



Sensitive intervention points to achieve net-zero emissions

Report of the Policy Advisory Group* of the Committee on Climate Change

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* The Policy Advisory Group of the CCC is an independent group established in 2020 to provide advice about cross-cutting policy interventions to facilitate the achievement of the UK's legislated target to achieve net-zero emissions by 2050. All members of the Policy Advisory Group served in their personal capacities. The views expressed in this report may not represent the views of their respective organisations. It should not be assumed that all authors agree with all statements in this report.

Context and Purpose

On 27 June 2019 the UK became the first major economy to legislate to achieve net-zero greenhouse gas emissions by 2050. This followed the Climate Change Committee report in May (CCC, 2019a) concluding net-zero is necessary, feasible and cost-effective.

However, the CCC report also concluded that a net-zero GHG target is not credible unless policy is “ramped up significantly”, stressing that delivery must progress with “far greater urgency” and that existing policies and plans were insufficiently ambitious, and proceeding too slowly, even for the previous target of 80% by 2050. There was a call for clear leadership right across government and the conclusion that the economics were moving favourably towards more ambitious action, with the annual resource costs of achieving net zero equivalent to around 1-2% of GDP in 2050 (CCC, 2019a).

This year, the CCC’s focus is on advising the pathway to the 2050 net-zero goal, in particular the emissions cap that UK should set in law for the period of the 6th carbon budget (2033-2037). The policy advisory group of the CCC is an independent group established in 2020 to provide advice about cross-cutting policy interventions to facilitate the achievement of the UK’s legislated target to achieve net-zero emissions by 2050, and the 6th carbon budget. The remit of the advisory group is to think beyond sectoral targets and to suggest cross-cutting, top-down view of changes in politics, business, society and technology that could accelerate progress towards achieving net zero emissions by 2050. The group had three meetings between July and September 2020. Its conclusions are summarised in this report.

Acknowledgements

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Executive Summary

Achieving net zero emissions involves an economic transformation on a scale comparable to the Victorian era, when the foundations of the infrastructure used in the United Kingdom today were put in place. The scale of the transformation ahead implies that, if successful, our generation will justly be considered the “Victorians of the 21st century”.

The transition to net zero emissions can and will occur. The international tailwinds are strengthening, with net zero commitments from the EU, China, Japan, and South Korea by mid-century. The economics are increasingly positive. The costs of renewables and batteries continue to fall. Similar trends are emerging in low-carbon hydrogen and ammonia, which can decarbonise major parts of heavy industry, as well as some long-distance transportation. As further deployment and innovations cut costs, it is no longer entirely implausible that net zero emissions could be achieved at net zero cost (even ignoring significant co-benefits and large benefits from avoiding the worst climate impacts). Net removal of greenhouse gases from the atmosphere, which appears very likely to be required post 2050, is also achievable. Exciting, positive tipping points are being crossed in our socio-technical systems. However, we are also reaching alarmingly dangerous tipping points in the physical climate system. The question is whether we will reach net zero in time.

This report considers this question by examining the UK economy as a complex adaptive system. We explore sensitive intervention points in nine key areas of our socio-technical system, highlighting recommendations that can accelerate progress and reduce the risks of unsatisfactory progress. We identify 40 potential sensitive intervention points organised into the nine categories as follows:

1. Deepen public engagement, with cross-party communications and monitoring;
2. Deliver a transition that is just, creating opportunities to level up society;
3. Reorganise government to lead on net zero from the centre;
4. Align incentives, through carbon pricing and a carbon takeback obligation;
5. Leverage global dynamics, with higher UK ambition and carbon border adjustments;
6. Increase business ambition, with closer engagement with key firms;
7. Accelerate technological progress, using “pathfinder” cities and regions to test integrated approaches to achieving net zero;
8. Redirect capital flows, including through accounting and audit interventions;
9. Harness the law, with a government legal team to drive legal and regulatory shifts.

Overall, we conclude that the pace of change required is fast but manageable. In many instances, progress can be made by building on current trends that are heading in the right direction. Exogenous shocks can and will happen, and these can be harnessed – intelligently designing the economic recovery post COVID-19 provides one example (Hepburn et al., 2020a; IEA, 2020d). Endogenous dynamics also create opportunities; Brexit offers a rare

opportunity to transform our food and agricultural system (Helm, 2017). Where key uncertainties remain, trials or “pathfinders” – specific cities or regions willing to go faster and earlier to net zero – could help establish what works, and what doesn’t.

This transformation is not simple, but failure is not an option, and success will leave future generations with a set of infrastructures and capital assets at which the Victorians would have marvelled. Our grandchildren will enjoy low-carbon infrastructure that has all largely been paid for; our once-in-a-generation push will leave a legacy of an economy that runs on largely free natural resources – the sun and the wind. Just as “freemium” models illustrate how many digital and internet services can be provided to billions of people at low marginal cost, our post-carbon economy will likely offer energy and mobility services at very low cost. With the ‘kicks’ and ‘shifts’ to our economic system set out in this report, the post-carbon economy could be cleaner, healthier, fairer, and significantly more prosperous.

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1. Introduction and Context

The UK net zero target was enshrined in law in the United Kingdom in 2019. Other countries are following suit, including China (Chinese Government, 2020), Japan and South Korea (NY Times, 2020; Financial Times, 2020) and the EU (European Commission, 2020). The economic case is increasingly compelling. When the CCC first assessed the cost of achieving the UK's 80% emissions reduction target in 2008, it suggested a cost of between 1-2% of GDP. Technology trends meant that by 2019, the more ambitious net-zero target could be achieved at the same overall annual resource cost of the equivalent of 1-2% of GDP in 2050,¹ even when including the last 20% of difficult to decarbonise emissions (CCC, 2019a).

There is little doubt that clean technologies will eventually dominate the global energy system. The foundational step – decarbonising the power sector – is well underway, with the carbon intensity of the UK's electricity falling from 500 gCO₂/kWh to 220 gCO₂/kWh over the last 10 years (CCC, 2019a). Progress on electrifying transport will accelerate, as is necessary, with the recent ban on the sale of internal combustion vehicles by 2030 as part of the Prime Minister's "Ten Point Plan" (HM Government, 2020). The plan for decarbonising buildings, heating and industry is becoming clearer, and the COVID-19 pandemic has triggered green recovery investments around the world that will support progress. Food systems are showing early signs of the transformation ahead, with growth in entrepreneurship and venture capital in alternative proteins, such as plant-based alternatives to meat and "cultured meat" grown in vitro in a lab (Oxford Martin School, 2019; Collett et al, forthcoming). COVID-19 recovery stimulus packages, such as that of France, could accelerate these trends as government funds are invested in 'plant protein' strategies. So, although we are crossing frightening tipping points in the physical climate system (Lenton et al, 2019), we are also reaching encouraging positive tipping points in our socio-technical systems.

While the transitions in energy, transport, buildings, industry and agriculture now all seem certain, their pace is not. Achieving net zero in the UK within three decades will involve new investment of over £50 billion per year in zero emissions electricity generation, networks, low-carbon heating technologies, electric vehicles and associated infrastructure (CCC, 2019a). This will create many new jobs in new low-carbon industries, well beyond the jobs that will need to be phased out in legacy fossil fuelled industries (CCC, 2019a; IEA 2020c, 2020d).

