why issues such as the gender pay gap, modern-day slavery, the north-south divide, wealth distribution, access to health care, equality etc. are discussed largely within the framework of morality, yet the energy efficacy of buildings is relegated to an engineering issue?

ENERGY USE IN BUILDINGS

If we look at where in an industrialised society carbon emissions come from, we find that around 40% are associated with heating, cooling, lighting and other activities in our buildings.[16] Making the built environment the largest contributor to climate change, not, as is often assumed, industry or transport.

For new build, it would seem reasonable to assume that with the invention of modern materials and techniques such as loft insulation, cavity walls and double-glazing, energy consumption per metre-squared must have fallen. Figure 1 shows the current mean energy use of a large number of schools in England as a function of the date of their construction. In general, a new school uses no less energy today than a 1920's school does today. This does not bode well if the main approach to reducing carbon emissions from the sector is via slightly more aggressive building regulations (codes). There has been more progress with domestic properties in the last few years, but even here the suppression of energy use has been modest, and only recent (Figure 2).[17] In addition, we don't need buildings that use a little less energy, we urgently need to apply a totally different philosophy and to make the jump to buildings that use almost no energy.

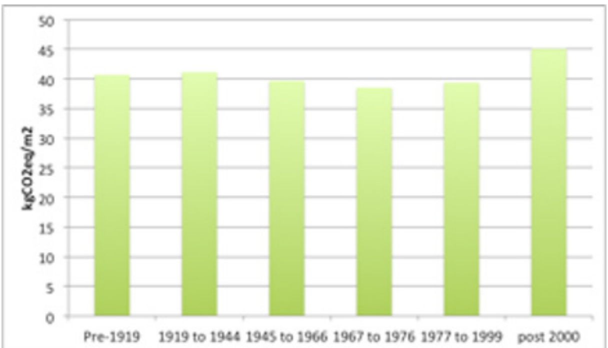

Figure 1. Mean current energy use (in Carbon units) of 1267 Schools in England and Wales as a function of the date of their construction.

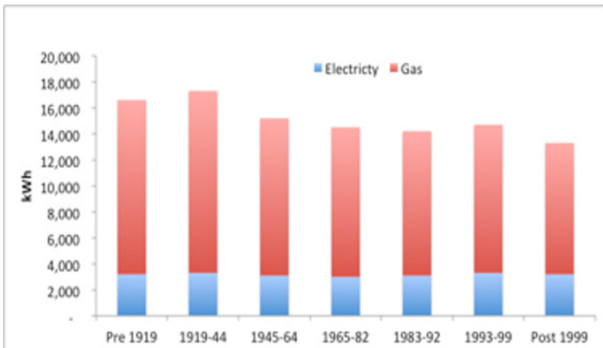

Figure 2. UK domestic consumption as a function of the age of the property. Data from Dept. for Business, Energy and Industrial Strategy, National Energy Efficiency Data-Framework (NEED). Data available from https://www.gov.uk/government/statistics/national-energy-efficiency-data-framework-need-report-summary-of-analysis-2018.

Much has been written on the reason for this lack of progress and its measurement[18,19,20] In the following we present the issue of excessive glazing as an illustration of design that we think should set alarm bells ringing – and possibly generate a visceral negative response in a member of the public, a developer or an architect. The idea is to move the debate from a quantitative analysis driven by specialist engineers and software programs to in part a visual one, open to all, and covering many of the most important issues. We need the public to demand nothing but near zero-energy buildings, developers to set zero-energy briefs and architects to draw zero-energy buildings—and all because they find anything else unacceptable and representative of unacceptable practice. We need to shift to seeing anything less as a moral failure.

Even a triple glazed window loses ten times the heat as a well-insulated wall of the same area. Over-glazing is also one of the main reasons buildings need air conditioning. An estimate of the scale of the problem can be made through a quick calculation. A large cube-like fully (double) glazed building 100x100x100m high might lose 2.4MW via its windows when no one is in the building on a winter's night. This is equivalent to the mean consumption of 1,500 UK homes. As most of this consumption can be eliminated using moderately sized (triple glazed) windows rather than ribbon glazing, it is hard to see such profligacy as anything but immoral. Here we wish to promote the idea that such poor design is also unattractive due to its responsibility for driving climate breakdown. We want to encourage the viewer to spot the defornocere and see such buildings as ugly.

There are many other, easy to spot, issues from poor build quality, gaps creating air ingress, the excessive use of steel and concrete, ridiculous numbers of light fittings, to the lack of renewable generation. Figure 3 shows the entrance and café area of a building where low energy use was part of the brief. From a defornocere angle, two things strike the viewer immediately: the scale of the glazing and the artificial lighting. There are 101 lamps in this small area, and all are on—despite the ribbon glazing. At approximately 160m2 we can expect the heat loss on a winter's night from the windows in the space (many are behind the photographer) to be around 8 kW. This is about the same as 250 modern laptops—running all night. There is no need for an in-depth, engineering led, analysis to see that this is less than ideal. Being open to spotting defornocere is all that is required, and finding it unacceptable.

Figure 3. Café area of a university building while the brief was for a low energy design.

A MORAL DESIGN PROCESS

There are now over 65,000 extremely low energy buildings built and tested across the world, so it is worth reflecting on why these have succeeded yet not become the norm. We believe much of the answer lies in those purchasing, developing and designing buildings not yet finding anything but near zero energy morally unacceptable. Hence it is the job of Government to change this, and it is here that focus should be aimed—rather than incremental changes to the building regulations. Yes, such changes will be needed, but the flame of demand and expectation should be fanned simultaneously, and should be done via a storyline of morality.

This in turn generates a simple starting point for the purchasing of, financing of, and the designing of any building: State the maximum annual energy/carbon consumption for the building you think is morally acceptable. This is not just a technical question, but an ethical one.

The moral stance of society has changed greatly with respect to many issues since the UN's first report on the likely impact of climate change in 1990. This is evidenced by attitudes to race, sexuality, and gender. , , One building-related example is the removal from buildings of calendars of naked women from the 1970's and 1980's. At the time these would have been typical items on the walls of many a workshop, canteen, or office. Although part of the answer for their removal is that society's views about such items and the values they represent have changed, it is also true that they were removed because it was easy to do so—because they weren't holding the roof up. A poorly performing building cannot be removed so easily, or so cheaply. Given the reality of climate change, the acres of glass and poorly insulated walls, the miles of heating and cooling ducts, with which we surround ourselves, can all be seen as statements about our morals. If nothing else, we need to future proof our decisions about new buildings. We need to make sure we aren't constructing liabilities that will reflect badly on us for a long time to come, and that will leave us with high costs when we are forced by law to upgrade them. At some point the public will start to recognise what in architecture is profligate, what is unacceptable, what is defornocere, and this could create expensive liabilities for stockholders, and reputational liabilities for others.

STIMULATING CHANGE IN A LAGGING INDUSTRY

The tipping point at which poor building design comes to be seen as unacceptable may be closer than we think. A recent survey of over one million people in 50 countries showed 64% of the population think climate change is a global emergency. The Attenborough inspired kickback against plastic packaging shows how quickly public opinion can turn against practices previously considered the norm. A whole industry was left scrambling to try and adjust to new citizen and consumer sentiments. The construction industry risks being caught in a similar backlash if they do not change their practices. There is much more Government should be doing to stimulate this change.

As a minimum the Government should be ensuring all new builds are Passivhaus accredited as standard. This could be achieved by removing stamp duty or lowering council tax rates for accredited building. In Brussels, a carbon tax on electricity was used to give tax relief on new Passivhaus builds. Now developers don't build anything else, even though the tax subsidy has been reduced. To make it easier and cheaper to achieve such high standards, VAT relief could be offered on repurposed materials and triple glazing windows.

Using a mission orientated approach, the Government should work with industry to develop and roll out truly zero carbon buildings. An award should be launched to spur the development of zero carbon (proved in-use) building designs. Covid-19 recovery funding could support development of zero carbon affordable housing across the country – addressing the housing crisis whilst normalising new building standards. This could be facilitated by easing planning regulations for any zero carbon development.

Once such changes have taken place, the industry will be forever transformed. In Germany it is now more expensive to produce a double glazing window than a triple glazing – standards have changed and production and supply chains have irrevocably changed with them. At present, we are lagging far behind.

SUMMARY AND CONCLUSION

By emphasising the scale of harm buildings are starting to do, we have tried to build a case for initiating the design process with a clear demonstration of morality. To aid this we have introduced the concept of defornocere and shown how it can be used to reflect on the climate changing aspects of designs or buildings. With conflicts, water shortages and famine being increasingly associated with climate change, there is a direct link between profligate energy use and such impacts.[25,26] The question is, can we move to a position where we see issues of bad building design through the same moral lens we view the human suffering directly attributable to climate breakdown?

ACKNOWLEDGEMENTS AND DATA

Thanks to Sung Min Hong, UCL Institute for Environmental Design and Engineering, for the school energy data shown in Figure 3; Anush Poghosyan Hopes and Dan Lash for pointing us to the household energy data.

4. GREEN SKIES THINKING

Andrew Selous MP*


Andrew Selous MP

The climate change debate is sometimes bifurcated between technological optimists and advocates for approaches that reduce demand for a given product or service. This divergence is seen perhaps most starkly in debates about the aviation industry. In recent years, aviation has become the bête noire of many climate campaigners. The decision to stop flying has become an overt behavioural signal of one's commitment to combatting climate change.

Yet we live in a globalised world. Many people have families and colleagues spread across continents. Many more have become accustomed to having the whole world effectively on their doorstep for travel, adventure, and holidaying. The Covid-19 pandemic has shown that whilst it is possible to ground nearly all flights, this necessarily requires a shrinking of our social, professional, and cultural worlds. On top of this, huge job losses in major airlines emphasise the significant role aviation plays in the UK economy. The ambition of a thriving, but climate friendly aviation sector is clearly worth striving for. We should be encouraged by growing UK leadership on sustainable aviation. It is not for nothing that pioneering green aviation firm ZeroAvia relocated to the UK from the USA. In September last year, this company successfully completed the first hydrogen-electric passenger flight from Cranfield Airport.

In this essay I seek to map out some of the complications inherent in discussions and action on aviation emissions. I do this partly to provide necessary clarifications, but also to allow for an honest appraisal of what is necessary to accommodate the UK's aviation sector within our ever-shrinking carbon budget. The essay proceeds by making a series of clarifying points on key debates, before discussing how the UK can become a global leader in clean aviation. As I explain below, reaching net zero emission in aviation will be a case of developing and scaling up new technologies, but also keeping demand growth under control. It is a case of and/with, not either/or.

CO_2 VS NON-CO_2 EMISSIONS

Dealing with aviation emissions is complicated by the fact only 35-40% of the overall warming associated with aviation comes from CO2. The remaining 60-65% is from non-CO¬2 greenhouse effects.[1] These effects are much shorter-lived CO2, and their overall warming effect is less well understood. Most emissions from flights occur high in the atmosphere, increasing their warming effect. These combined issues bring a larger level of uncertainty when defining the overall climate impact of aviation compared to other sectors.

Ultimately, all greenhouse gas emissions associated with aviation must be reduced, but there is good reason to place CO2 centre stage. The longevity of CO2 means that near linear relationship exists between cumulative CO2 emissions and global mean temperatures.[2] However, any approach to address carbon emissions from aviation must also consider the impact on other greenhouse gases.

Emissions from UK aviation have not grown since 2005, despite a 25% growth in passenger numbers. Stable emissions should be applauded, however the longevity of CO2 in the atmosphere, coupled with a high plateau in aviation emissions mean it is still a significant contributor to global warming. Even if aviation emissions are not rising, the accumulated atmospheric CO2 related to aviation is still increasing annually. It is therefore imperative the aviation sector achieves carbon neutrality as soon as possible – even then, we will require significant permanent carbon capture in the following years to draw down the CO2 already emitted.

* with scientific advice from Professor David Lee of Manchester Metropolitan University

DOMESTIC VS INTERNATIONAL EMISSIONS

A second confusion when discussing aviation emissions arises from how they are attributed to different countries and reflected in different targets. The norm in international negotiations is to account for emissions on a territorial basis. This means that international aviation, as well as shipping, are not deemed to be the responsibility of any given state. Though this is the convention, robust methodologies exist to attribute emissions from international flight to a given state. There is therefore no barrier to the UK integrating its contribution to international aviation into its targets. The recently announced UK Nationally Determined Contribution explicitly excludes international aviation, as is the norm – however, the UK has shown leadership by setting the target higher than the assumed domestic target for 2030 to reflect the exclusion of international aviation (68% reduction vs 64% reduction).

Following advice from the Climate Change Committee – most recently in the 6th Carbon Budget advice - the UK has declared that international aviation emissions will now be included in all emissions reduction targets.

DOMESTIC POLICY VS INTERNATIONAL AGREEMENT

Aviation is a classic ‘global’ industry, with many emissions being generated within territories different from the aircrafts home nation, or not within any nation at all. Similarly, airlines operate in a globally competitive marketplace. There is significant potential for ‘carbon leakage’, where policy moves in one jurisdiction drive airlines to increase their activities in alternative jurisdictions, leaving no overall reduction in emissions. For this reasons, it is often argued that climate policy for aviation must be coordinated and delivered at an international level, and that unilateral action by individual states may be counter-productive. Issues of carbon pricing, fuel standards and decarbonisation targets will be most effective if the global industry is on a level playing field.

To date however, efforts at generating an international agreement consistent with net zero emissions by 2050 have produced disappointing results. The CORSIA agreement operated by the International Civil Aviation Organisation commits only to limiting emissions to 2019 levels through to 2035. The scheme has three flaws. First, the agreement only stretches to 2035 - there is an urgent need for a net zero consistent strategy stretching to 2050. Second, the agreement only aims to keep emissions at 2019 levels, not to reduce them. This is problematic for reasons set out above. Finally, the target is achieved entirely using offsets, most of which are ‘avoidance’ offsets. The verifiability and additionality of international offsets is variable and requires close monitoring.

The UK must continue to play a constructive role in driving for an international agreement and expansion of the CORSIA programme. However, many of the technological and demand reduction measures explored below can only be supported and delivered at the domestic level. The UK aviation industry has already made a commitment in 2020 to deliver net zero emissions by 2050. Achieving this will require a supportive policy framework combined with ingenuity and creativity from the sector. To date, UK policy has focused on match funding for industry initiative aiming to develop sustainable aviation fuels and other technologies. The Government have the opportunity in the upcoming Sustainable Aviation Strategy to set out a fuller policy framework.