There are several reasons to think that we might just succeed. First, the path ahead is capital intensive, but private capital is plentiful and public interest rates are still low. The UK can and potentially will lead the way in establishing the world's first net-zero financial system (Robins and Pierfederici, 2020). Second, many new skills and jobs will also be created. For better or worse, the COVID-19 tragedy means that we are in a unique situation of urgently needing to

¹ Specifically, the annual resource costs of all abatement measures in place in 2050 are estimated to be equivalent to 1.3% of GDP in 2050. Note that resource costs are not necessarily the same as GDP impacts.

find jobs for a workforce, particularly the young, who will otherwise be disadvantaged for their entire working lives. Third, democratic consent and social licence is vital to achieving a rapid pace of change. The climate assemblies show that, for the moment, people are hungry for the clarity of vision and purpose and really want to “get on with it”.

But there are also reasons to think that we could fail. This report identifies and confronts these challenges head on, acknowledging that net zero requires more than a continuation of current trends, but a shift in behaviour and attitudes so significant it will permeate all of society. The Climate Change Committee has examined the requirements, sector by sector, for net-zero emissions. Here, we take a complementary lens, seeking out cross sectoral sensitive intervention points to accelerate, and overcome obstacles, to net zero. We embrace the fact that socio-technical systems are complex adaptive systems that rarely behave in straightforward or linear ways (section 2).

Using our complexity science lens, we isolate 9 categories of interventions to accelerate action, as follows. **First**, public engagement on climate could be stronger. As recently as March 2020, 61% of the British public were either completely unaware of the concept of “net zero emissions” (42%) or had heard ‘hardly anything about it’ (19%) (BEIS, 2020b). These figures are improving, however. By September 2020, 53% had heard nothing (30%) or hardly anything (23%) about net zero. The announcement of the Prime Minister’s “Ten Point Plan” in November 2020 has also presumably increased awareness. **Deeper public engagement** with the changes ahead is necessary (see section 3.1). **Second**, the transition, while net positive, will create winners and losers. The losers should know that they will be supported through the transition to ensure **social justice** (section 3.2). Without such support, progress could falter or stop completely. **Third**, the institutions of government are not geared up for such a mammoth effort. Political leadership can come and go, bold decisions can be shied away from, and trade-offs made where achieving net zero is not the top priority. A **reorganisation of government** is required (section 3.3). **Fourth**, some of largest polluters do not face the biggest penalties. Following the **polluter pays principle**, we recommend continued efforts on carbon pricing, the removal of fossil subsidies, and a ‘carbon takeback obligation’ requiring firms who extract or import fossil fuels to put an increasing proportion of the carbon back in the ground (section 3.4). **Fifth**, the UK has a role in **leveraging global dynamics** (section 3.5) in the transition, particularly as host of COP 26. This means embracing the fact that the UK can affect emissions beyond its borders, and that action can and should be taken to complement domestic measures. **Sixth**, we note the role of business in embracing net-zero and suggest how to build on **growing business climate ambition** (section 3.6). **Seventh**, ongoing global technological advances are occurring, and we suggest opportunities for the UK to intervene, where appropriate, to **accelerate technological trends**, for the UK’s, and the world’s benefit (section 3.7). **Eighth**,

53%

had heard nothing or hardly anything about “net zero” in September 2020.

we acknowledge the work being done to align the UK's business and financial systems to the world's climate objectives and suggest **Paris-aligned accounts** as a simple way to accelerate this (section 3.8). **Ninth**, but not least, we note how incremental changes to the UK's **legal frameworks** can help unlock faster progress (section 3.9).

The range of insights emerging from the analysis in section 3 are pulled together into a set of conclusions and recommendations for the CCC and government in section 4, which are also highlighted in boxes throughout the report. Overall, the portfolio of interventions is likely to add to more than the sum of the parts because, as described in the following section, these interventions will interact and feed upon each other in complex ways to help to shift the system towards a net zero emissions future.

2. Net zero in a complex system

2.1 Dynamics of complex systems

A complex system has a multitude of components that interact with one another, often producing phenomena that exhibit non-linear dynamics.² Feedback loops and even chaotic behaviour are common in these systems. Earth's climate is one such system. Elements including solar irradiation, plant transpiration, cloud formation, ocean circulation, among many others, all interact to produce weather patterns. Although climatic change normally occurs on timescales that are hard to comprehend over individual lifetimes, we now understand that self-reinforcing feedback dynamics can change, and have changed, Earth's climate significantly. Higher concentrations of greenhouse gases in the atmosphere contribute to warming, which melts polar ice caps, which in turn leads to lower albedo (reflection of incoming radiation), thereby further warming the climate (Lenton et al., 2019). The phase of climatic stability which saw the rise of *homo sapiens* is now under threat as we push our climatic system over irreversible tipping points.

Much like Earth's climate system, the socio-economic system is also complex and adaptive, carrying with it the potential for rapid, non-linear change (Geels, 2002; Bentley et al. 2014; Hepburn and Famer, 2020). This potential can be harnessed for sustainable development. A critical mass of attitudes, technologies, and actors can lead to system-wide transformation away from hydrocarbons. Network effects, economies of scale, and bandwagon dynamics can create self-reinforcing feedback loops such that a small push in the right direction can have outsized impacts (Meadows, 1999). Within this lens, we can identify "sensitive intervention points" (Farmer et al 2019) – several of which are discussed below – to accelerate the transition to a net-zero emissions future.

The CCC's 6th Carbon Budget analysis identifies the need for a scale-up in low-carbon technologies and behaviours in the 2020s, so that by the early 2030s the low-carbon option is favoured over the high carbon option across all areas and is being deployed at scale. This includes making clean power the dominant form of electricity production, increasing energy efficiency, switching the two million fossil fuelled vehicles and 1 million gas boilers sold every year to electric alternatives, scaling up new low-carbon industries from scratch – including CCS, hydrogen and emissions removals – and shifting behaviours towards lower-carbon diets and connectivity (low-emissions mobility or substitutions towards digital interactions).

2.2 Identifying sensitive intervention points

Identifying sensitive intervention points (SIPs) first requires identifying areas of the system that are at or near a state of "criticality", where positive feedback loops or amplification dynamics

² See <https://complexityexplained.github.io> for a wonderful introduction.

imply that a modest intervention can lead to disproportionate effects. Second, once potential areas are identified, we seek specific interventions (either a “kick” or “shift” as discussed below) that might produce outsized effects. In complex systems, there is rarely any certainty, and a portfolio of interventions – many of which may fail but all of which work in the same direction – is the objective.

2.2.1 System criticality, kicks, and shifts

A system at, or near, a state of criticality will exhibit one or more tipping points. If the system is nudged over the tipping point it will move to a different regime, or phase, or “basin of attraction”, which could be very different to the starting point. There are many examples of such dynamics within the physical and social sciences. For instance, in politics, resistance to an incumbent regime can build quietly until the conditions are ripe for a “hero” to emerge and catalyse the “silent majority” to topple the system. Regime changes around the world tend to involve system criticality prior to the trigger that led to the change (e.g. decolonisation movements, the women’s suffragette movement, the end of apartheid and the abolition of slavery). Arguably, such criticality is also visible in the transition to net-zero emissions: the conditions now exist for Greta Thunberg to galvanize students from around the world to strike for climate. Two decades ago, the system was not ready for the emergence of such a leader – Greta Thunberg or otherwise. Climate change did not enjoy the salience that it does today, awareness levels were lower, social media platforms to amplify messages didn’t exist, and frustration, fear and anger were not bubbling up to critical levels. Popular awareness and engagement creates the space for political and business declarations from the world’s largest emitters to put the Paris Agreement’s temperature goals within reach.

Other types of systems are in a near-perpetual state of criticality, where a small shift in one or another direction can create landslides. Stock markets and other financial systems, where self-reinforcing expectations and animal spirits are strong drivers of change, are examples. Indeed, one of the background papers to this report argues that a small “shift” in accounting rules requiring companies to disclose climate risks could massively affect shareholder behaviour and valuations, and thus corporate decision making (Sarasin & Partners, 2020).

Typically, system criticality involves being in a state where at least one of the following positive feedback loops can overcome resistance (Arthur, 1988, 1989, 1990):

- **Self-reinforcing expectations:** where expectations trigger actions that reinforce the truth of the expectation, triggering the diffusion of the expectation and action;
- **Learning effects:** where the deployment of a technology reduces its cost, increasing the net benefits of further deployment;
- **Network and coordination effects:** where there are greater advantages to ‘going along’ with others, the more other economic agents are taking similar action;

- **Large fixed costs (economies of scale):** where, once the initial fixed costs have been incurred, low unit costs encourage increased output.

Sometimes preparatory actions are needed to bring a system to a state of criticality. For example, NASA’s investment in solar panels was necessary for the genesis of the PV industry. After decades of fundamental research and development, solar technology was in state such that a highly targeted intervention such as Germany’s feed-in-tariff (a “kick”, as discussed below), would be enough to signal widescale uptake and adoption. The feed-in-tariff encouraged uptake, which reduced costs, which in turn incentivised more uptake. China, upon seeing a growing market, leveraged its manufacturing prowess to make low-cost solar panels. The story of solar PV encapsulates all four positive feedback dynamics: self-reinforcing expectations on market size, learning, network effects, and economies of scale. Today, other complementary technologies may be on the precipice of a learning curve, which could be triggered with the right intervention.

2.2.2 Interventions

Once a sensitive intervention point (SIP) has been identified, the next question is what type of intervention will most effectively trigger positive feedbacks? We classify two broad categories of interventions: “kicks” and “shifts” (Farmer et al 2019) shown in Figure 1.

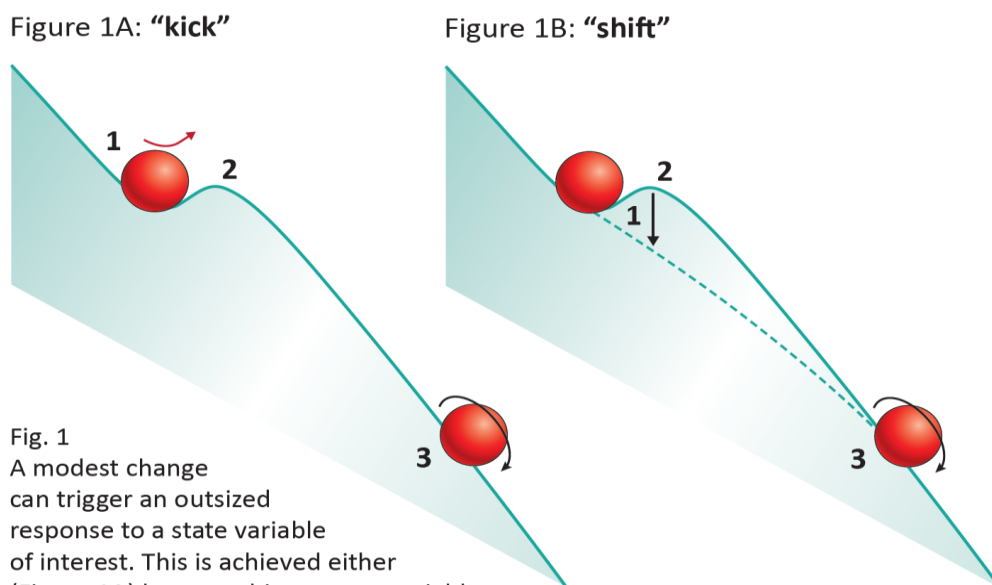


Fig. 1
A modest change can trigger an outsized response to a state variable of interest. This is achieved either (Figure 1A) by perturbing a state variable, called a **kick**, so that it moves to a new trajectory in the current system or (Figure 1B) by modifying the system so that its trajectory is altered, called a **shift**. In this example, following the intervention, the ball rolls on its own.

Figure 1. Kicks and shifts to alter system dynamics (Farmer et al, 2019)

A **kick** is an intervention that is possible within the paradigm of the status quo, while a shift changes the paradigm. For example, a kick might include a subsidy for green products. A kick could also include salient instances of civil society action such as Greta Thunberg’s mobilisation of students. A **shift**, by contrast, requires a fundamental change to institutions

that govern society. This might include the establishment of an independent body to hold the government accountable to its climate targets (such as the UK Climate Change Committee), new laws to more stringently monitor the licensing of fossil fuel permits, or mandatory disclosure of climate risks. An economy-wide carbon price could be seen as a shift in the “fitness landscape” (Richter and Engelbrecht, 2014) for all firms operating in the economy, shifting the topology of the economy and triggering change across multiple sectors.

While kicks are important, shifts may be more powerful and interesting to understand because they can create new trajectories for the post-carbon transition; trajectories that might be faster than what we already have. Shifts may also unlock new types of kicks. Three centuries of fossil fuel ascendance have locked-in institutions that favour incumbent interests and resist change. Transforming these institutions is a necessary shift in tackling climate change. For example, obtaining permits for excavating fossil fuels is notoriously easy in many parts of the world³ and not reflective of the reality of climate change. Revising fossil fuel permitting law may be an extremely important shift in terms of achieving net-zero emissions (Rafaty and Srivastav, forthcoming). What also makes shifts particularly interesting for a body such as the CCC is that they can be catalysed by governments, judiciaries and independent commissions.

Kicks and particularly shifts are not always trivial to trigger because of resistance by incumbents. In section 2.3.2 we discuss strategies to overcome this resistance so that strong and decisive climate policy can be implemented.

2.3 Application to the net-zero transition

2.3.1 Identifying interventions

The CCC regularly reports on technology and sector-specific policies necessary to meet net zero emissions by 2050, including 5-yearly sets of advice on carbon budget levels for the UK, and annual reports analysing historical emissions trends and progress towards future climate goals. In its work on net-zero in 2019, and its work on the 6th Carbon Budget in 2020, the CCC has presented a vision of a future net-zero UK, where residual emissions across most sectors are reduced close to near-zero, and any remaining emissions – likely from animal agriculture and aviation – are permanently removed from the atmosphere, through enhancing natural sinks including tree planting or via engineered carbon sequestration.