TECHNOLOGY VS DEMAND REDUCTION

With all these pieces in place, we can now move on to specific approaches to addressing aviation emissions. I will start with technological solutions. These come in three basic forms – the first is efficiency improvement through both aircraft design and airspace innovations. Second, is the use of alternative fuels such as biofuels and synthetic fuels, known as Sustainable Aviation Fuels or SAFs. Finally, is the use of electrification, or electrification with hydrogen. Through a combination of these approaches, a large amount of aviation emissions can be addressed.

Though electrification gets significant attention, conventional fuel efficiency innovations have accounted for much of the progress so far and will likely do so for some time yet. However, ultimately alternative fuels and power sources will have to reach mass market in the longer term if we are to create a thriving, carbon neutral aviation sector. There are a number of projects running in the UK to create alternative aviation fuels from sources including landfill waste. By 2035 there is the potential to have 14 plants making sustainable fuels across the UK, helping economic growth and creating over 13,000 jobs. These would bring at least £2.5 billion of economic value to the UK through the generation of the fuel, the jobs and economic and export opportunities.

To date however, the industry has made limited progress on meeting targets for integrating alternative fuels. There are a number of reasons for this. Most importantly, many alternative fuels will only become cost-competitive and be rolled out if driven by a carbon price. The carbon prices predicted to be generated through the international CORSIA scheme will not get to the necessary level to drive fuel-switching for another 10 to 15 years. Alongside funding to support R&D and infrastructure for the production of SAFs, the UK will have to look closely at options for making sustainable fuels cost competitive if they are to become a significant part of the fuel mix in the coming decades.

Another exciting area of technological development is in the use of hydrogen to power aircraft. As mentioned above, ZeroAvia recently completed a successful flight with a hydrogen-electric passenger plane. Moving towards hydrogen could see airports become hydrogen hubs - entirely run off this potentially zero-carbon fuel. This would bring addition benefits for the climate and air quality by removing fossil fuels from airport coaches, taxies and employees cars.

However, even in the most optimistic scenario for technological development, the Climate Change Committee have made clear that demand management of some type will be required. A number of options exist to achieve this. The Climate Assembly commissioned by the BEIS Select Committee found support for a frequent flyer levy to curb demand.

Even with a dedicated strategy addressing both technological and demand led approaches, the Climate Change Committee anticipate aviation emissions of 23 MtCO2e by 2050. This will require nearly half of anticipated carbon capture and storage capacity by this point to bring the sector to net zero emissions. How the costs of the need for emissions removal is distributed is a key question for the aviation sector in the coming years. Any mechanisms that sees the cost reflected in ticket price may have an added impact through demand reduction. However, excessive curbs on demand will hamper the profitability of the sector, limiting the scope for investment in technological improvements.

Navigating these issues requires carefully thought through policy. This necessitates collaborative working between the Government, industry and researchers at UK Universities. The industry has been innovating for years and is ready to pay their part. The Prince of Wales has challenged the Whittle Laboratory at the University of Cambridge to make sustainable aviation a reality by 2035. The final part of the puzzle is clear steer from Government. The upcoming Jet Zero sustainable aviation strategy provide the perfect opportunity for Government to set the framework for achieving the goal of a thriving, clean aviation sector.

5. DRIVING THE ELECTRIC VEHICLE REVOLUTION

Lilian Greenwood MP and Prof. David Greenwood

BACKGROUND AND DRIVERS FOR ELECTRIFICATION OF TRANSPORT

Lilian Greenwood MP

Prof. David Greenwood

Prior to the coronavirus pandemic, we could already see accelerating adoption of electric vehicles (EVs) – driven by a mix of regulation aimed to mitigate climate change and improve urban air quality, and increasing consumer appreciation of the powerful, smooth and quiet driving experience. In real terms though, they still represent less than 1% of the cars on UK roads.

Whilst the coronavirus pandemic has resulted in devastating personal and economic impacts, it has also caused us to challenge some of our preconceptions. The public has experienced clean air as a result of reduced transport and industrial emissions. People have taken to their bikes in record numbers and with the trials of rental e-scooters there's a real opportunity for them to replace car and public transport usage for short journeys - at least in good weather. Many roles previously thought of as being only possible from an office environment have successfully transitioned to home working, and online shopping with home delivery has significantly increased.

These behavioural shifts, along with the persistent drivers of air quality and climate change reinforce the shift to EVs.

WHY AREN'T MORE PEOPLE BUYING AND/OR USING ELECTRIC CARS?

Repeated surveys of car buyers have stated that three factors dominate the buying decision for an EV – cost, range, and availability of charging infrastructure. These three factors are highly interrelated as will be seen.

Electric cars are more expensive to make than conventional vehicles. The engine is replaced by an electric motor and power electronics that cost a similar amount, but the necessary additional large battery can add 30-50% to the total cost of the vehicle parts. The vehicle range is directly related to the size (and cost) of the battery – long range batteries can deliver 300+ miles of range, but at a part cost of around £18,000. Smaller batteries are proportionately cheaper, but require more regular recharging. At present, purchase incentives are provided in most countries to mitigate the additional technology costs on the vehicle.

To overcome these barriers to adoption, and reduce the need for long term incentives, two things need to happen:

- Vehicle charging needs to become widespread, predictable, and easily accessible
- Batteries need to get better and cheaper
- (a third possibility would be to accelerate the banning of sale or use of petrol and diesel (ICE) vehicles as the Government has now chosen to do, but this could have unintended consequences discussed below)

BUILDING A UK CHARGING NETWORK

Many options exist for charging of EVs, and they are used interchangeably according to the circumstance. There is no one-size-fits-all solution, and neither is one likely to emerge.

Where a private garage or driveway is available, vehicles can be charged at home at low power – typically overnight. On-street home charging could deliver similar functionality, but users cannot guarantee availability. Workplace charging can also be done at low power as the vehicle is usually parked for many hours. As 98% of journeys in the UK are less than 50 miles, these charging methods can easily deliver for the majority of journeys without the need for rapid public charging.

For those without access to these methods, fast charging at a motorway service station or local amenity is likely to be required. Given that average driving distances are circa 20-25 miles per day, a 200-mile range EV would typically require charging for around 1 hour once every 8-10 days whilst the user goes shopping or exercises.

For longer journey exceeding the range of the vehicle battery, rapid charging at a motorway service station (or similar) will be required. This type of charging in particular can unlock greater adoption of EVs by removing the barrier of range. To achieve it will need investment not only in the charging stations, but also the high power electricity supply needed to run it – and it is the latter (partly a result of current regulation) which is often the biggest barrier.

The UK public EV charging infrastructure is expanding at a reasonable rate, but it remains an "early adopter" experience – the motorist needs to be a member of multiples schemes, have apps on their phone, and carry multiple payment cards and/or key fobs. This must be simplified to provide an acceptable mass-market experience – with users able to easily roam across systems. Ideally, these facilities should become bookable so drivers can leave home confident that a charger meeting their needs will be functional and available when they arrive to use it.

Getting this right will mean battery sizes in EVs can get smaller – delivering maybe 150 miles real world range rather than 300+. This will make the car significantly cheaper to purchase and use, bringing EV technology within the financial reach of the mass market without the need for large purchase incentives.

STIMULATING DEMAND FOR ELECTRIC CARS

Whilst increased interest in EVs is noted above, the economic impact of the 2020 pandemic is likely to result in a significant reduction of vehicles sales, which in turn will deprive vehicle manufacturers of the revenues and profits they rely upon to invest in R&D and new model development. Existing mechanisms to support such development (like APC and FBC) could be strengthened and used to ensure continued investment in competitive zero carbon future technology even in the face of difficult market conditions.

Measures to increase demand for new vehicles, such as purchase incentives for EVs, scrappage schemes, reduction in first year Vehicle Excise Duty and changes to company vehicle taxation could assist with this, as well as consideration of how government procurement may be used more creatively. Ideally as many of these new vehicles as possible will be EVs or at least hybrids, but generally speaking, taking older vehicles off the road and replacing them with newer ones – even ICE vehicles, will produce measurable benefits , and would make the car industry more able to invest in competitive future technology. Care must however be taken not to inadvertently damage social mobility by making transport more expensive for those on lower incomes who are unlikely to purchase or use a new electric car and are more likely to own a second hand ICE vehicle. Public transport, which provides a viable alternative to vehicle ownership in some places became very difficult in light of coronavirus and people may remain wary of taking the bus, tram or train for some time to come.

ALTERNATIVES TO THE CAR

One significant new opportunity arising from the behavioural shift we have observed from the pandemic is the use of bikes, e-bikes and e-scooters in place of cars for short urban and suburban journeys. Government provided emergency funding for 'pop-up' cycle lanes and other temporary infrastructure and the legalisation of rental e-scooters in certain locations. Until recently, these types of vehicles were illegal for use on roads or cycle paths – yet they offer the possibility of swapping an expensive 1500kg car for a cheaper 15kg EV. Done well, this could improve congestion, emissions, and parking problems in cities and suburban areas – but without proper regulation and infrastructure provision this could result in major road safety issues, littering of pavements and unsustainable disposal of aged or damaged scooters. Doing this right means looking carefully at cycle lane provision and junction design, only allowing use on-road in areas where this is safe (and not 40mph dual carriageways for instance) regulating for safe and sustainable vehicle designs, and promoting public safety through training and PPE. The current rush for deployment risks adverse results, which could set back the effort by many years but the potential benefits warrant significant effort to achieve safe and sustainable deployment.

TAKING UK ECONOMIC BENEFIT FROM THE SHIFT TO ELECTRIC CARS

The car industry is important to the UK – employing over 800,000 people, generating £82bn of turnover, and accounting for over 14% of total UK export of goods. More than 30 manufacturers build over 70 vehicle models in the UK, supported by a supply chain of over 2500 component suppliers.[37]

The UK already has a strong history of EV manufacturing, with the Nissan leaf, built in Sunderland being one of the biggest selling European models. To retain and grow this industry, it must be able to invest in EV technology and manufacturing here in the UK. This has three steps; retain the car industry in the face of post-Brexit trade rules, enable UK car companies to invest in new technology and new (electrified) models, and enable battery manufacture and its supply chain to locate and be competitive in the UK. Mechanisms are in place to deliver these three priorities, but given the post-pandemic economic situation, these may need reinforcing.

Done well, we will protect our existing car industry and grow an additional battery industry worth £5-10bn/year, creating new employment in supply chains which could significantly exceed the jobs and value lost as the UK ICE industry reduces in size.

We must also think ahead to the end-of-life challenges and opportunities – investing in a battery recycling infrastructure, allowing us to reclaim the valuable materials used in the battery, and ensuring that these products cannot cause environmental problems through inappropriate disposal. This in itself can create a valuable industrial opportunity as between one and two million cars per year are scrapped in the UK.

THE ROLE OF REGIONAL AND NATIONAL POLICY AND REGULATION:

To conclude, the unusual circumstances in which we find ourselves gives rise to an opportunity not to bounce-back to where we came from, but to bounce forward to a cleaner and more prosperous future. To get there, policy makers in particular should consider measures to:

- Maintain and strengthen current measures to encourage EV purchase and use – providing consistent policy direction and framework against which the public and industry can make long term decisions
- Stimulate demand for new vehicles – and preferentially for electric and plug-in hybrids
- Support R&D and new product development for electrified vehicles and their component technologies
- Build a convenient, affordable, reliable and interoperable EV charging infrastructure
- Develop plans for safe and sustainable deployment of e-scooters and the innovations which will follow them
- Retain and grow automotive manufacturing in post-Brexit UK – including battery manufacture and its supply chain, plus a responsible and effective EV battery recycling industry

With concerted and co-ordinated effort by policy makers at national, regional and local levels, as well as working closely with the auto and energy industries, we can deliver clean air, mitigate climate change, and create jobs and prosperity for the UK.

6. ACHIEVING NET ZERO EMISSIONS FROM THE UK TRANSPORT SECTOR BY 2050: THE ROLE OF FUEL CELL ELECTRIC VEHICLES

Alexander Stafford MP and Laurie King/Yagya Regmi

Alexander Stafford MP

Laurie King

Yagya Regmi

BACKGROUND

The UK transportation sector currently accounts for 34% of carbon dioxide emissions (CDE); the largest proportion emanating from road transport.[38] Significant improvements in internal combustion engine efficiencies combined with the introduction of battery electric and hybrid vehicles (BEVs and HVs) have recently reduced CDE (119.6 Mt in 2019) below the 1990 levels (125.4 Mt). Since 2016, there has also been a decline in the number of new diesel car registrations, alongside a reduction in CDE emissions (2.8%).[39] Despite these encouraging advances, net ownership of ultra-low emission vehicles accounts for only 0.7% of licensed vehicles in the UK. These statistics highlight the urgent need for a significant and accelerated approach in transforming the UK's transportation sector to enable us to meet the 2050 Net Zero emissions targets.

WHY IS THE TRANSPORTATION SECTOR ADDICTED TO FOSSIL FUELS?

Petroleum and diesel fuel are still preferred in transportation due to the significant advantages that fossil fuels provide. These include an accessible infrastructure, affordability of internal combustion engines, rapid and convenient refuelling, and vehicle range. The perceived abundance of fossil fuels has also led to their dominance in transportation. Understanding the convenience of fossil fuels is necessary if we are to build a landscape that encourages a population-level shift in the entire network to meet Net Zero 2050 targets. Alternative technologies must either be associated with advantages to the consumer over existing technologies, or be mandated by government, in order for acceptance of the new technology.

In this essay, we highlight some of the advantages of hydrogen fuel cell electric vehicles (HFCEVs) with examples of where this technology has the greatest potential and greatest ease to help meet the Net Zero Targets for the UK transportation sector.

HYDROGEN FUEL CELL VEHICLES

A fuel cell (FC) is an electrochemical device that combines hydrogen and oxygen to generate electricity – powering a vehicle's electric motor or charging a battery. Heat and water are the only waste products from a hydrogen FC. Oxygen is sourced from the air, but hydrogen must be manufactured requiring an energy input. HFCEVs coupled to sustainable hydrogen production hold the tantalising possibility to revolutionise not only the transportation sector, but also the entire energy landscape, decarbonising industrial processes such as fertiliser production, as well as residential and industrial heating.

Unlike state-of-the-art battery vehicles, HFCEV refuelling times and driving ranges are comparable to that of petroleum and diesel engines and thus the consumer habits (number of vehicles per household, refuelling scheduling) need not change. A typical HFCEV car can be refuelled in 5- 7 mins, with a range of 300-500 miles. HFCEV heavy goods vehicles (HGVs) are currently being developed with refuelling times of 15 min and ranges of 500-750 miles, again matching both the range and refuelling times of existing HGVs.[40]

EARLY ADOPTION OF HFCEVS IN THE UK

HFCEVs are still in their infancy worldwide and in the UK, but several major UK groups have committed to introducing hydrogen bus and taxi fleets in the near future. In the UK today, there exist two leading FC manufacturers (Intelligent Energy and Ceres Power). A total of 20 UK-based companies are known to be developing FC technologies, with a further 13 developing materials for FC components.[41] Only a handful of HFCEV personal vehicle models are commercially available (Toyota Mirai, Honda Clarity, and Hyandi Nexo), with >13,000 vehicles on the road around the world, and >140 HFCEV cars, scooters and vans in the UK.[42] There are also only 15 hydrogen-refuelling stations in the UK. Examples of recent uptake in the UK include the taxi firm Green Tomato Cars (London-based service founded on the concept of clean air quality) who operate a fleet of 50 HFCEVs, and Jo Bamford, the new owner of Wrightbus, who has recently announced plans to roll out 3,000 HFCEV buses in the UK by 2024.[43] There are also plans to introduce HFCEVs in several UK cities, including Aberdeen, Birmingham and London.[44] A recent announcement in April 2020 by Arcola Energy Ltd and Optare Group Ltd revealed plans for a new Metrodecker H2 bus for the UK and international market. With the entire bus to be manufactured in the UK, the Metrodecker H2 bus is scheduled to enter service in 2021.

The two primary hurdles for wider adoption are the higher cost of hydrogen vehicles and fuel, and a lack of hydrogen infrastructure tailored to the transportation sector.

CHALLENGE: THE COST OF HFCEVS

Although hydrogen vehicles and fuel are more expensive than conventional vehicles, two major areas where HFCEVs may provide a cost-effective solution that can significantly reduce carbon emissions are in warehouses and freight vehicle fleets.

The largest fleet of HFCEVs today is the >25,000 forklifts deployed in warehouses of Amazon and Walmart (USA).[45] This early adoption was driven by both the required zero-emission at the point of use (preventing exposure of workers to pollutants) coupled to an economic difference favouring the lower operational costs associated with FC technology relative to BEV. The lower costs are due to a difference in the time taken for battery replacement (for charging) relative to the 2-3 minute refuelling HFCEVs, leading to higher productivity for warehouses operating 24 hours a day, 7 days a week. Such return-to-base fleets requiring round-the-clock operation are expected to drive the uptake and establishment of HFCEVs and the associated refuelling infrastructure.[46]

Analogous to an internal combustion engine, the size of the fuel tank dictates the HFCEV range, not the engine size. This seemingly subtle fact has significant consequences when powering large vehicle such as heavy goods vehicles (HGVs), ships and aeroplanes. In the case of a BEV, one must double the size of the battery to double the vehicle range (energy storage). Conversely, to double an HFCEV range, one must double the size of the storage tank, not the fuel cell. One argument commonly made is that BEVs offer higher energy efficiencies over HFCEVs, and hence, BEVs will always outcompete FC technologies. Although these efficiency claims are true, because a BEV will necessarily become increasingly heavy as the number of batteries increase to extend the range, the vehicle weight will increase and accordingly there will be a reduction in the vehicle efficiency. Several companies have invested in HFCEVs for HGVs, including a partnership in Switzerland with Hyundai Motor (1600 by 2025), and in the US, Nikola (>13000 FC trucks pre-ordered).

CHALLENGE: INFRASTRUCTURE FOR HYDROGEN GENERATION, STORAGE AND DISTRIBUTION

Infrastructure for hydrogen generation, storage and distribution in the UK is currently at a scale where the technology does not benefit from an economy of scale, contributing to high prices for the consumer.

The majority of hydrogen production is today based on fossil fuel technologies resulting in CDEs. While alternative carbon-free technologies exist (electrolysers) to produce "green hydrogen" from renewable energy sources, these technologies are currently more expensive than hydrogen manufactured from natural gas. However, the UK is home to several electrolyser manufacturing global leaders, including ITM Power who recently announced plans to open the world's largest electrolyser factory (1 GW per year) in Sheffield. Furthermore, UK-based Johnson Matthey is a global leader in the supply of catalysts used in hydrogen technologies.

Hydrogen distribution in the UK is mainly managed through on-site production, dedicated short pipelines, and tube trailers by road.[48] Hydrogen can be stored as condensed gas, as liquid under extremely low temperatures or converted to another liquid (ammonia or methanol). It is also possible to store and transport hydrogen using existing fossil fuel infrastructure, such as salt caverns, pipelines, tankers and ship liners when pressurised or liquefied.

While establishing a far-reaching hydrogen distribution network across the UK remains a challenging proposition, there is significant interest in decarbonisation of industrial and residential heating gas through fuel switching from natural gas to hydrogen. For example the recent and significant investment in HyNet, a ground-breaking project with the aim for the North West to become the UK's first low carbon industrial cluster by 2030.[49] The £70m project (including government investment) will couple hydrogen production with carbon capture technologies, resulting in minimal carbon emissions. While there is an important difference in the hydrogen purity requirements of FCs and such industrial and heating uses, the large scale of these projects represent significant steps in establishing hydrogen distribution networks that have the potential to unlock investment and technological engagement in hydrogen for the transportation sector.

CONCLUSIONS AND OUTLOOK

Worldwide and across the UK, fossil fuels today dominate the transportation sector due to the significant advantages they currently offer and their perceived abundance. Commercial HFCEVs are still in their infancy, but they have very recently received growing attention with various UK groups committing to the introduction of hydrogen bus and taxi fleets. Although hydrogen vehicles and fuel are more expensive than conventional vehicles, two major areas where HFCEVs can already provide a cost-effective solution that can significantly reduce carbon emissions are in warehouses and freight vehicle fleets. The infrastructure required for HFCEVs (hydrogen generation, storage and distribution) in the UK is currently at a scale where the technology does not benefit from an economy of scale, contribution to high prices for the consumer. However, if appropriate energy and industrial strategy policies can be implemented to take advantage of the significant financial and intellectual competitiveness present in the UK, hydrogen technologies could act as the catalyst for long-term prosperity and sustainability. The UK Hydrogen Strategy is a step in the right direction with its focus on the transport applications of hydrogen.[50] Building on this, the UK can transition to a hydrogen economy, through investment from industry and government, and emerge as a world leader with a huge range of technological and economic advantages.

7. FROM OIL TO SOIL: REGENERATIVE AGRICULTURE AS A CLIMATE SOLUTION

Barry Sheerman MP and Dr Anna Krzywoszynska

Barry Sheerman MP

Dr Anna Krzywoszynska

INTRODUCTION – THE NEED FOR LAND USE CHANGE AND REGENERATIVE AGRICULTURE IN THE UK

Land use is critically connected with climate change. Land use is a significant contributor to overall greenhouse gas emissions, while the effects of changing climate are also leading to further land degradation.[51] Changes to land use can contribute to limiting the extent of climate change, and are needed to create land-based ecosystems which are resilient to climate disruptions. A change in the way land is used in the UK is crucial to achieving its ambition of Net Zero emissions by 2050. To maintain a strong agricultural sector while also achieving climate mitigation and environmental objectives a fundamental change to land use in the UK is needed. This includes increasing the productivity of UK agriculture, afforestation and rewilding, and restoration of peatlands.[52] The vast majority of UK land is devoted to food-growing purposes, especially in England, making interventions in agricultural land use particularly important.[53]

UK agriculture is a significant emitter of greenhouse gases, estimated to account for 10% of all emissions in 2017.[54] This figure should however be revised upwards. These statistics do not account for emissions embedded in the production of additives used on-farm (for example, 40% of emissions behind a loaf of bread are due to the manufacturing of ammonium nitrate fertilisers).[55] They also do not account for greenhouse gas emissions directly from land due to oxidation of soil organic matter. In 2013 nearly 5% (22.29 Mt CO2e) of all UK emissions came from this source.[56] This is particularly pronounced in UK peatlands, which are emitting around 3Mt of CO2 annually.[57] Overall, it is crucial to embed climate change mitigation in UK's land use change strategies.

Adopting regenerative agriculture can significantly limit direct and indirect emissions linked to agricultural land use. Regenerative agriculture seeks to optimize nutrient use through crop rotations, and so has the potential to limit fertilizer-related emissions. It further aims to build up the levels of soil organic matter; as a result, it has the potential to limit direct emissions from land by halting the oxidation process described above. There is also some indication that under regenerative agriculture some soils can become carbon sinks, further reducing net agricultural emissions.[58] Most importantly, increasing soil organic matter ensures long-term sustainability of soils' environmental and productive functions. It does this by increasing the soil's resilience to physical and biological stresses,[59] particularly in the context of climate change impacts.[60]

WHAT IS REGENERATIVE AGRICULTURE?

Regenerative agriculture presents a systemic approach to land use, with key elements including limiting tillage, maintaining soil cover (with living or non-living organic material, e.g. cover crops or crop residue), fostering plant diversity (e.g. through more complex rotations), and (re)integrating livestock into arable farming.[61] The key objective of regenerative farming is improving the quality of soil, mainly through increasing soil organic carbon.[62] To achieve its benefits regenerative agriculture requires a systemic shift in farming systems, not just stand-alone adoption of some practices. Regenerative agriculture differs from conventional agriculture in its focus on biological rather than agro-chemical tools, and in its focus on enhancing soil health as an objective of farming.

In comparison to conventional agriculture, regenerative agriculture is more knowledge intensive, as it requires an active adaptation of broad principles to the specific conditions of each farm through observation, experimentation, and shared learning. Other related terms include climate smart agriculture, conservation agriculture, and holistic livestock management. Through a focus on using organic matter (e.g. compost), objectives of regenerative agriculture link well with the objectives of circular economy approaches. Regenerative agriculture could also be considered to fall within the broad category of agroecological farming approaches.[63]

Adopting regenerative agriculture has multiple benefits beyond limiting emissions from land. These include: positive impacts on biodiversity and environmental services such as flooding prevention; linking urban and rural areas through organic matter cycling and other elements of circular economy; and enhancing food security of the UK by ensuring a resilient resource base. There is also some evidence that regenerative agriculture is a source of positive self-identity for farmers.[64]

WHAT IS THE UPTAKE OF REGENERATIVE AGRICULTURE IN THE UK?

Regenerative agriculture is not currently wide-spread in the UK. A recent survey of 300 farmers and growers in the UK found that while there is a notable uptake of singular sustainable soil management practices (e.g. no-tillage, cover crops, and manure applications), the uptake of regenerative agriculture systems, which combine a number of practices, is low.[65] The uptake of these singular practices, such as reduced tillage, which appears to be growing, may provide a basis for developing more systemic approaches.[66]

BARRIERS AND OPPORTUNITIES FOR ENHANCING UPTAKE

Adoption of regenerative agriculture is location specific and requires adaptation of broad principles to farming systems and agro-ecologies. Research has found that participation in peer communities support the systemic transition;[67] however, few farming groups and organisations exist in the UK today which are dedicated to regenerative agriculture. Lack of access to tailored knowledge support, lack of training as part of agricultural education, barriers to investing in new machinery (e.g. no-tillage drills), and short-term tenancies are known barriers to adoption of regenerative agriculture by farmers.[68] There is a strong call from within the farming community for more farmer-led research within this area.[69]

POLICY CONTEXT AND OPPORTUNITIES

NEW PAYMENT SCHEME

The Agriculture Bill's commitment to 'public money for public goods' is crucial for underpinning a shift towards a more agroecological approach. Though its implementation, it needs to effectively support conversion to, and management of, regenerative and agroecological whole farm systems which can provide significant carbon sequestration and reduce emissions. There is a risk that farmers could 'cherry pick' public goods from the list, and it is unfortunate that the Act is not stronger in terms of the whole-farm approach (although equally, it is understood that not all farmers will be able to deliver across the range of public goods, depending on what they produce, where their farms are located, and so on).

FOCUSING ON SYSTEMIC CHANGE

As the aim of regenerative agriculture is to increase soil organic matter, some have proposed linking increases to payments for public goods. However, soil organic matter changes over long periods of time, the potential for increases depends on the soil type, and soils can become saturated and plateau; this could produce unfair advantages. As a result, linking payments to adoption of systemic practices (which include other carbon store approaches such as agroforestry) is more appropriate.

REGULATORY BASELINE

To support low-carbon farming the current baseline of standards and regulations needs to be strengthened through additional compliance rules, use of existing legislation (e.g. UK adoption of the rules under the Nitrates Directives) and the introduction of new policy (e.g. the Clean Air Strategy), and a strengthened enforcement regime to ensure compliance.[70] There is concern, that the still delayed Environment Bill, is creating a 'regulatory gap'.

NATURE BASED SOLUTIONS

Nature based solutions such as agroforestry and farm woodlands, peatland soils, hedgerows need a strong boost via Environmental Land Management Schemes, financial support and other policies (productivity and ancillary, skills and training, R&D). Existing farm woodland, farm trees and orchards should be protected and managed for nature and carbon sequestration.

OTHER POTENTIAL AREAS FOR POLICY ACTION

In addition to ongoing policy changes, there are a number of other areas that require Government action to increase the uptake of regenerative agriculture practices in the UK:

- Supporting better linkages between urban and rural areas on organic matter cycling.
- Supporting the creation of peer-to-peer soil-health oriented learning – small grants for farming groups; Support for farmer-led research, along the lines of the Innovative Farmers model, and affordable or free advice for hard to reach or smallest farm businesses so they can access advice.
- Support for investments on machinery and other small capital requirements needed for low impact farming and trading.
- Stronger enforcement of soil degradation legislation (currently under Basic Payment Scheme) and certainly no lowering or removal of soil regulations.