The analysis in section 3 of this report takes a complementary perspective, taking a view on how this transition can be achieved, by focussing on sensitive intervention points at a broader societal level. Rather than examining technologies and behaviours in particular sectors, or even the policies that can steer technologies and behaviours, here we focus on the deeper and more fundamental changes in system dynamics. We are looking for system interventions

³ For example, many of Germany’s permitting laws were written at a time when the speedy excavation of coal was necessary for economic development and war effort. Safeguards were kept to a minimum. Similarly, in a forthcoming article, Srivastav and Pratap (forthcoming) will show that India’s coal bearing areas act misses important safety protocol and effectively subsidises coal production.

(kicks and shifts) which increase the likelihood of a net zero outcome, given the underlying structure of the socio-technical system and the system responses (self-reinforcing positive feedbacks on the one hand and resistance (negative feedbacks) on the other). Figure 2 shows this interconnected socio-technical landscape, where the dynamics include feedbacks within and across nodes of the system. The development of this socio-technical system affects physical outcomes, including the climate system, which in turn feeds back to the socio-technical system as climate impacts occur, shifting beliefs and narratives and costs and benefits of action.

2.3.2 Overcoming resistance

Identifying the feedback dynamics and triggers to accelerate progress can be powerful, as the ideas in this report hopefully demonstrate. But it would be naïve not to expect inertia, resistance, obstruction, problems and challenges to emerge as the transition plays out that could delay progress. We employ a framework developed in a background paper for this report (Srivastav and Rafaty, 2020) for identifying and surmounting obstacles on the path ahead.

The starting point is that the UK has already reduced emissions by 43% over the last 30 years (HM Government, 2020), but the actions taken to achieve this – switching from coal to gas and renewable electricity generation, reducing HFCs and diverting wastes from landfill – look relatively easy compared to the changes ahead. The challenges are significant, and there will be many decelerating dynamics and obstacles of various forms. The question is, how can these obstacles be overcome?

First, some large emitters have recognised the necessity of the transition and have embarked on the process of changing their firms from within. The **co-optation** of incumbents can emerge through pressure from shareholders, advisory boards, CEOs and their advisers. Co-optation can lead to internal carbon pricing, shifts in capital allocation, executive pay tied to emissions reductions, green bond issuance, zero deforestation supply chains and transparency in reporting and measuring progress. Transparency is key in ensuring that co-optation results in meaningful change, rather than “greenwashing”.

Second, and most relevant here, new **institutions and rules** can help overcome blockages. The Climate Change Committee itself may be one example, providing regular advice and transparency on the progress to climate stability. Institutional reforms can encode the transition to net zero and sustainable development more deeply into law. Others include institutions to oversee the mandatory disclosures of climate risks, and changes in processes at HM Treasury in the appraisal of public tax, spend and subsidy regimes as well as regulations (especially in relation to fossil fuels). Regulations and policies can drive change in mature markets, facilitate price discovery and promote cost reductions.

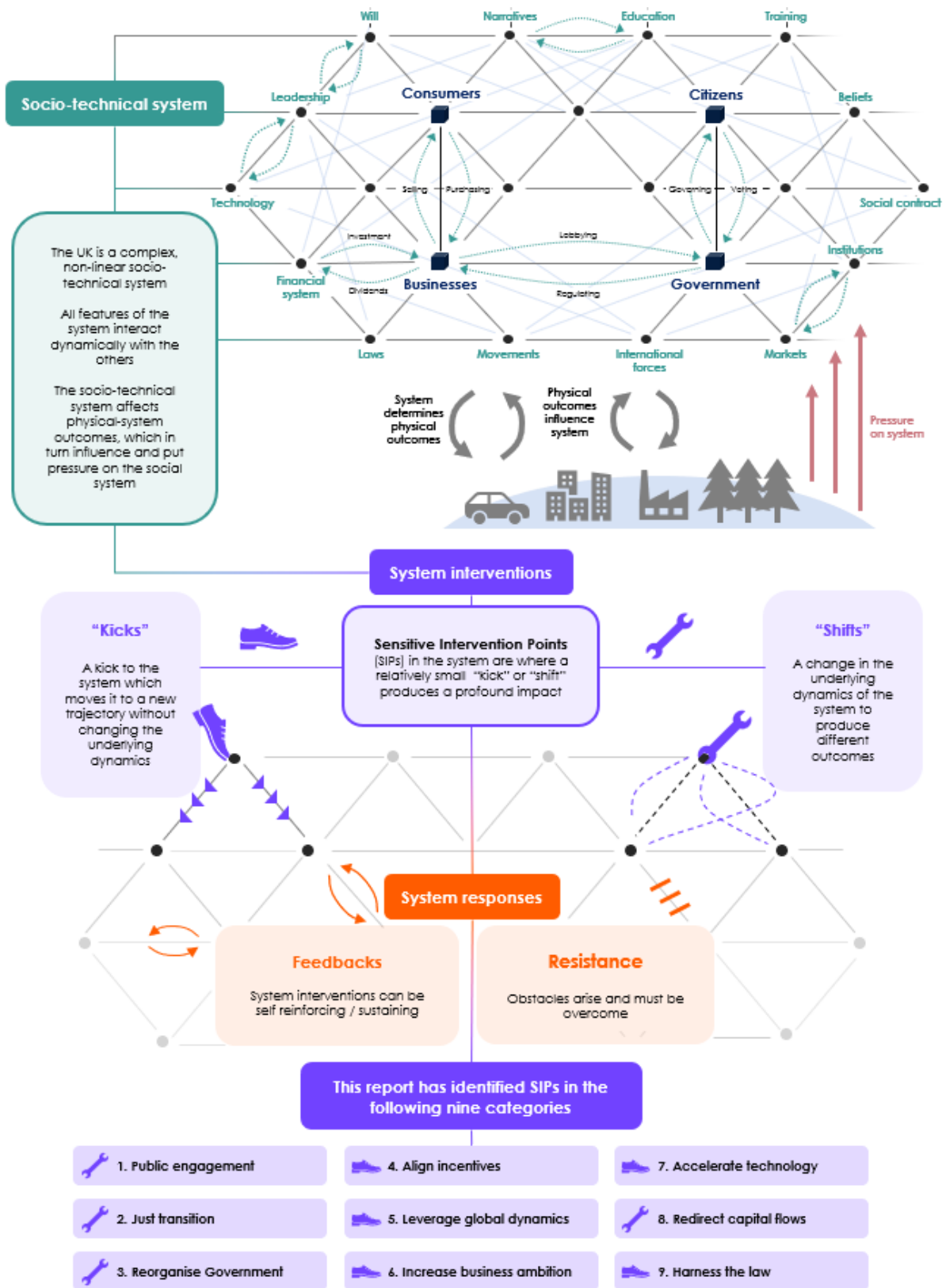


Figure 2. A complexity economics framework for the transition to net zero emissions⁴

⁴ Contributed by Jake Langmead-Jones (Committee on Climate Change).