8. NATURE'S OWN CLIMATE SOLUTION: TREE PLANTING AND THE ROAD TO NET ZERO

Daisy Cooper MP and Dr Cat Scott

Daisy Cooper MP

Dr Cat Scott

INTRODUCTION

The UK has signed up to the Paris Agreement commitment to keep global temperature rise below 2oC this century and to pursue efforts to limit it to 1.5oC. To do this, scientists from the Intergovernmental Panel on Climate Change (IPCC) estimate that we will need to halve our emissions of carbon dioxide in the next decade and reach net-zero emissions by the middle of the 21st century.[71]

The scale and pace of change required is unprecedented. Greenhouse gas (GHG) emissions from every sector must be almost entirely eliminated during the next 30 years – in some sectors, like agriculture and aviation, this will be extremely challenging. Another contribution to reaching net-zero is to enhance processes that take greenhouse gases out of the air, either naturally or artificially; this might include tree planting and forest restoration, direct chemical capture of carbon dioxide from the air, and the production of bioenergy with carbon capture and storage.

In the UK, the Climate Change Committee estimate that between 30,000 and 50,000 hectares of new woodland will need to be created every year until 2050 to contribute to net-zero by taking up around 5% of the UK's current GHG emissions.[72] One hectare is roughly the size of a rugby pitch, so that's 30,000 to 50,000 rugby pitches. The current Government target is to create 30,000 hectares per year across the UK by 2025.

WHY TREES?

Planting and restoring trees and woodlands will play a critical role in tackling both the climate and biodiversity crises society currently faces. Trees are one of the most effective and cheapest ways of taking carbon out of the air. Trees also provide a number of other environmental and social benefits.[73]

In addition to being a vital habitat for the nation's wildlife, access to trees and green spaces has a positive impact on our own physical and mental well-being. Spending time in green spaces has been shown to have positive impacts on blood pressure and to produce levels and patterns of chemicals in the brain that are associated with low stress.[74,75], In towns and cities, trees play a role in reducing our exposure to poor air quality by collecting gases and particles on their leaves and bark.[76] By slowing the rate that rainwater reaches our rivers, upland tree-planting and woodland regeneration can also help to reduce flood risk.[77] Achieving our afforestation targets is vital for climate, for people, and for nature, and makes connections between our towns, cities and our countryside.

HOW DOES IT WORK?

Carbon dioxide is taken in during plant photosynthesis. Some of this carbon is stored long-term in tree branches, trunk, roots and surrounding soils, whilst the rest is released back into the air as the forest respires. The rate at which carbon is taken up by a woodland depends on the tree species present, how old it is, the local climate and how it is being managed. Most of our knowledge comes from commercially managed forests; there's still a lot we don't know about the rate at which less intensively managed woodlands will take up carbon.

Carbon sequestration is the net amount of carbon taken out of the air by a woodland each year, carbon storage is how much carbon the woodland has accumulated over time.

THE CURRENT SITUATION

The UK has one of the lowest levels of woodland coverage in Europe. A mere 3.2 million hectares of woodland gives us just 13% tree cover, against a European average of around 44%.[78,79], This UK wide average masks a discrepancy between the nations. Scotland has canopy cover of 19% and Wales 15%, with England and Northern Ireland at only 10% and 9% respectively.

Despite the UK being home to only three native conifer species, conifers occupy around half of our woodland area, with a single non-native species (Sitka spruce) dominating. A lack of genetic and species diversity can put forests at risk from pests, diseases and future climate changes. Our broadleaf woodlands are more varied, with birch, oak, ash and sycamore dominating.

In recent years, UK planting rates have fluctuated between highs of around 13,000 hectares (e.g., 2019-2020) and lows of less than 6,000 hectares (e.g., 2015-2016) per year;[3] even the highest recent planting rate is less than a third of the Government's new target (13,000 hectares per year compared to the recommended 30-50,000 hectares per year).

OPPORTUNITIES

The CCC's recommended 30,000 – 50,000 hectares of new woodland per year to 2050 would increase the UK's tree cover from 13% to between 17 and 19%. When new woodlands are created, trees tend to be planted at around 400 to 4000 trees per hectare, so this target represents somewhere between 360 million and 6 billion new trees in total over the next 30 years across the UK. This is equivalent to planting between 30,000 and 550,000 trees per day. These numbers sound incredible, but are absolutely achievable given a single skilled tree planter can plant up to 4000 trees a day – many more if aided by modern technology.[80]

Historically, responsibility has sat with local authorities to monitor their tree cover and to develop targets and strategies to create new woodlands, without any over-arching strategic planning or guidance. This is now starting to change.

The March 2020 budget included a £640 million Nature for Climate Fund to provide public money for public goods and increase planting rates in the UK to 30,000 hectares per year by 2025. How this money will be used was set out in the recently announced England Tree Action Plan. This is a welcome start but more public funding will be needed not only for planting trees, but for managing them too; we must ensure that this funding is used to achieve the greatest possible level of public benefit. These benefits include:

Trees and nature for well-being: The ongoing coronavirus pandemic has brought home the importance of people's well-being and the extent to which both physical and mental health can be supported by access to nature within a short-distance of home. In addition to woodlands, street trees and trees in parks and green spaces can offer huge social, amenity and cultural benefits due to their accessibility.

Connecting cities and towns with the countryside: Recent research shows that flowering plants are sometimes better pollinated in urban than in rural areas,[81] highlighting the need for a tree strategy that delivers nature corridors to help connect our cities and towns with the countryside.

Employment: Investment in woodland creation, in addition to peatland restoration, could create scores of jobs in tree planting and maintenance, the tree nursery supply chain and biosecurity at a time of economic uncertainty.

Woodland composition: Whilst increasing woodland area in the UK we have the opportunity to diversify, restore the balance between native and non-native species, and increase the resilience of our forests. Areas of former native woodland are able to regenerate naturally if there is a supply of seeds available from other nearby woodlands and new saplings are protected from herbivores.[82]

Multi-purpose land: Agroforestry involves planting trees on crop or pasture land and, along with hedgerow expansion, represents a way to introduce more trees to the landscape whilst continuing to farm the land. Introducing agroforestry to 10% of the UK's current farmland, and restoring our hedges, could draw down the equivalent of 1% of current GHG emissions.[83]

Timber production: Although the majority of tree planting in the UK is for commercial purposes, we do not produce enough timber to meet our domestic demand;[84] strengthening our domestic timber supply could therefore reduce our reliance on imports from overseas.

CURRENT BARRIERS TO TREE PLANTING

Funding: Whilst there are a number of grant schemes through which tree planting can be supported, funding is not always easily accessible to landowners and land managers.[85] For landowners that are new to tree planting, navigating this process can be a real obstacle. In addition, whilst funding is available for trees and tree planting, the long-term planning, maintenance and management of woodlands is currently under-funded.

Availability of land: Clearly, not all land is suitable for tree planting. Whilst some land is physically unavailable due to existing infrastructure there are other types of land, specifically peatlands, on which tree planting can be detrimental to carbon sequestration and storage. Some strategic sites for large-scale woodland creation can be identified based on current data, whilst other areas will need local site surveys first to better understand what is already there and may need to be protected. Tree planting must always be balanced with the protection of other nature rich habitats.

Long-term nature of change: To create woodland, landowners and land managers must make the choice to permanently alter the use of their land. For some land managers, the short-term nature of their tenancy means that a long-term change like planting trees is not possible. For others, the assurances and incentives to do so are not yet in place.

Regulations: Common Agricultural Policy laws historically adopted from the EU limited tree planting for farmers in receipt of direct subsidy; the new Environmental Land Management scheme provides a vital opportunity for reform.

In May of 2021, the Government released a Tree Action Plan for England. This Action Plan takes the necessary step of setting an England specific target of trebling tree planning rates by the end of the current Parliament. Yet this Plan only lays out how previously announced financial support would be spent. There is much more that needs to be done to ensure that tree planting is expanded over the longer term and that new trees are planted in the right place and well managed to the benefit of everyone. This should include additional financial support in the upcoming Budget and Comprehensive Spending Review.

OUR RECOMMENDATIONS

We recommend the following:

- **Central government funding is needed to support woodland creation, as well as the planting and maintenance of trees outside woodlands.** Local authorities should be financially supported to monitor and maintain existing woodlands and deliver an increase in tree canopy cover. Any tax breaks or grants that might be offered to private investors or companies must not inadvertently incentivise tree-planting in the wrong place: lessons must be learnt from tree planting on Scottish bogs during the 1970s and 1980s, which took years and millions of pounds to put right.
- **We must take steps now to ensure the future security of our woodlands and the tree supply chain.** This will require additional research into the resilience of our native species under a changing climate, early investment in tree nurseries to ensure adequate supply, and strict biosecurity to reduce risk of importing pests and diseases. Whilst challenging, scaling up the woodland creation and landscape restoration sector will create much needed employment.
- **We must learn as we go by coordinating research, development and adaptation across all four nations of the UK.** Site specific information should be collected and combined with existing data to inform decisions about where to establish new woodlands; specifically, an inventory of valuable grassland habitats would help to align their protection and any new woodland creation plans. Through this iterative process we can develop a world leading knowledge base that can be exchanged with our closest neighbours.
- **Woodlands must be accessible.** Less than one-third of UK woodland is publicly owned. People are more likely to visit green spaces if they do not need to travel far to reach them and the most frequent visitors report the greatest benefits to their mental well-being . As the England Tree Action Plan is implemented, we must keep in mind the overarching goals of delivering for the climate, nature and people, as well as linking up our cities and towns with our countryside.

9. SLOWING DOWN FAST FASHION: CIRCULAR ECONOMY PRINCIPLES IN PRACTICE

Lisa Cameron MP and Dr Mark Sumner

The Fashion industry may not seem an obvious choice for a discussion on reducing carbon emissions, especially for the UK, a country where much of our fashion is manufactured in developing nations using materials sourced from such diverse countries as the USA, Australia, Mongolia, East and West Africa, South Africa and India.

Lisa Cameron MP

Dr Mark Sumner

However, the UK is the home of the Fast Fashion phenomena and virtually everyone on the planet engages with fashion in one form or another. The fashion industry is one of the largest in the world, employing in excess of 300 million workers and worth up to $2.5 trillion and responsible for 7% of global trade.[88,89] Estimates have suggested the fashion industry is responsible for up to 5 billion tonnes of CO2e - possibly 10% of global emissions.[90] As a truly global industry, achieving net zero for the fashion industry would be a remarkable achievement and one that would make a significant contribution to minimising the impact of climate change for our generation and for future generations.

AN INDUSTRY OF INDUSTRIES

The fashion industry is not a single industry. The garments in our wardrobes are the result of complex connections between a number of diverse and equally large industries. Raw materials are produced from the agricultural industry, with cotton, wool, cashmere, and leather the products of farms and herders across the developed and developing world. Man-made materials are derived from the oil industry with polyester, nylon and, elastane being common plastic fibres. Other man-made fibres started life in the forests in the USA, South Africa, and Asia and were converted into dissolving pulp ready for the production of regenerated cellulosic materials such as viscose and modal.

Fashion is heavily reliant on various chemical industries; highly concentrated acids used to drive the regenerated cellulosic process, bleaches to whiten fabrics, and dyes to create the colours that set fashion trends. Heavy engineering makes its contribution to build the machines that create the fabrics in our clothes - including denim dyeing ranges worth many $10's million and the size of football pitches.

At the end of life, when a garment is no longer needed, the re-use and recycling industry, often referred to as the shoddy industry, plays its part in cleaning up fashion waste and recycling materials for use in mattresses, building material, and the automotive industry.

Within this amalgamation of industries that make up fashion is the UK's retail industry, worth over £32 billion and supporting in excess of 800,000 jobs.[91]

The complex interactions of the industry is intensified by the nature of the extended supply chain that links all of these individual parts together. A truly global supply chain that is in continual flux and is opaque and difficult to navigate. It is in the supply chain where the majority of the sustainability issues for the industry reside. Almost every aspect of modern slavery can occur throughout the supply chain, with ethical labour risks much higher in cotton production than in garment factories. In general, the carbon footprint of the retail component of the industry is so small it's normally ignored, as is the footprint for garment making. The carbon footprint of shipping products around the world is a less than 8% of the total emissions from industry.[92] The vast bulk of the carbon footprint for the industry is in the supply chain, so to achieve net zero, this is where attention is needed.

MANAGING NON-UK EMISSIONS

The bulk of a garments carbon emissions are the result of decisions and activities in the supply chain used to source the raw materials and convert those materials into the cotton t-shirts, polyester dresses or wool suits purchased in the UK. Any given garment may have a supply chain that touches a multitude of countries and regions. A Fairtrade cotton t-shirt may have its cotton grown in Senegal, yarn spun in Pakistan, fabric produced in China, and be made in Sri Lanka.

To achieve reductions in carbon emissions requires collaboration across the supply chain and exchange of knowledge and data between each production site. Importantly, there needs to be alignment between the UK objectives to reduce carbon, and the targets of manufacturing country and that of the local communities. In many cases, the UK demands for carbon reduction can compete with the local basic needs such as cleaning drinking water, poverty alleviation, and economic growth.

Research carried out the University of Leeds on implementing the UK's Modern Slavery Act demonstrated that UK Government policies and UK retailer action must be sensitive to the objectives of host countries, local communities, and workers in the supply chain. Strategies for carbon reduction need to be co-designed with the supply chain for mutual benefit of the UK as actors further up the chain. Furthermore, according to research carried out by the MISTRA project, the single most effective way to minimise carbon emissions from the industry would be to ensure the power generation of production counties are decarbonised. For example if China were to reduces its dependency on coal or India to move away from the use of biomass.[93] It is questionable whether UK retailers have any influence to demand sovereign states reduce their reliance on these fuels.

PRIORITISING CLIMATE CHANGE

The sheer scale and diversity of the fashion industry means that, although carbon is a global issue the industry must address, there are many other equally important environmental and social issues to be considered. Fashion consumes vast quantities of water for cotton production. The dyeing of fabrics uses up to 215 billion tonnes of water as well as discharging millions of litres of polluted effluent.[94] The industry is also associated with the use of over 3000 different chemicals as fertilisers, pesticides, plasticisers, dyes, PFCs, and other chemicals linked to environmental harm and human health issues. As an industry that is strongly linked to the agricultural industry, it is exposed to a full range of modern slavery issues and many aspects of worker health and safety violations.

Taking action to reduce greenhouse gas emissions and the impact of climate change is vitally important. But taking action on climate change must not be to the detriment of taking action on other environmental and social issues. A dyehouse in India can reduce its carbon footprint with no cost to its production capacity and workers in the factory by 'turning off' its effluent treatment plant. However, this results in untreated, highly contaminant water being discharged into the water supply for the surrounding communities in that region.

It is important that any action taken to achieve net zero is done so in an informed way and in co-operation with the supply chain to avoid unintended consequences of a UK centric focus solely on carbon.

THE ROLE OF THE CONSUMER

How the consumer cares (washing, drying, and ironing) for their garments can also have a significant impact on carbon emissions. Eight million tonnes of CO_2e was associated with UK garment care in 2016.[95] How long a consumer uses a garment can also impact on its carbon footprint; extending the useful life of a garment by nine months and therefore delaying new purchases of garments, can reduce the carbon footprint by 8%.[96] If the garment is donated to charity for reuse at the end of its life it can also help the industry reduce its footprint; a 3% saving in carbon could be achieved if there is a 10% increase in old clothing being diverted from landfill to reuse.[97]

However, the single biggest opportunity for consumers to reduce their contribution to the industry's carbon footprint is by significantly reducing their consumption of clothing which means a shift away from fast fashion. The UK consumer purchases over 26kg of clothing per year, more than most other European countries and the average utilisation (how long a garment is used for) has fallen by 36%.[98,99] We are buying more, and using clothes for a shorter time, and as a result over 1.3 million tonnes of clothing waste is created in the UK every year. Approximately 300,000 tonnes of this goes into landfill.[100]

Reducing consumption will reduce the carbon footprint of the supply chain and reduce other environmental impacts, and it will reduce waste in the UK. However, a unilateral shift to a slower fashion model has consequences for workers and developing countries who rely on export dollars generated by fashion. It would also impact UK clothing retailers and brands, currently worth in excess of £35 billion per year and over 800,000 jobs (pre-covid).[101] This at a time when the impact of the Covid-19 pandemic is wreaking havoc on the clothing retail market.

THE PATHWAY TO NET ZERO

In a market currently driven by low prices and poor quality, relying on the short-termism of market dynamics will not achieve the change that is required at the rate which the world demands it.

Positive progress has been made by some responsible brands, with initiatives such as SCAP demonstrating that the industry can reduce its carbon footprint. For each tonne of clothing sold, CO2e emissions and water consumption for SCAP members has been reduced by 13% and 18% respectively.[102] But these members are selling more tonnes of clothing each year, negating this progress.

Much more must be done, and can be done through best practice, new technologies and new business models that align with consumers need for fashion, whilst ensuring that this fashion is delivered in a more sustainable way. A clear message from many within the industry is the need for progressive legislation and nationwide policies to incentivise best practice and punish poor practice.

Progressive application of extended producer responsibility to the industry, could be used to reward those retailers taking action to tackle climate change, expose those that are not. This could also reduce clothing waste going to landfill whilst generating funding to facilitate the development of new technologies and business models that address carbon emissions.

SECTION 2: Whole System Challenges

10. UK'S INFLUENCE ON GREENHOUSE GAS EMISSIONS

Bill Esterson MP and Prof. John Barrett

Bill Esterson MP

Prof. John Barrett

BACKGROUND – UK'S GHG EMISSIONS

The UK has legally committed to reduce Greenhouse Gas Emissions (GHGs) to net zero by 2050.[103] Therefore, the level of GHGs in 2050 will need to be equal to the level of emissions sequestrated from the atmosphere. In line with the United Nations Frame Convention on Climate Change (UNFCCC) the UK reports the level of GHGs that are emitted within the territory of the UK, known as "territorial emissions".[104] The net zero target is based on this principle. In addition to the net zero target in 2050, the UK has also committed to interim carbon budgets defined over 5 yearly blocks, to ensure that the pathway to net zero recognises the need to reduce cumulative emissions.[105] Evidence from climate scientists is clear that it is not the end goal that is important but the total GHGs emitted over a given time period that results in climate change. If the UK were to follow a linear path to net zero by 2050, emissions would need to reduce by at least 8% a year.[106] Arguably, the UK should be exceeding this rate as between 1990 and 2017, the UK has only decreased its GHG emissions by more than 8% in one out of the 28 years.

GHG emissions in the UK's territory have reduced, on average, by 1.5% a year between 1990 and 2050.[107] However, GHG emissions also occur in other countries to satisfy UK consumption. A complimentary approach, known as consumption-based emissions, takes into account all of the embodied emissions associated with what we consume.[108] That includes the embodied emissions in imports, minus the embodied emissions of exports. When including the embodied emissions of imports and subtracting the embodied emissions of exports, the UK has reduced its GHG emissions, on average, by 0.6% a year.[109] The biggest reason for the gap between our reduction in territorial and consumption emissions is that the UK has become increasingly reliant on imports. When there has been an increase in demand it is more likely to be met by imports than by an increase in domestic production. In 2017, GHG emissions embodied in imports were roughly equivalent to all of the emissions occurring within the territory of the UK.

INFLUENCING GHG EMISSIONS IN THE UK

The current territorial approach to measuring our emissions and establishing targets elicits a specific policy response. This narrow framing means policy is focused on reducing emissions occurring in the UK, whilst ignoring how the UK could reduce global emissions to maximum effect. For example, there is considerable evidence that resource efficiency strategies have more potential than industrial energy efficiency measures, however a significant majority of the emission reduction would occur outside the UK.[110] If a country is purely focused on reducing territorial emissions, policy options could be ignored despite contributing to significant reductions in global emissions.

As the UK has increasingly become a service based economy, a greater proportion of the emissions associated with UK consumption have been offshored. Policies that merely reduce territorial emissions are producing diminishing returns. There is a significant possibility the UK continues to reduce territorial emissions while becoming increasingly reliant on imports - thus outsourcing emissions to other countries. This does not mean that territorial emissions are "wrong", but they are not complete. Depending on the question we're asking, we should use the correct accounting framework. If the UK is concerned with influencing global GHG emissions as much as possible then it requires accounting systems that provide evidence on the most effective strategies to achieve this, irrespective of whether the emissions occur within the UK or not. Multiple complimentary accounting frameworks are required and this should include both territorial and consumption based accounting. Without multiple accounting systems, we could ignore some options for reducing emissions. Wherever the tonne of CO2 is emitted, it has the same contribution for global temperature rise.

POLICY RESPONSES

The UK has taken initial steps to consider the UK's consumption emissions. The Department for Environment, Food and Rural Affairs (Defra) publish the UK's consumption based emissions on an annual basis.[111]There are a number of Government strategies that could potentially reduce the embodied emissions of imports including the Resources and Waste Strategy and international trade investment aiming to deliver low carbon projects.[112] The Climate Change Commitee (CCC) who are an independent body with the statutory duty to oversee the UK's transition to net zero, have now committed to including the UK's consumption based emissions alongside the territorial figures in all their publications.[113] Their recent 6th Carbon Budget advice included specific recommendations on addressing the UK's consumption based emissions. However, there has still been no assessment of the policy options to reduce consumption based emissions undertaken by the UK Government. In fact, the UK Government has failed to publish a coherent strategy on how it will reduce GHG emissions to net zero from a territorial perspective, let alone from a consumption perspective.

We have outlined the additional policy options that could be considered to reduce the UK's consumption based GHG emissions below. Existing domestic policies will also have an effect on consumption emissions, however this effect will diminish as an increasing proportion of overall emission relates to imported products.

In reality, there are only three broad strategies for addressing GHG emissions. These include reducing carbon intensity, reducing energy demand, or carbon removal. Addressing embodied emissions in imports merely means extending our response to include them under these three broad approaches. This includes supporting key trading partners to reduce the carbon intensity of production, as well as changing our consumption patterns to reduce emission from domestic and international supply chains. The possible responses include:

- **International strategies** – e.g. import regulations and standards as well as trade agreements which aim to reduce carbon intensity in countries which have strong trade relationships with the UK.
- **Domestic strategies** – e.g. use, repair and remanufacture of products; circular economy and industrial symbiosis; changing consumption patterns, including diet; investment in new business models through the Industrial Strategy and infrastructure that allows changes in social practices and behaviour with the aim of reducing energy demand.

As the UK has decided to leave the largest single market in the world, it now has the possibility to establish individual trade policy with any country. Future trade agreements could be centred on reducing the carbon intensity of imported products to the UK through a range of measures. These measures include border carbon adjustments, product standards, and technology support. Border carbon adjustments would place an adjusted price on imported products to align imports with the carbon costs assigned to domestic production. They face a number of difficulties related to understanding the carbon content on imported products due to the complexity of global supply chains, legal challenges through the World Trade Organisation, and potentially limited impact if price of carbon in the domestic market is negotiable - as is the current situation. A positive example of progressive international policy is the recent announcement by the Prime Minister putting an end to the UK Government's direct support for the fossil fuel energy sector overseas.[114]

Domestic strategies should include ensuring the longevity of high carbon products from buildings to electrical appliances, shifting from goods to services, changing diets, circular economy and waste strategies, and reducing the consumption of the most carbon intensive products and services (such as aviation). Many of these strategies do now feature in the UK Government's Resources and Waste Strategy but lack ambition in terms of scale and timeline. Many of these policies would also deliver improvements in quality of life such as healthier diets, improvements in local air quality, and reduced costs for manufacturing companies. In terms of policy, product standards offer an excellent opportunity to reduce the embodied emissions in products.

All the strategies to reduce our consumption based emissions need to consider whether they are just, i.e. will they further exasperate or alleviate inequality. This involves ensuring that any policy costs are not placed on low income households which is currently the situation.[115]

RECOMMENDATIONS

- The UK Government should set a target for the UK's consumption based GHG emissions alongside the existing territorial target. This target should recognise the opportunities the UK has to influence its global emissions in line with global agreed climate targets.
- The Department for Business, Energy and Industrial Strategy (BEIS) should be jointly responsible with Defra to report on consumption based GHG emissions. These should be displayed alongside territorial emissions to ensure that offshoring is not seen as a policy success in reducing emissions. This would emulate the recent move by the Climate Change Committee.
- After the consideration of a target, the UK Government should produce a coherent plan with detailed policies to reduce the global impact of UK consumption. This should also include a strong recognition of the co-benefits of changing consumption patterns.

11. OVERCOMING THE BARRIERS TO A CIRCULAR ECONOMY

Ben Lake MP and Prof. Kerry Kirwan

Ben Lake MP

Prof. Kerry Kirwan

BACKGROUND

It is well recognised that the UK has an opportunity to grow and improve both profitability and productivity by transitioning to a more circular economy. In such an economy, materials and resources enter the UK system, flow around it for as long as possible before dropping out as some form of energy rather than going to landfill, air or sea. In order to achieve this, we need to examine how we process our resources with sustainability, waste minimisation and efficiency in mind. Product lifecycles must be optimised to generate more economic and social value including by recycling and/or reuse.

Transitioning from our current highly linear system to circularity is proving stubbornly difficult to achieve. It will requires a sea change in how we have historically sourced, processed, used and disposed of resources. There is a critical need for clear, evidence-based, implementation pathways, with broad underpinning research evidence that provides not only technical, technological and scientific advances, but also delivers the social, behavioural, cultural, ethical, environmental, economic, legal and regulatory understanding required to support a successful transition.

COVID-19 CONTEXT

It is clear that the beneficial environmental impacts that accrued as a result of the initial covid-19 lockdown highlighted and reinforced consumers' concerns over our general sustainability. Polls regularly show that many do not want to go backwards as things come back on line. Practical measures such as restrictions on travel and access to shops has increased interest in reuse and repair whilst showing that alternative approaches to working and living can reduce environmental damage and resource consumption.

Covid also exposed frailties in our traditional approaches to resources and their supply chains. Emergent geo-political issues threaten to further destabilise these supply chains and our access to critical materials on the global platform. The importance of achieving a circular economy is clearly critical in not only building resilience into our supply base, but also as part of the wider green post-Covid employment and economic recovery.

ACHIEVEMENTS TO DATE

There have been some limited examples of successful delivery of circular economy principles within the UK and further afield. Examination of these reveals some common features. First, a close (and often closed) transactional relationships between supplier and customer which provides clear and effective pathways for returns and replacement post-initial sale. This closed relationship enables (and incentivises) end of life options and alternatives to be taken into account at the very beginning of a product or service design rather than more traditional approach to bolting them on later in the process.

Second, emergent and proactive exponents of circular economy are often SMEs (small and medium-sized enterprises) that operate at a local level and are starting anew from a business perspective. They are often able to build brand reputation and customer base around their green credentials which gives them an advantage over more established companies. However, SMEs unfortunately, despite being success stories in their own right, do not represent a large portion of the overall UK resource footprint.

BARRIERS TO CHANGE IN MAJOR INDUSTRIES

Having identified that SMEs have shown great strides in implementing circular economy principles, it is important to understand what inhibits other players in the market. Discussion and investigations with companies has identified a number of key issues holding them back – we discuss each in turn here.

SIZE AND VERTICAL NATURE OF THE ORGANISATION

Larger, more layered organisations struggle to implement circular economy principles in practice as organisational layers dilute/inhibit effectiveness and change. Risk (or aversion to it) often prevents the necessary change from happening.

INVESTMENT LEGACIES AND RISKS TO FINANCE OR REPUTATION

There are well recognised risks to moving towards a circular economy approach in terms of costs, poor implementation and potential damage to reputation. These risks often inhibit action being taken as it is perceived that 'fast followers' may accrue greater benefit by learning from others mistakes. This can be compounded if new materials or processes are needed that are significantly different to what an organisation is used to working with (or has invested significantly in previously). Some sort of early adopter incentivisation may help break these barriers down.

SKILL SHORTAGE

Circular economy is a relatively new concept that has not yet developed a sufficiently large pool of individuals with the correct skill sets across the entire landscape to oversee and implement it in practice. UK government funding through UKRI is helping to address this barrier (e.g. through Centres for Doctoral Training).

LARGE AND DISPERSED GLOBAL SUPPLY CHAINS

Large companies tend to utilise large (or very large) supply chains that are another natural barrier to successful circular economy implementation. In some instances, visibility or provenance of materials only happens when they arrive at the factory gate and stops when it leaves. This means the accuracy of a product or services eco-footprint is often difficult to establish and therefore it is difficult to demonstrate direct benefits that could accrue. Using competitive pressures (rather than maintaining prolonged and significant individual relationships) is also a significant disincentive for suppliers to improve their environmental attributes as costs/quality will be overriding priorities to keep contracts in place.