Third, a combination of technological advancement, with supportive private finance and public policies can combine as a **countervailance** strategy – where clean alternatives outcompete dirty incumbents. Government support for green technologies, R&D programmes, innovation incubators, renewable portfolio standards, green investment banks, clean energy auctions, etc. can help. The financial sector can construct appropriate vehicles to channel more funding towards green technologies. Countervailance has had successes thus far – solar PV and wind now outcompete fossil fuels on cost – and electric vehicles are arguably increasingly in a similar position of outcompeting internal combustion engines.

Fourth, the transition to net zero will inevitably create losers who may need to be compensated or **appeased** in some form. For workers, this could involve enhanced social security, reskilling and retraining programmes. For regions that are highly dependent on fossil fuels, regional transition funds that can help the local economy diversify. The UK's track record here is relatively poor, but experience elsewhere coupled with more granular data on adjacent clean industries may help (Mealy and Teytelboym, 2020). For instance, community involvement with and payment from wind and solar farms can increase public acceptability (Azarova et al., 2019; Roddis et al., 2018; Vuichard et al., 2019). Finally, compensating capital owners is also a tool to “buy” cooperation. A controversial and questionable historical precedent for this is the abolition of slavery in UK, where slave-owners were paid to forgo their “assets”. While compensating workers is often considered as fair and just, compensating capital-owners is morally ambiguous as it may be viewed as “bailing out polluters”. Nevertheless, it is one method to appease powerful vested interests that may otherwise mobilise against the necessary transition.

Fifth, if all else fails, resistance to change can be overcome by **antagonism**. Examples include protests and lawsuits to damage reputations and increase operating costs, divestment, naming and shaming, and boycotting companies that fail to take measurable action consistent with our net zero target (Thornton and Goodman, 2017). As one example, educational institutions may decide that their careers service will no longer host oil and gas companies unless they demonstrate a tangible pathway to net-zero.

3. A Portfolio of Interventions

Rewiring our economies to net zero starts with a realistic understanding of our current economic system and the underlying socio-technical dynamics. Modern economies are complex systems, with many interdependencies and connections. Ideas spread faster than viruses, and physical supply chains still deliver goods rapidly across national boundaries. The idea of “net zero” has spread, many nations are now aiming to eliminate net emissions by mid-century. The path ahead won’t be linear, and global trends spanning multiple decades are difficult to predict. We don’t know with any certainty what the world will look like in 2035 or 2050, or how the systems we have today will evolve. We do, however, know the sources of emissions today, and we can identify the sorts of changes in technologies and behaviours that could reduce emissions towards zero. But it is difficult if not impossible to be certain of the impact of intervention.

Given this irreducible uncertainty, a portfolio of interventions – where some will fail – is an optimal strategy. This section identifies plausible **kicks** that take advantage of existing favourable dynamics, and potential deeper **shifts** in the underlying system that could accelerating changes towards net-zero. These shifts and kicks (see section 2.2.1 above) form a portfolio of interventions, some of which will fail, but all of which are worthy of consideration, development and possible implementation.

3.1 Deepen public engagement*

3.1.1 Why it matters?

Public engagement with net zero is a critical factor for success (CCC, 2019a). This is because the changes in behaviour required will be impossible without a reconfiguration of lifestyles and broader changes in society, which themselves rest upon a shift in associated values and norms. In 2019, the CCC estimated that over 60% of the emissions reductions in their scenarios required behavioural and social change (CCC, 2019). The IEA estimated that behavioural changes related to energy use could fill 15% of the global emissions gap to net-zero (IEA, 2020c).

The food system provides a good example of the importance of public engagement. Greenhouse gas (GHG) emissions directly or indirectly related to food make up 26% of global greenhouse gas emissions (Poore and Nemecek, 2018)⁵ and of this, animal-related products (meat, fish, dairy, eggs etc.) account for almost 60%. Shifts in personal choices and diets could make significant progress towards net zero as well as achieving other social goals, such as improved health. Deployment of novel technologies (such as precision fermentation and

* Particular thanks to Lorraine Whitmarsh (in her personal capacity) for her input into this section.

⁵ Note this is on a GWP100 basis, which is controversial.

cellular agriculture) in the food system will be limited unless people engage with them and accept them (Stephens et al, 2019).

Transport provides another good example. Changes in travel modes from driving to walking can reduce emissions and contribute significantly to public health objectives. The point is made humorously and powerfully in Figure 3. While some net zero policies may be less invasive in the personal sphere – such as supply-side reform or negative emissions technologies – these also need to be socially robust (Cox et al, 2020) and public support must be maintained over time.



Figure 3. Clear and memorable messages can help change behaviour⁶

3.1.2 What challenges need to be overcome?

Citizens' involvement in decision-making processes and delivering on action are two interlinked forms of public engagement. A shared national narrative – whether around “remaking Britain”, the “Green Industrial Revolution” or “net zero” – might strengthen consensus and render desired behavioural changes and actions more feasible. Ensuring inclusive and participatory engagement in decision-making requires clear and consistent communication as well as providing arenas for dialogue. Awareness of the concept of “net zero” is increasing – see Figure 4 – which is welcome, although it may be that a shared national narrative should be built around a more tangible concept. Action points, like buying a car or home appliances, reiterate why a shared narrative is key, as these are decisions which will typically go through intermediaries (businesses), who must also enable action on the same agenda, as discussed further in section 6. Similarly, engagement in delivery involves a

⁶ Photo by Peter Drew of Adelaide. See <https://www.flickr.com/photos/carltonreid/4646637491/>

plethora of actors and actions. Technology adoption is important, and so is political and community action, trend-setting or normalising low-carbon lifestyles and infrastructure.

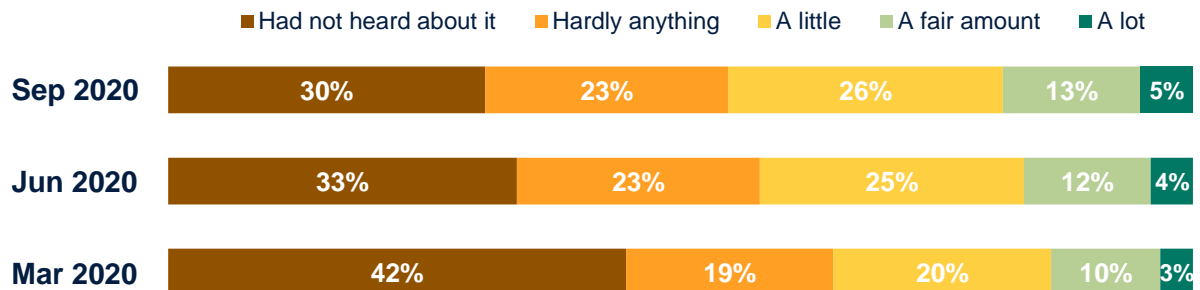


Figure 4. BEIS Public Attitudes Tracker: Wave 33-35 (BEIS, 2020b)⁷

3.1.3 Recommendations

The core recommendation is to deepen public engagement with the challenges and opportunities presented by the transition to net zero. Specific actions are proposed in the Box; many involve changing public perceptions and narratives. Strategic shifts of a critical segment of the population may serve to catalyse positive feedback effects. Evidence shows that support from a small proportion of a population may suffice to overcome the thresholds holding back such positive feedback (Chenoweth, 2013; Doyle et al., 2016; Cantola et al., 2018; Otto et al., 2020). Once an idea, such as a society with zero emissions, becomes prevalent and accepted in a proportion of the population, rapid change can happen driven by amplifying self-reinforcing expectations. Informing, monitoring and understanding public attitudes will be critical to keeping the pace of the transition comfortable for the population, and to identify opportunities to accelerate and to minimise counteracting feedback effects.