THIRD PARTY SALES RELATIONSHIPS

Very often large companies are not directly in a relationship with their customers (i.e. sales are via wholesalers, stores or brokers) which means that the direct transactional relationship that can be found with SME's does not exist. This means producer or manufacturer involvement with a product or service is limited to when it leaves the factory gate, inhibiting timely and known return pathways at the end of life. End-of-life issues are normally dealt with by third parties for many sectors which is another significant issue for overall circularity.

PRIORITISATION OF PRIMARY PRODUCTS OVER SECONDARY

There is often an issue with consumer acceptance of second hand products, with them wanting to have primary products (i.e. brand new) as opposed to remanufactured/refurbished variants, despite them having similar warranties and guarantees. Paradoxically, this is particularly true for lower value items, however the practice is more acceptable for higher value (and theoretically therefore more risky investment) products such as electronics and vehicles.

SEPARATE PRODUCTION AND DISPOSAL/WASTE STREAMS

In order to enhance the circularity of a product or service, it is essential that end-of-life considerations are factored in at the initial design phase so that they have a clear and understood treatment pathway. Unfortunately many of the UK's end-of-life operators are third parties who are not part of the initial design process which results in many challenges for them such as effective separation of components/material, a clear understanding of the state of health of a component or product (which will influence its suitability for repair, reuse, remanufacture etc.) and even which other markets and/or supply chains could be supported with end-of-life products, components or materials. As such, many end-of-life products are purely treated for efficient recovery of specific valuable materials with energy production as a small bi-product. This means that many other potentially valuable resources are effectively destroyed as a result.

CONSUMERS NOT PREPARED TO SHARE BURDEN

Although the situation is slowly changing, consumers have traditionally resisted the burden of any direct cost increases that the circular economy could cause despite overwhelming recognition that the environment is suffering. For the majority of consumers, environmental responsibility remains a 'nice to have' performance criteria, rather than a critical consideration such as costs and maintenance. Fiscal policies have tried to incentivise consumers in many areas (e.g. solar panels and electric cars), but the long term and sustained change in consumer behaviour remains questionable at present.

LOOKING FORWARD

In order to transition towards a circular economy, we need the ability to understand, reconfigure and align business practices, supply chains and market structures. We also need to deepen our understanding of how people experience and engage with resources and products and what influences their behaviour long term.

The UK must address the implications of how new business models and approaches would be de-risked, financed and how these should interact within the general regulatory framework. Significant attention is also needed to consider the ethical, public acceptability and responsible innovation aspects from the beginning of a product or service life, rather than later in its development and/or deployment.

As always, significant consideration needs to be given to the risks and trade-offs associated with the circular economy. These include the consequences for certain sectors and employment levels, how circularity relates to product safety, considerations of environmental impact of new products and processes, and how risks can be mitigated (or first movers incentivised) to enable a stable and profitable business environment to mature.

12. ACHIEVING NET ZERO: DECARBONISING INDUSTRY

Des Browne (Lord Browne of Ladyton) and Dr. Gbemi Oluleye

Des Browne (Lord Browne of Ladyton)

Dr. Gbemi Oluleye

Decarbonising industry is among the most difficult challenges of the net zero transition. This transition requires action from the Government, but also action from within industry itself. It is a shared responsibility and will require an openness to change and the courage to do things differently. No single technology is going to do the job and there is not a simple policy fix. Industries of the future will need to innovate their business models to remain competitive in a global marketplace.

In this essay, we present a model for combining and prioritising among different decarbonisation approaches. This model can help businesses owners and policy makers navigate the net zero transition, whilst maintaining the competitiveness of UK industry.

Industrial processes, excluding power generation, are responsible for one-third of global energy use and 40% of global carbon dioxide emissions (CO2) emissions. These include emissions from heavy industry such as steel and cement production, as well as sectors such as electronics manufacturing. Eliminating industrial emissions would also go a long way to keeping global temperature increases below 1.5°C. Accelerating the decarbonisation of UK industry is important not only to satisfy the UK's 2050 target, but also to get us on track to meet the future carbon budgets and the UK's Nationally Determined Contribution submitted ahead of COP26.

But far from just being sources of pollution, industrial sectors are also at the core of developing low-carbon solutions. The goal is to reduce emissions from industrial operations whilst industry continues to supply transformational infrastructure and technologies needed to decarbonise other sectors like power, buildings and transport. The process industry also makes a significant contribution to the UK economy with a share of 17.4% GDP, providing employment to over 40,000 people directly and many more through supply chains. Decarbonising the industrial sector whilst ensuring it continues to thrive is vital for transitioning the UK to a green economy – yet so far progress has been painfully slow.

Much discussion about industrial decarbonisation focuses on the roll out of technological innovations such as carbon capture and storage (CCS). The lack of progress in developing these technologies to the scale necessary should instill a healthy dose of caution. They will have a role to play but cannot be relied on to do all of the heavily lifting. Also, resources are limited, and public finances are stretched. Every pound spent on expensive new technologies is a pound not spent on other existing opportunities and processes that are tried and tested. We want to focus less on individual technologies, and more on systems that businesses can use to decarbonise in the most cost-effective manner possible. Only when we embrace decarbonisation systems in the round can we achieve net zero whilst at the same time supporting thriving industries.

FROM SINGLE TECHNOLOGIES TO THINKING IN SYSTEMS

Any system to decarbonise a sector will require a series of concepts that in turn may utilise a range of technologies. Focusing on concepts for decarbonisation instead of single technologies is necessary, as a combination of technologies will be required in any given sector or industrial process. Achieving net zero within an industrial site or several sites within a region, known as a 'cluster', requires a combination of concepts, and their associated technologies. There are three main concepts that businesses can use.

MATERIAL AND ENERGY EFFICIENCY

Increasing efficiency means reducing material and energy demand for a given unit of output. For example, through the simultaneous production of heat and power (electricity), known as Combined Heat and Power (CHP). A wide range of technologies, both existing and under research and development, can contribute to greater efficiency in material and energy use.

SWITCHING TO ALTERNATIVE FUELS AND FEEDSTOCK'S

Fuel switching requires changing to lower-carbon fuels (e.g. hydrogen, biomass, synthetic methane) and switching to electricity. Feedstock switching involves material substitution, light-weighting and 'circular economy' interventions. Altering how the consumer uses products, including through shifts from goods to services and improving product longevity, can further reduce energy demand.

CARBON CAPTURE AND STORAGE (CCS)

CCS ultimately may be the only way to stop CO2 from some industrial processes (e.g. from making cement) from entering the atmosphere. While carbon capture technology has reached demonstration scale in the power sector, application in industry is less advanced.

PICKING THE RIGHT CONCEPTS

Implementing the concepts is not a one size fits all exercise. The industrial sector is diverse and includes manufacturing processes which range from highly energy-intensive steel production and petrochemicals processing to low-energy electronics fabrication. This diversity is reflected in the GHG emissions per sector and final energy use (Figures 1 and 2). Concepts for decarbonisation will be unique to each industrial sectors characteristics and location.

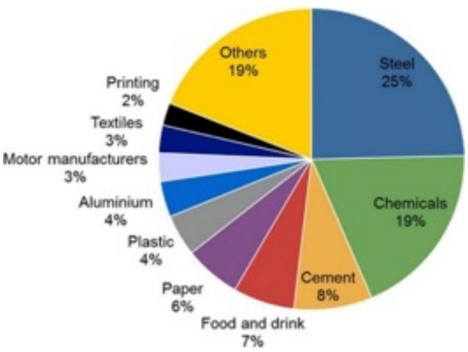

Figure 1. Greenhouse gas (GHG) emissions from UK industry. Source: https://onlinelibrary.wiley.com/doi/full/10.1002/wene.212

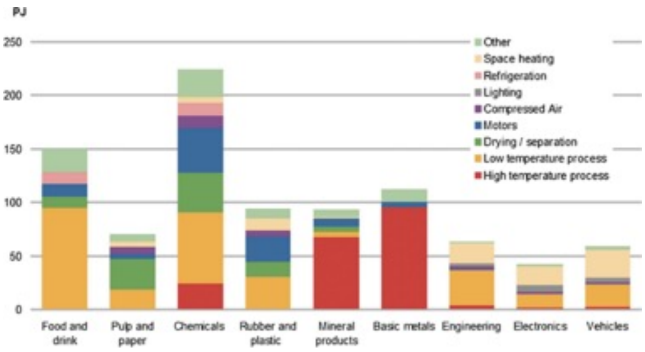

Figure 2. Final UK energy demand by industrial sub-sector and end-use. Source: https://doi.org/10.1016/j.apenergy.2017.08.010

To accelerate the transition, multiple concepts will need to be married together into an industrial decarbonisation system. Industrial decarbonisation systems, combinations of different concepts for any given site, create demand volumes for new technologies capable of driving down costs. A hierarchical ordering of concepts for any site can help achieve cost-effective decarbonisation. The hierarchy presented in figure 3 illustrates the idea of exhausting least cost decarbonisation concepts first in the creation of a decarbonisation system.

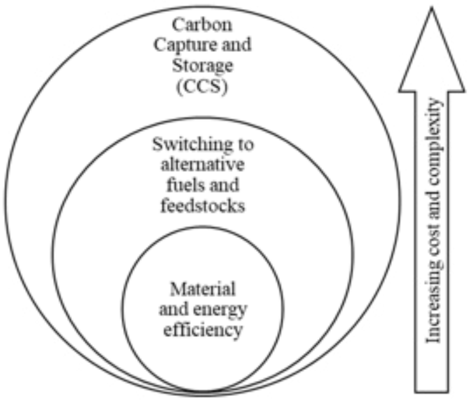

Figure 3. Hierarchy of industrial decarbonisation concepts within a system. Concept introduced by Oluleye. Source:https://doi.org/https://energypost.eu/decarbonising-industry-how-much-policy-driven-adoption-is-needed-to-let-the-market-take-over/

BARRIERS TO UPTAKE

The current level of adoption of decarbonisation concepts that actually can achieve radical reductions in GHG emissions is zero. This is due to five known broad barriers to adopting such concepts.

The first barrier is **financial** and arises from the higher capital and operating costs of concepts and associated technologies for decarbonisation. Primary process equipment has high initial investment costs with a pay-back period of up to 50 years, as in the case of cement plants. Such equipment also has a long design life of more than 20 years, as in the case of furnaces for the iron & steel industry.[117]

The second barrier is the potential **loss of competitiveness** resulting from the adoption of capital-intensive strategies. The products of energy intensive industries are traded in globally competitive markets. High levels of competition also tend to prevent collaboration on decarbonisation projects. Such collaborations are important for sharing Research and Development (R&D) risks and creating demand volumes to reduce the cost of capital-intensive technologies. Increased production costs in one region compared to another with less stringent mitigation targets will reduce competitiveness.

The third barrier is **technical**, covering challenges associated with delivering engineering solutions - especially the lack of tested and reliable disruptive technologies. Unaddressed technical barriers reduce both investor and end-user confidence in emerging technologies.

The fourth barrier is **regulatory uncertainty**. Uncertainty regarding future policy and regulation undermines investor confidence and further increases investor risks, which translate into higher costs of capital, and ultimately undermines the economic case for capital-intensive equipment.

A fifth barrier is associated with **industrial characteristics**. Conservatism in some sectors, implies new technologies need to be evolutionary rather than radical, or need first to have been established in other sectors, prior to adoption. Some industries typically operate in the business-to-business market. These industries do not have a direct relationship with consumers and as such pressure to improve their environmental performance is indirect. Consequently, improved environmental performance is difficult to sell at a premium.

Overall, if left unaddressed, the barriers above will reduce the achievable level of industrial decarbonisation by 2050. Addressing the barriers requires a focus on industrial decarbonisation systems, strong and robust policy support, and innovations in business models which set the competitive strategy of businesses.

Crucially, this cannot all come from Government. Businesses need to be proactive in planning for the transition. In the automobile sector, innovation is going beyond electrification. New models, such as 'mobility-as-a-service' are being developed and trialed. This is the type of thinking that we need to see from inside UK industry.

Policy interventions provide mandates and incentives to support decarbonisation since no single policy is ever a "silver bullet the diversity inherent in industrial sectors and processes implies that a comprehensive package of policies would be required. .Furthermore, given that 2050 is less than 30 years away, there is an urgent need to find the most efficient way to implement policy.

Several policy instruments exists to support a net zero economy in the UK: Research and Development (R&D) grants, R&D tax credits, Industrial decarbonisation and energy efficiency action plans and clean growth, fuel switching, industrial strategy challenge and clean steel funds. However, gaps still remain in the UK's industrial decarbonisation policy framework including market pull policy interventions to support full scale commercialisation. Additionally high-value policies like carbon pricing with border adjustments or government procurement of low-carbon goods can help create a market for low-carbon technologies and products.

As part of their Covid-19 response the Government has made some encouraging steps forwards. However, not enough focus, especially in the industrial sector is given to how business models can be improved to allow for disruptive innovation. There is a need for policies that allow new business models to be trialed and encourage a shift in mindset from businesses owners. Far from being a burden, such innovation could enhance industrial competitiveness if innovations in business models occur simultaneously with technical, policy and finance model innovations.

Corporate decision-makers and policymakers each have a part to play in hastening a sustainable transition to net zero industry. Simultaneous innovations in business models and policies can accelerate adoption of industrial decarbonisation systems while, at the same time, decarbonising UK industry and maintaining competitiveness.

SECTION 3: Delivery Challenges

13. LEVELLING HIERARCHIES: THE NEED FOR ARTS-BASED APPROACHES TO CLIMATE ENGAGEMENT

Lord Teverson and Dr Sam Illingworth

Lord Teverson

Dr Sam Illingworth

THE CHALLENGE

In June 2019 the UK Government legally committed to reducing greenhouse gas emissions to net zero by 2050. As a result, individuals, industry, and local and national governments will need to work together to bring about the largescale societal changes that such a target will require. However, the negative impacts of climate change from expert assessments do not align with those of non-experts, who perceive less of a threat, and are thus potentially less willing to take the drastic action that is needed.[118] As such it is critical that the UK public is effectively engaged in revisiting these expectations, and in developing strategies that enable the rapid societal and behavioural transformations that will be necessary in order to achieve net zero.

WHAT DO WE MEAN BY THE PUBLIC?

The UK public is in fact made up of many different 'publics', each of which have their own needs, experiences, beliefs, and values. As such, the idea of a one-size-fits-all engagement strategy for communicating any concept with the 'general public' is an inaccuracy.[119] Instead it is necessary to better consider the range of various communities, and the specific communication and engagement strategies that are most effective for working with each of these. This is especially true for the ways in which different groups react to, and engage with, topics related to anthropogenic climate change.[120]

There has been an up swell in public awareness and concern around climate change in recent years. Yet this is far from universal, and concern about climate change does not necessarily translate into an understanding of coming disruptive policy changes. There is still a clear need for extensive public engagement in the detail of the net zero transition. Some groups within the UK are known or expected to be under-reached and under-represented through typical approaches to public engagement. These groups tend to be those that are disadvantaged, or have traditionally been under-heard by wider society in some way; for example, people living with mental health needs, people living with disabilities, people with low socio-economic status, and people of faith.[121] Many of these groups have a relatively low carbon footprint but will be amongst the most affected by the negative impacts of climate change.[122] They are also often the least aware of such impacts or the policy responses required.[123] As such it is vital that these groups are sought out and engaged in developing an effective strategy to achieve net zero.

WHY SHOULD WE INVOLVE THE PUBLIC?

Effective public engagement with scientific topics should move away from a one-way model of communication (from expert to non-expert), and instead towards a two-way model of co-creation and participation.[124] Adopting such an approach grants agency, builds trust, and creates a platform for diverse solutions. In such a model knowledge can flow both ways, with those impacted by climate change and climate policy sharing vital insights necessary to create sustainable solutions.

Within a UK science and policy framework, many attempts at dialogue-based interactions have served more as a function for understanding public perceptions and attitudes, rather than as deliberative processes that feed directly into policymaking.[125] Though this trend is slowly being reversed with the upsurge in the use of citizens' assemblies and juries, there is still much further to go. Involving the public in the policymaking process for achieving net zero emissions will likely help overcome the political distrust that many associate with the government in relation to climate change and other scientific topics.[126] Outside policymaking, the development of public-specific dialogue is also more likely to engender personal changes in behaviour, in part because of the agency that it affords.

By neglecting to involve the various different 'publics' that make up the UK, any engagement initiative fails to account for the expertise of these so called 'non-experts'. Whilst these publics might not be employed in either scientific research or policymaking, they still have a large amount of tacit and lived expertise that is potentially vital for creating effective mitigation strategies. For example, faith groups will be able to both share their own strategies in developing stewardship of the Earth and highlight any solutions that would be inappropriate/ unlikely to be adopted by their communities.

LEVELLING HIERARCHIES

Creating an environment in which there are perceived experts and non-experts can create a hierarchy of intellect, which can act to block dialogue. It is therefore necessary to create an environment in which these hierarchies can be levelled, and through which the different understanding and opinions can be fully expressed. Creating such an environment also helps to build trust, and to ensure that those affected are drivers of change rather than recipients of actions to which they had no ownership.[127]

In June 2019, six Select Committees of the House of Commons called a citizens' assembly to understand public preferences on how the UK should tackle climate change because of the impact these decisions will have on people's lives.[128] This Assembly reported back in September 2020, with incredibly useful insights for policy makers looking to develop robust, but socially acceptable climate policy.[129] The 'Climate Assembly UK' was successful as it went some way towards levelling hierarchies and creating a pipeline to policy and action. However, such assemblies represent only one potential form of public engagement and can be limited in their capacity to involve and engage all different communities, particularly underserved audiences.[130]

A complementary public engagement methodology to that of Climate Assembly UK is the use of an arts-based approach to establish dialogue, build agency and trust, and co-create potential solutions. Such an approach is effective in that it helps to level hierarchies of intellect by creating a shared sense of vulnerability, removing the notions of 'experts' and 'non-experts', and instead creating a space in which all voices can be heard and acted upon. Examples of such an approach include the use of poetry,[131] participatory arts,[132] and film.[133] These methods have been utilised to engage various publics by monitoring, deliberating, and responding to their attitudes towards the negative effects of anthropogenic climate change.

CHALLENGES

Adopting an arts-based approach to public engagement is not without its challenges. Such interventions require significant resources, especially if they are to be done in a way that can help to influence policymaking and behaviours, and if a concerted effort is made to ensure that traditionally underserved audiences are appropriately engaged.

Finally, it is worth noting that even if an effective public engagement strategy is devised that creates a platform for all publics, levelling hierarchies, and granting agency and trust, it is no guarantee that the UK will achieve net zero by 2050.[134] This is why it is essential to also look beyond 2050, and to create a platform in which all voices can be heard, both now and in the future.

Acknowledgements

The All-Party Parliamentary Climate Change would like to thank the sponsors of this collection: Manchester Metropolitan University, Durham University, the University of Leeds, the University of Sheffield, the University of Warwick, the UKRI Natural Environment Research Council and UCL Public Policy; and everyone who contributed to the roundtable discussions that informed these essays.

[1] BEIS, 2021. Energy Consumption in the UK (ECUK) 1970 to 2019. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/928350/2020_Energy_Consumption_in_the_UK__ECUK_.pdf

[2] Durham Energy Institute, 2021. Geothermal energy. https://www.durham.ac.uk/research/institutes-and-centres/durham-energy-institute/research-profile/current-projects/geothermal-energy/

[3] BEIS, 2017. Clean growth strategy. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/700496/clean-growth-strategy-correction-april-2018.pdf

[4] Imperial College and Frontier Economics, 2015. Research on district heating and local approaches to heat decarbonisation. https://www.theccc.org.uk/publication/element-energy-for-ccc-research-on-district-heating-and-local-approaches-to-heat-decarbonisation/

[5] Global CCS Institute, 2020. Global status of CCS 2020. https://www.globalccsinstitute.com/resources/global-status-report/

[6] Demanuele et al., 2010. Bridging the gap between predicted and actual energy performance in schools. https://www.semanticscholar.org/paper/Bridging-the-gap-between-predicted-and-actual-in-Demanuele-Tweddell/b375de752077a7eac70f79fb1ee67d135b021b4c

[7] Bordass et al., 2001. Assessing building performance in use 3: energy performance of probe buildings. https://www.tandfonline.com/doi/abs/10.1080/09613210010008036

[8] Menezesab et al.,2012. Predicted vs. actual energy performance of non-domestic buildings: Using post-occupancy evaluation data to reduce the performance gap. https://www.sciencedirect.com/science/article/abs/pii/S0306261911007811

[9] Beyrer et al., 2013. Global epidemiology of HIV infection in men who have sex with men. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3805037/

[10] Lindsay et al., 2008. Is his heroism hailed and hers hidden? Women, men, and the social construction of heroism. https://journals.sagepub.com/doi/abs/10.1111/j.1471-6402.2008.00455.x

[11] Maass and Clark, 1984. Hidden impact of minorities: Fifteen years of minority influence research. https://psycnet.apa.org/record/1984-23065-001

[12] Stern, 2006. Stern review: the economics of climate change. https://www.osti.gov/etdeweb/biblio/20838308

[13] Patz et al., 2005. Impact of regional climate change on human health. https://www.nature.com/articles/nature04188

[14] Schmidhuber and Tubiello, 2007. Global food security under climate change. https://www.pnas.org/content/104/50/19703

[15] Dow and Downing, 2011. The atlas of climate change: Mapping the world's greatest challenge. https://www.ucpress.edu/book/9780520268234/the-atlas-of-climate-change

[16] Climate Change Committee, 2013. Chapter 3: Progress reducing emissions from buildings. https://www.theccc.org.uk/wp-content/uploads/2013/06/CCC-Prog-Rep_Chap3_singles_web_1.pdf

[17] Evans, 2014. A detailed look at why UK homes are using less energy. https://www.carbonbrief.org/a-detailed-look-at-why-uk-homes-are-using-less-energy

[18] Gillingham et al., 2016. The rebound effect and energy efficiency policy. https://environment.yale.edu/gillingham/GillinghamRapsonWagner_Rebound.pdf

[19] de Wilde. 2014. The gap between predicted and measured energy performance of buildings: A framework for investigation. https://www.sciencedirect.com/science/article/abs/pii/S092658051400034X

[20] Almeida et al., 2010. A framework for combining risk management and performance-based building approaches. https://www.tandfonline.com/doi/abs/10.1080/09613210903516719

[21] Intergovernmental Panel on Climate Change, 1990. Climate change: The IPCC 1990 and 1992 assessments. https://www.ipcc.ch/report/climate-change-the-ipcc-1990-and-1992-assessments/

[22] Jeffrey et al., 2014. Social distance in the United States: Sex, race, religion, age, and education homophily among confidants, 1985 to 2004. https://journals.sagepub.com/doi/10.1177/0003122414531776

[23] Kite and Bryant-Lees, 2016. Historical and contemporary attitudes toward homosexuality. https://journals.sagepub.com/doi/10.1177/0098628316636297

[24] Donnelly et al., 2015. Attitudes toward women's work and family roles in the United States, 1976–2013. https://journals.sagepub.com/doi/full/10.1177/0361684315590774

[25] Connolly-Boutin and Smit, 2016. Climate change, food security, and livelihoods in sub-Saharan Africa. https://doi.org/10.1007/s10113-015-0761-x

[26] Kelley et al., 2015. Climate change in the Fertile Crescent and implications of the recent Syrian drought. https://doi.org/10.1073/pnas.1421533112

[27] Lee, 2018. The current state of scientific understanding of the non-CO2 effects of aviation on climate. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/813342/non-CO2-effects-report.pdf

[28] Intergovernmental Panel on Climate Change, 2018. Special report: Global warming of 1.5oC. https://www.ipcc.ch/sr15/

[29] Climate Change Committee, 2021. The sixth carbon budget: Aviation. https://www.theccc.org.uk/wp-content/uploads/2020/12/Sector-summary-Aviation.pdf

[30] Climate Change Committee, 2020. Policies for the sixth carbon budget and net zero. https://www.theccc.org.uk/wp-content/uploads/2020/12/Policies-for-the-Sixth-Carbon-Budget-and-Net-Zero.pdf

[31] Climate Assembly UK, 2020. The path to net zero: Climate Assembly UK full report. Executive summary. https://www.climateassembly.uk/report/read/executive-summary.html#executive-summary

[32] Climate Change Committee, 2021. The sixth carbon budget: Aviation. https://www.theccc.org.uk/wp-content/uploads/2020/12/Sector-summary-Aviation.pdf

[33] Department for Transport, 2021. VEH0203: Licensed cars by propulsion or fuel type: Great Britain and United Kingdom. https://www.gov.uk/government/statistical-data-sets/veh02-licensed-cars

[34] Department for Transport, 2021. NTS0303: Average number of trips, stages, miles and time spent travelling by main mode: England. https://www.gov.uk/government/statistical-data-sets/nts03-modal-comparisons

[35] Advanced Propulsion Centre UK, www.apcuk.co.uk

[36] Faraday Battery Challenge, www.ukri.org/innovation/industrial-strategy-challenge-fund/faraday-battery-challenge/

[37] Society of Motor Manufacturers and Traders, www.smmt.co.uk

[38] Department for Business, Energy and Industrial Strategy, 2020. 2019 UK greenhouse gas emissions, provisional figures. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/875485/2019_UK_greenhouse_gas_emissions_provisional_figures_statistical_release.pdf

[39] Department for Transport, 2020. Vehicle licensing statistics: annual 2019. https://www.gov.uk/government/statistics/vehicle-licensing-statistics-2019

[40] Nikola Energy, 2021. Fueling forward: Accelerating zero-emissions with innovative energy solutions. https://nikolamotor.com/hydrogen

[41] Dodds et al., 2020. Opportunities for hydrogen and fuel cell technologies to contribute to clean growth in the UK. http://www.h2fcsupergen.com/opportunities-for-hydrogen-fuel-cell-clean-growth-uk/

[42] Garland et al., 2019. AFC TCP 2019 survey on the number of fuel cell vehicles, hydrogen refueling stations and targets. https://www.ieafuelcell.com/fileadmin/publications/2019-04_AFC_TCP_survey_status_FCEV_2018.pdf

[43] UK H2 Mobility, 2020. Accelerate H2 a hydrogen mobility strategy for the early 2020s. http://www.ukh2mobility.co.uk/wp-content/uploads/2020/07/UK-H2Mobility-Accelerate-H2.pdf

[44] funded by the Horizon 2020 JIVE project

[45] Staffell et al., 2019. The role of hydrogen and fuel cells in the global energy system. https://pubs.rsc.org/en/content/articlelanding/2019/ee/c8ee01157e

[46] Vickers et al., 2020. Hydrogen production cost from PEM electrolysis – 2019. https://www.hydrogen.energy.gov/pdfs/20004-cost-electrolytic-hydrogen-production.pdf

[47] ITM Power, https://www.itm-power.com/itemlist/tag/refhyne

[48] The Society of Motor Manufacturers and Traders, 2019. Hydrogen fuel cell electric vehicles a quick guide to the UK market, technology and infrastructure. https://www.smmt.co.uk/wp-content/uploads/sites/2/2019.03.11-SMMT-FCEV-guide-FINAL.pdf

[49] North West Cluster, https://northwestcluster.co.uk/

[50] Department for Business, Energy, and Industrial Strategy, 2021. UK Hydrogen strategy. https://www.gov.uk/government/publications/uk-hydrogen-strategy

[51] Intergovernmental Panel on Climate Change, 2019. Special Report on Climate Change and Land. https://www.ipcc.ch/srccl/

[52] Climate Change Committee, 2020. Land use: Policies for a Net Zero UK. https://www.theccc.org.uk/publication/land-use-policies-for-a-net-zero-uk/

[53] Rae, 2017. UK land cover atlas. https://doi.org/10.15131/shef.data.5219956

[54] Department for Environment, Food and Rural Affairs, 2019. Agricultural statistics and climate change. https://www.gov.uk/government/statistics/agricultural-statistics-and-climate-change

[55] Goucher et al., 2017. GOUCHER, L., BRUCE, R., CAMERON, D. D., LENNY KOH, S. C. & HORTON, P. 2017. The environmental impact of fertilizer embodied in a wheat-to-bread supply chain. Nature Plants, 3, 17012. https://www.nature.com/articles/nplants201712

[56] Malcolm, 2016. Written evidence to the Climate Change Commission. http://data.parliament.uk/writtenevidence/committeeevidence.svc/evidencedocument/environmental-audit-committee/soil-health/written/31642.pdf