⁷ Totals do not sum to 100% due to the exclusion of ‘don’t know’ responses. From Question 220: “The Government promotes the concept of “Net Zero”. Before today, how much, if anything, did you know about this concept?”.

RECOMMENDATION 1: DEEPEN PUBLIC ENGAGEMENT

- **Political Leadership:** A **cross-party statement** by party leaders (**Johnson, Starmer, Davey**) that net zero and green recovery is a key priority, with a credible, coherent programme of actions and consistent ‘branding’/vision.
- **Dialogue:** A **national conversation** that provides vertical and horizontal alignment across scales and sectors on the importance of net zero and options to achieve it. Dialogue would also include **community engagement** to identify tailored local solutions and motivate place-based action.
- **Narratives:** Media coverage, including by the **BBC**, can build public support around an **inspiring collective vision** (e.g. a “Green Industrial Revolution”) and strengthening political mandate for bold action.
- **Behaviour change:** Investment by government to support **visible lifestyle changes** (e.g. energy efficiency, ICT to reduce travel, meat alternatives etc) and **targeting** interventions more effectively to ‘windows of opportunity’ where habits are disrupted and to segments who may be most receptive.
- **Share good practice:** identifying and disseminating exemplars of net zero lifestyles, cities, businesses, policies, etc. to increase sense that change is both possible and desirable.
- **Conduct public information campaigns and monitor public attitudes:** Fill gaps in the **BEIS** Public Attitudes Tracker to cover determinants of the **pace of progress that is politically possible**.

3.2 Deliver social justice*

3.2.1 Why it matters?

Achieving net zero by 2050 will require significant changes across society. Wide social consent will be necessary. This requires paying consideration to key groups in decision-making and ensuring no one is left behind. If critical groups are left behind in the transition, public support for the transition to net zero emissions is likely to wane. The importance of this is amplified by COVID-19, which has exposed our societies and economies to additional stress, amplifying inequalities and adding complexity.

3.2.2 What challenges need to be overcome?

There are many possible ways to achieve net zero emissions, some more socially just than others. In lieu of a formal definition, the Scottish Just Transition Commission has identified three guiding principles of a just transition (Scottish Government, 2020):

* Particular thanks to Jim Skea (in his personal capacity) for his input into this section.

1. **Planning ahead** – clear transition plans should be developed down to the sectoral level so that surprises are minimised. Unplanned transitions tend to be unjust transitions.
2. **Engagement** – people need to be brought into the decision-making process and derive a sense of ownership of the net zero project.
3. **Equity** – climate policies need to be systematically screened for their impact on vulnerable and excluded groups and for the opportunity to address existing inequalities.

3.2.3 Recommendations

The decarbonisation of our societies must ensure justice across the many and various processes of the transition, including procedural, distributive, recognition and restorative justice. To deliver, the net zero agenda needs to situate and frame these guiding policies within a UK context. Investing in skills and labour requires sensitivity to varying needs across sectors and locations. The fossil fuel industry, as well as the clean energy, agriculture and land use sectors must be activated, on both the consumer's and producer's ends.

Not all green investments generate jobs, and this can cause an avoidable spatial mismatch between technological growth and local economic activity. It is vital to consider the re-deployment of skills in the net zero transition. There are also positive multiplier effects between net zero and the social justice principles – examples of such synergies include energy efficient homes, heat-supply, afforestation and peatland restoration. COVID-19 may offer a window of opportunity to capture and reconfigure under-utilised skills for a future low-carbon economy.

RECOMMENDATION 2: DELIVER A JUST TRANSITION

- **Plan ahead.** BEIS (**Sharma**) should develop clear transition plans, especially for deprived regions and sectors, so that surprises are minimised. Unplanned transitions tend to be unjust transitions.
- **Put equity at the heart of climate change policies.** Systematically screen climate policies for their impact on vulnerable and excluded groups and for the opportunity to address existing inequalities (**Sunak**).
- **Identify opportunities for labour in declining sectors.** For instance, oil and gas workers will be needed for offshore decommissioning (plugging and abandonment), building offshore and geothermal renewables, CCUS and hydrogen (**Coffey**).
- **Procure green technology with local requirements:** Jobs in green supply chains are created locally, where possible, sharing the benefits of the transition.
- **Educate and train the young:** There are many more green jobs than fossil jobs and the Department for Education (**Williamson**) should ensure that young people have the skills required to do the many jobs necessary to meet net zero.
- **Reward and recognise positive behaviours:** Farmers are often alienated due to livestock emissions. Defra (**Eustice**) should recognise and reward them for a range of positive actions, including soil management, redirecting public subsidy for public goods.

3.3 Reorganise government*

3.3.1 Why it matters?

To deliver net zero, government must aptly manage conflicting interests and ensure consistency in messaging across all branches. A sense of ownership by the departments is key – net zero belongs to all and ought not be assigned to one in particular. Sideways guidance by another department is likely to be less potent than ‘top-down’ management, in particular when the priorities of the department are in conflict with changes required to achieve net zero. Institutionalisation of the challenge is necessary given the relatively rapid turnover in political leadership, as shown in Figure 1. Progress can be embedded with legal and administrative mechanisms – the 2008 Climate Change Act and Climate Change Committee provide examples – but political equivalents are now required.

* Particular thanks Giles Wilkes (in his personal capacity) for his input into this section.