[57] Natural England, 2010. England's peatlands: carbon storage and greenhouse gases. http://publications.naturalengland.org.uk/publication/30021

[58] Intergovernmental Panel on Climate Change, 2019. Special Report on Climate Change and Land. https://www.ipcc.ch/srccl/

[59] Lal, 2014. Societal value of soil carbon. https://www.jswconline.org/content/69/6/186A

[60] Gregory et al., 2015. A review of the impacts of degradation threats on soil properties in the UK. https://onlinelibrary.wiley.com/doi/full/10.1111/sum.12212

[61] Lacanne and Lundgren, 2018. Regenerative agriculture: merging farming and natural resource conservation profitably. https://www.ncbi.nlm.nih.gov/pubmed/29503771

[62] Rhodes, 2017. The imperative for regenerative agriculture. https://journals.sagepub.com/doi/abs/10.3184/003685017X14876775256165

[63] Aubert et al., 2019. Agroecology and carbon neutrality in europe by 2050: what are the issues? Findings from the TYFA modelling exercise. https://www.soilassociation.org/media/18569/agroecology-and-carbon-neutrality-in-europe-by-2050-what-are-the-issues.pdf

[64] Krzywoszynska, 2019. Making knowledge and meaning in communities of practice: what role may science play? The case of sustainable soil management in England. https://onlinelibrary.wiley.com/doi/abs/10.1111/sum.12487

[65] Krzywoszynska and Outhwaite, 2020. What is the state of sustainable soil management in the UK? A national survey. Unpublished raw data

[66] Townsend et al., 2016. How do we cultivate in England? Tillage practices in crop production systems. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4986281/

[67] Krzywoszynska, 2019. Making knowledge and meaning in communities of practice: what role may science play? The case of sustainable soil management in England. https://onlinelibrary.wiley.com/doi/abs/10.1111/sum.12487

[68] Krzywoszynska and Outhwaite, 2020. What is the state of sustainable soil management in the UK? A national survey. Unpublished raw data

[69] Krzywoszynska, 2019. Making knowledge and meaning in communities of practice: what role may science play? The case of sustainable soil management in England. https://onlinelibrary.wiley.com/doi/abs/10.1111/sum.12487

[70] Climate Change Committee, 2020, Land use: Policies for a Net Zero UK. https://www.theccc.org.uk/publication/land-use-policies-for-a-net-zero-uk/

[71] Intergovernmental Panel on Climate Change, 2018. Special report: Global warming of 1.5oC. https://www.ipcc.ch/sr15/

[72] Climate Change Committee, 2019. Net Zero – the UK's contribution to stopping global warming. https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/

[73] University of Leeds & United Bank of Carbon, 2015. Urban green space. https://leaf.leeds.ac.uk/green-space/

[74] Hartig et al., 2003. Tracking restoration in natural and urban field settings. https://www.sciencedirect.com/science/article/pii/S0272494402001093

[75] Ward-Thompson et al., 2012. More green space is linked to less stress in deprived communities: Evidence from salivary cortisol patterns. https://www.sciencedirect.com/science/article/pii/S0169204611003665

[76] Hewitt et al., 2020. Using green infrastructure to improve urban air quality. https://link.springer.com/article/10.1007/s13280-019-01164-3

[77] Nisbet et al., 2011. Woodland for water: Woodland measures for meeting Water Framework Directive objectives. https://www.forestresearch.gov.uk/research/woodland-for-water-woodland-measures-for-meeting-water-framework-directive-objectives/.

[78] Forest Research, 2020. Woodland statistics. https://www.forestresearch.gov.uk/tools-and-resources/statistics/statistics-by-topic/woodland-statistics/

[79] Forest Research, 2015. Forest cover: international comparisons. https://www.forestresearch.gov.uk/tools-and-resources/statistics/forestry-statistics/forestry-statistics-2018/international-forestry/forest-cover-international-comparisons/

[80] Creating Tomorrows Forests, 2021. Introducing the tree planters. https://creatingtomorrowsforests.co.uk/blogs/news/introducing-the-tree-planters

[81] Theodorou et al., 2020. Urban areas as hotsposts for bees and pollination but not a panacea for all insects. https://www.nature.com/articles/s41467-020-14496-6

[82] Spracklen et al., 2013. Regeneration of native broadleaved species on clearfelled conifer plantations in upland Britain. https://www.sciencedirect.com/science/article/pii/S0378112713005288?via%3Dihub

[83] Climate Change Committee, 2020. Land use: policies for a Net Zero UK. https://www.theccc.org.uk/publication/land-use-policies-for-a-net-zero-uk/.

[84] Forest Research, 2020. UK wood production and trade. https://www.forestresearch.gov.uk/documents/7605/ukwpt20_UwNEVZr.pdf

[85] Forestry Commission, 2021. Woodland grants and incentives overview table. https://www.gov.uk/government/publications/woodland-grants-and-incentives-overview-table

[86] Natural England, 2019. People's engagement with nature. https://defra.maps.arcgis.com/apps/Cascade/index.html?appid=d5fe6191e3fe400189a3756ab3a4057c

[87] Dallimer et al., 2014. What personal and environmental factors determine frequency of urban greenspace use?. https://www.mdpi.com/1660-4601/11/8/7977

[88] McKinsey & Company, 2019. The state of fashion 2019: A year of awakening. https://www.mckinsey.com/industries/retail/our-insights/the-state-of-fashion-2019-a-year-of-awakening

[89] Ellen MacArthur Foundation, 2017. A new textiles economy: Redesigning fashion's future. https://www.ellenmacarthurfoundation.org/publications/a-new-textiles-economy-redesigning-fashions-future

[90] Niinimäki et al., 2020. The environmental price of fast fashion. https://www.nature.com/articles/s43017-020-0039-9

[91] British Fashion Council, 2019. Annual report & accounts: FY 2018/19. https://www.britishfashioncouncil.co.uk/uploads/files/1/01.08.19%20BFC_AR2019_Final.pdf

[92] Grant et al., 2017. Sustainable logistics and supply chain management: Principles and practices for sustainable operations and management. http://dspace.vnbrims.org:13000/xmlui/bitstream/handle/123456789/4171/Sustainable%20Logistics%20and%20Supply%20Chain%20Management%20Principles%20and%20Practices%20for%20Sustainable%20Operations%20and%20Management.pdf?sequence=1

[93] Mistra Future Fashion, 2019. Environmental assessment of Swedish clothing consumption – six garments, sustainable futures. http://mistrafuturefashion.com/wp-content/uploads/2019/08/G.Sandin-Environmental-assessment-of-Swedish-clothing-consumption.MistraFutureFashionReport-2019.05.pdf

[94] Quantis, 2018. Measuring fashion: Insights from the environmental impact of the global apparel and footwear industries study. https://quantis-intl.com/report/measuring-fashion-report/

[95] WRAP, 2017. Valuing our clothes: The cost of UK fashion. https://www.wrap.org.uk/sustainable-textiles/valuing-our-clothes%20

[96] Ibid.

[97] Ibid.

[98] Niinimäki et al., 2020. The environmental price of fast fashion. https://www.nature.com/articles/s43017-020-0039-9

[99] Ellen MacArthur Foundation, 2017. A new textiles economy: Redesigning fashion's future. https://www.ellenmacarthurfoundation.org/publications/a-new-textiles-economy-redesigning-fashions-future

[100] WRAP, 2017. Valuing our clothes: The cost of UK fashion. https://www.wrap.org.uk/sustainable-textiles/valuing-our-clothes%20

[101] British Fashion Council, 2019. Annual report & accounts: FY 2018/19. https://www.britishfashioncouncil.co.uk/uploads/files/1/01.08.19%20BFC_AR2019_Final.pdf

[102] WRAP, 2020. SCAP 2020 progress 2012-2017. https://wrap.org.uk/resources/report/scap-2020-progress-2012-2017

[103] UK Parliament, 2019. The Climate Change Act 2008 (2050 Target Amendment) Order 2019. https://www.legislation.gov.uk/uksi/2019/1056/contents/made

[104] United Nations Framework Convention on Climate Change, 2021. Time series – Annex I. https://di.unfccc.int/time_series

[105] UK Parliament, 2016. The Carbon Budget Order 2016. https://www.legislation.gov.uk/uksi/2016/785/made

[106] Owen and Barrett, 2019. Carbon Brief Guest post: The UK's carbon footprint is at its lowest level for 20 years. https://www.carbonbrief.org/guest-post-the-uks-carbon-footprint-is-at-its-lowest-level-for-20-years

[107] Department for Buisness, Energy and Industrial Strategy, 2021. Provisional UK greenhouse gas emissions national statistics. https://data.gov.uk/dataset/9a1e58e5-d1b6-457d-a414-335ca546d52c/provisional-uk-greenhouse-gas-emissions-national-statistics

[108] Barrett et al., 2013. Consumer-based GHG emission accounting: a UK case study. http://dx.doi.org/10.1080/14693062.2013.788858

[109] WWF, 2020. Carbon footprint: Exploring the UK's contribution to climate change. http://wwf.org.uk/carbon-report-2020

[110] Scott et al., 2020. Bridging the climate mitigation gap with economy-wide material productivity. https://doi.org/10.1111/jiec.12831

[111] Department for Environment, Food and Rural Affairs, 2021. UK's carbon footprint. https://www.gov.uk/government/statistics/uks-carbon-footprint

[112] Department for Environment, Food and Rural Affairs, 2018. Resources and waste strategy for England. https://www.gov.uk/government/publications/resources-and-waste-strategy-for-england

[113] e.g. Climate Change Committee, 2020. Reducing UK emissions: 2020 progress report to Parliament. https://www.theccc.org.uk/publication/reducing-uk-emissions-2020-progress-report-to-parliament/

[114] UK Government, 2020. PM announces the UK will end support for fossil fuel sector overseas. https://www.gov.uk/government/news/pm-announces-the-uk-will-end-support-for-fossil-fuel-sector-overseas

[115] Owen and Barrett, 2020. Reducing inequality resulting from UK low-carbon policy. https://www.tandfonline.com/doi/full/10.1080/14693062.2020.1773754

[116] Brown et al., 2012. Reducing CO2 emissions from heavy industry: a review of technologies and considerations for policy makers. https://www.imperial.ac.uk/media/imperial-college/grantham-institute/public/publications/briefing-papers/Reducing-CO2-emissions-from-heavy-industry---Grantham-BP-7.pdf

[117] Wesseling et al., 2017. The transition of energy intensive processing industries towards deep decarbonisation: Characteristics and implications for future research. https://doi.org/10.1016/j.rser.2017.05.156

[118] Taylor et al., 2019. Public priorities and expectations of climate change impacts in the United Kingdom. https://doi.org/10.1080/13669877.2017.1351479

[119] Scheufele, 2018. Beyond the choir? The need to understand multiple publics for science. https://doi.org/10.1080/17524032.2018.1521543

[120] Nisbet, 2009. Communicating climate change: Why frames matter for public engagement. https://doi.org/10.3200/ENVT.51.2.12-23

[121] Dawson, 2018. Reimagining publics and (non) participation: exploring exclusion from science communication through the experiences of low-income, minority ethnic groups. https://doi.org/10.1177%2F0963662517750072

[122] Kreslake et al., 2016. Developing effective communication materials on the health effects of climate change for vulnerable groups: a mixed methods study. https://doi.org/10.1186/s12889-016-3546-3

[123] Joseph Roundtree Foundation, 2014. Climate change and social justice: an evidence review. https://www.jrf.org.uk/report/climate-change-and-social-justice-evidence-review

[124] Chilvers and Kearnes, 2020. Remaking participation in science and democracy. https://doi.org/10.1177%2F0162243919850885

[125] Pieczka and Escobar, 2013. Dialogue and science: Innovation in policy-making and the discourse of public engagement in the UK. https://doi.org/10.1093/scipol/scs073

[126] Lorenzoni et al., 2007. Barriers perceived to engaging with climate change among the UK public and their policy implications. https://doi.org/10.1016/j.gloenvcha.2007.01.004

[127] Illingworth and Jack, 2018. Rhyme and reason-using poetry to talk to underserved audiences about environmental change. https://doi.org/10.1016/j.crm.2018.01.001

[128] Climate Assembly UK, 2020. The path to net zero: Climate Assembly UK full report. Executive summary. https://www.climateassembly.uk/report/read/executive-summary.html#executive-summary

[129] Ibid.

[130] Devaney et al.,2020. Ireland's citizens' assembly on climate change: Lessons for deliberative public engagement and communication. https://doi.org/10.1080/17524032.2019.1708429

[131] Llingworth et al., 2018. Representing the majority and not the minority: the importance of the individual in communicating climate change. https://doi.org/10.5194/gc-1-9-2018

[132] Burke et al., 2018. Participatory arts and affective engagement with climate change: The missing link in achieving climate compatible behaviour change?. https://doi.org/10.1016/j.gloenvcha.2018.02.007

[133] Howell, 2011. Lights, camera... action? Altered attitudes and behaviour in response to the climate change film The Age of Stupid. https://doi.org/10.1016/j.gloenvcha.2010.09.004

[134] Pye et al., 2017. Achieving net-zero emissions through the reframing of UK national targets in the post-Paris Agreement era. https://doi.org/10.1038/nenergy.2017.24

Policy Connect

Policy Connect is a membership-based, not-for-profit, cross-party think tank. We bring together parliamentarians and government in collaboration with academia, business and civil society to inform, influence and improve UK public policy through debate, research and innovative thinking, so as to improve peoples' lives. We lead and manage an extensive network of parliamentary groups, research commissions, forums and campaigns. We are a London living wage and disability confident employer and a Member of Social Enterprise UK, and have been operating since 1995. Our work focuses on key policy areas including: health & accessibility; education & skills; industry, technology & innovation; and sustainability. We shape policy in Westminster through meetings, events, research and impact work.

All-Party Parliamentary Climate Change Group

The All-Party Parliamentary Climate Change Group runs events and activities in parliament with the purpose of advancing understanding of policy issues surrounding climate change and enabling cross-party discussion and action on climate policy.

CONTACT

Policy Connect
CAN Mezzanine
7-14 Great Dover Street
London SE1 4YR

@Policy_Connect
policy-connect
info@policyconnect.org.uk
0207 202 8585

Design & Production Ashley Ads Ltd. 01603 701700 | ashleyads.co.uk