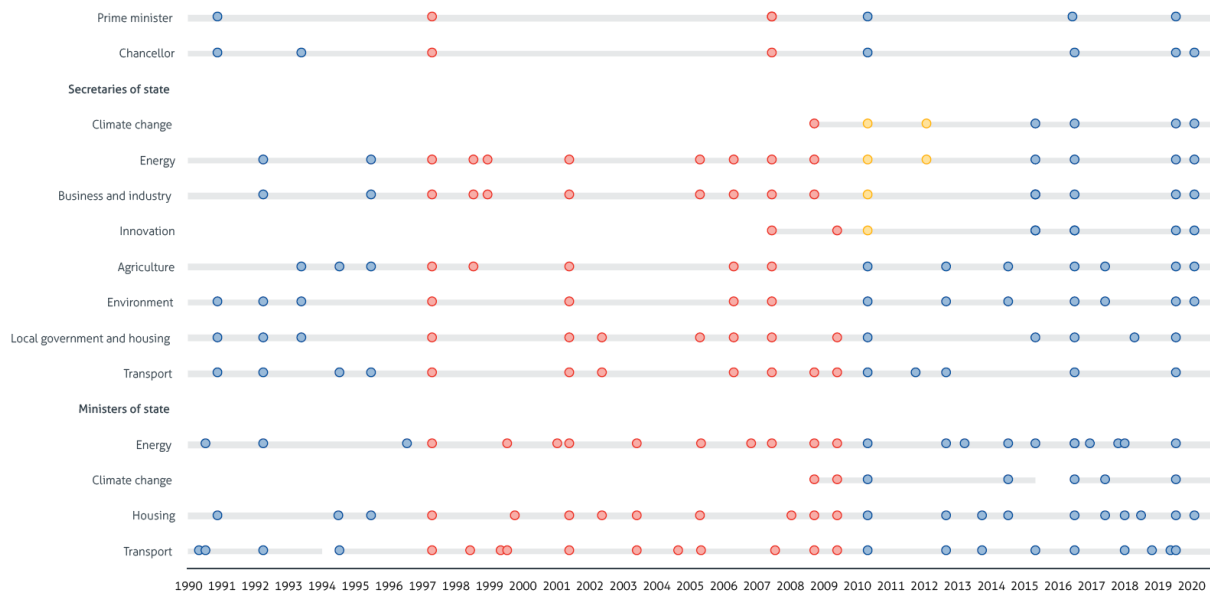


Figure 1. Rapid ministerial turnover may be unsuited to meeting long-term challenges (Sasse et al, 2020)

3.3.2 What challenges need to be overcome?

The scale of the task at hand implies that climate objectives can no longer be led by the department for Business Energy and Industrial Strategy (BEIS) and the Department for Environment, Farming and Rural Affairs (Defra) alone, but will require all departments to review how their policies interact with the UK's net zero target. Maintaining governance and guidance centrally in the heart of Government can enable an efficient coordination of net zero, for instance in setting climate targets, implementing policy proposals, responding to analyses from the Climate Change Committee and in leading international negotiations. The Government's creation of a Cabinet Committee on Climate Change is a step in the right direction. However, tools with which to solve conflicting interests require more than an organisational re-drawing of lines. Regulations and responsibilities within departments need re-defining, too, but such changes are likely to be met with resistance if they are perceived as a threat to existing priorities. For instance, HM Treasury's concern over emissions constraints must be equal that of its financial obligations. The task to untie such knots falls to the democratic legitimacy of the political leadership, which must be decisive and committed. The political whistle must each time blow the final ruling in the same (net zero) direction.

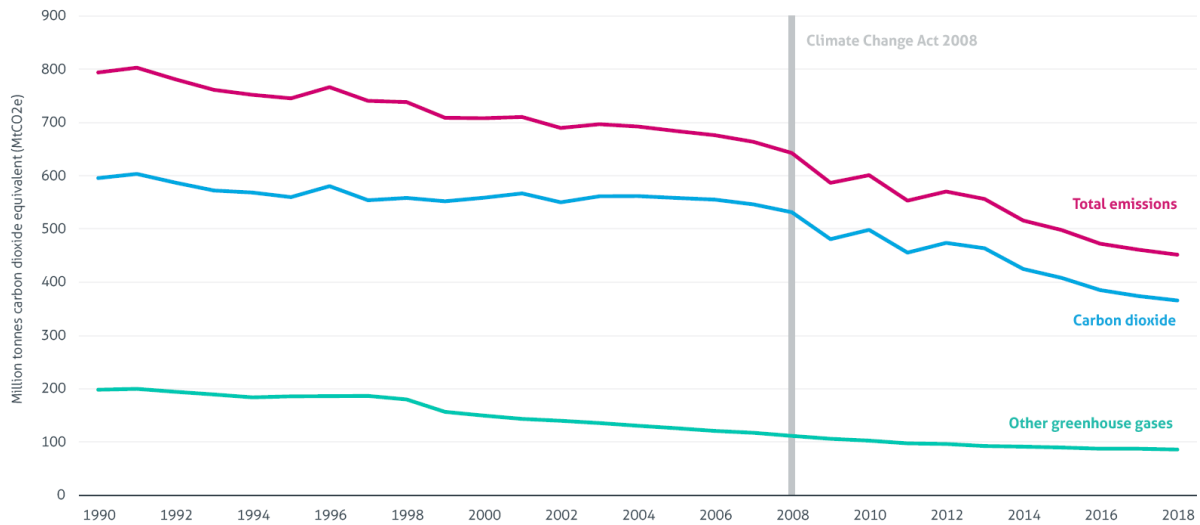


Figure 2. Progress has been made following the Climate Change Act (Sasse et al., 2020)

3.3.3 Recommendations

Leadership to achieve net zero is required across four dimensions. It must solve for *vertical* distortion of priorities and reach each departmental responsibility and function from top tiers of government. Similarly, *horizontal* governance ensures an equal shouldering of responsibility by the political leadership of departments and portfolios. Consistent leadership must also be maintained over *time*. Targets and priorities may be long-term, but they are also vulnerable to depletion by changed mandates and preferences. Finally, as the above sections have outlined, the political leadership must continuously seek *democratic legitimacy* in the eyes of its citizens. A dynamic dialogue through existing and innovative information and accountability mechanisms enables a continued mandate for the net zero agenda.

To satisfy these great demands and to clearly show the way along the levels of government, leadership must be decisive and committed. It must be well known across the system that the final vote will favour net zero. The “Task Force Net Zero” announced by the Prime Minister in November (HM Government, 2020) promises a “systems approach at the heart of our thinking”. If this body has the resource and political weight in current and future governments, it would be a step in the right direction.

RECOMMENDATION 3: REORGANISE GOVERNMENT

- **PM-backed Climate Change Minister:** Current and future PMs cannot be the climate minister but must prominently champion this person who should be feared for their clout. The PM should be actively and visibly involved in climate decisions.
- **Cabinet Office Responsibility:** Cabinet should set climate targets in response to the CCC, making the trade-offs passed up to it by ministers, oversee delivery, and conduct the international climate negotiations.
- **Vertical alignment:** The Cabinet Secretary (**Case**) must ensure that decisions of the Cabinet Office are followed by individual ministries and lower-level bodies.
- **Horizontal alignment:** Around the cabinet table, agendas come into conflict. When conflicts occur, the Cabinet Minister (**Gove**) needs to remind colleagues of the commitment to net zero that must be achieved.
- **Net Zero Corporate Plans:** Require any company meeting with ministers or secretaries of state to have a plan to reach net zero emissions.

3.4 Align incentives*

3.4.1 Why it matters?

Explicit and implicit incentives to reduce emissions and remove CO₂ from the atmosphere must be maintained and broadened if net zero is to be achieved. Carbon pricing in its various forms – carbon taxation, obligation and trading schemes or implicit prices through related interventions – can achieve this. A closely-related market-oriented proposal is the Carbon Takeback Obligation (CTBO), which would require all importers and extractors of fossil fuels to permanently dispose of one unit of carbon dioxide for every unit generated.⁸ Something akin to this obligation is required to achieve net zero: every tonne of carbon extracted for use as a fossil fuel will need to be offset with a tonne that is permanently captured and disposed of.

3.4.2 What challenges need to be overcome?

The politics of achieving high carbon prices is non-trivial (Klenert et al, 2019) and, in part because of this, carbon prices alone will clearly not be enough (Hepburn et al, 2020b). A CTBO might overcome some of these challenges, but faces its own difficulties. Lessons from the EU Emissions Trading System (ETS) have shown that a carbon market is not able to provide enough certainty to incentivise capital-intensive climate solutions (Laing et al, 2014). As fossil fuel industries are weakened, and as new cleaner energy sources become more dominant,

* Particular thanks to Myles Allen, Stuart Jenkins, Eli Mitchell-Larson and Stuart Haszeldine for their input into this section.

⁸ See <https://carbontakeback.org/about/> for more information.

the politics of carbon prices and a CBTO should become easier. Introducing high explicit carbon prices suddenly, however, has rarely been feasible. Starting low and increasing gradually is more plausible. The equivalent move for a CBTO is to impose a very low initial proportion of carbon extracted or imported that must be sequestered. In the case of carbon pricing, the shrewd use of revenues is critical to public acceptability and to the overall impact and effectiveness (Klenert et al, 2019); some portion of the revenues could be applied to instruments such as CfDs that will pull down costs, by reducing risk (which reduces financing costs) and by increasing deployment.

3.4.3 Recommendations

Introducing, broadening and increasing average carbon prices (which can vary significantly across different sources of emissions) is a standard recommendation from climate economics, and we repeat that message here. We would also recommend considering the gradual imposition of a Carbon Takeback Obligation (CTBO) that would ramp up to covering 100% of imported or extracted carbon by 2050 – this is required for net zero. Allen (2020) argues that the UK could commit to sequestering 1% of its carbon emissions in 2023, and 10% by 2030, and that such an intervention could help birth an international carbon dioxide disposal industry, unlock thousands of jobs, protect offshore industry and relieve pension funds of being locked into investments at risk of being ‘sunk’ in a net zero trajectory.

RECOMMENDATION 4: ALIGN INCENTIVES

- **Carbon prices:** Carbon prices should continue in the UK economy after Brexit. Part of the revenues of domestic carbon prices and border carbon adjustments could be used to fund policies to pull down the relative costs of clean technologies. This report is agnostic on whether pricing is implemented predominantly through taxation or a trading mechanism.
- **Carbon Takeback Obligation:** BEIS ([Sharma](#)) should consider gradually introducing a CTBO, covering 1% of emissions in 2023, rising to covering 10% of emissions in 2030 and 100% of emissions in 2050, to ensure that net zero is achieved on target.

3.5 Leverage global dynamics*

3.5.1 Why it matters?

The UK is a relative small emitter compared to many other countries and we can’t solve this problem alone. The UK has and can continue to play a significant role on the global stage, for several reasons. The scientific and broader academic strengths of the UK are world leading. The UK retains international clout as a member of the G7, the United Nations Security Council, and as host of COP26. As part of Europe (if not the EU), it is part of the largest set of economic

* Particular thanks to Bryony Worthington (in her personal capacity) for her input into this section.

consumers on Earth. The UK also retains a world-leading financial centre, and a degree of respect for its governmental institutions and law and policy making expertise.

UK climate legislation for net zero prioritises domestic action, though we have a considerable overseas impact both in terms of our investments and consumption.⁹ Helping to reduce global emissions is therefore a strong necessary complement to domestic efforts.

The UK can and should therefore think about interventions at home and abroad that are likely to trigger scaled up action internationally. Understanding international dynamics also implies looking for ways that the UK can take leadership and capture new markets, while also protecting the small number of industries that might be disadvantaged by the UK pushing harder or faster towards net zero.

3.5.2 What challenges need to be overcome?

The tragedy of the commons (Hardin, 1968) is not insoluble (Ostrom, 1990), and UK leadership might “tip” an inefficient equilibrium to an efficient one (Heal and Kunreuther, 2010, 2011). A global carbon price is unlikely and perhaps even less than optimal (Hepburn et al., 2020b; Cullenward and Victor, 2020), but carbon pricing can be sensibly employed beyond the existing coverage of the ETS. Taxes could be imposed upon sources of carbon emissions in the UK that are currently untaxed (e.g. gas use in buildings, agriculture, shipping and aviation) and rationalising the UK’s array of implicit and explicit carbon prices to ensure market signals align with low-carbon options.¹⁰ At the same time, action to reduce emissions taken in the UK should avoid importation of higher-carbon alternatives from abroad.

3.5.3 Recommendations

Carbon pricing can be complemented with trade regulation policies. Border Carbon Adjustments (BCAs) aim to ensure that imported goods produced under less ambitious climate regimes do not negatively harm the industries inside the trade union or country (Helm et al., 2012). This can create positive price signals to producers in such regimes and exposed domestic industries can be protected, for instance by payment of the carbon price, taxation on imported goods, or by surrendering appropriate emissions allowances, or through other trade mechanisms. They are now a serious possibility, with a public consultation closing in October 2020 and the European Commission expected to publish its proposals in the second quarter of 2021 (Morgan, 2020). Faced with a BCA imposed by one country (A), the likely optimal response a second country (B), rather than engage in a trade war, is to impose carbon pricing on its own production and/or exports to collect the revenues available, as modelled in Helm et al. (2012) and shown in Figure 3. A domino effects could follow, broadening carbon pricing globally. However, if countries with net-zero targets follow through with higher carbon prices, BCAs may in effect apply only to Australia, India, African countries and some least developed

⁹ According to ONS (2019) in 2016 UK’s territory based greenhouse gas emissions were 473 million tonnes, while its consumption-based emissions (including aviation, shipping and net imported emissions) were 784 million tonnes, a difference of 311 million tonnes.

¹⁰ See, for example, ESC (2019) Rethinking Decarbonisation Incentives.

countries. While Australian coal and gas exports would be rightly in the crosshairs, fairness and justice considerations might moderate the application of BCAs to the least developed countries.

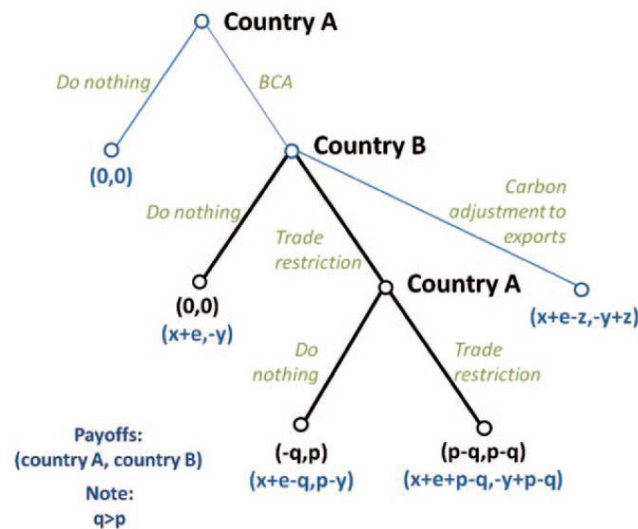


Figure 3. A border carbon adjustment could have a domino effect

Second, internationally, action to reorient investments and address the UK’s consumption emissions could potentially count towards a more ambitious UK NDC and domestic target. Bilateral and multilateral agreements to invest in international abatement and leveraging Official Development Assistance (ODA) to support zero carbon transitions could also count towards the UK’s NDC. Creating markets for zero carbon solutions overseas can also support UK exports of goods and services.

The UK’s net zero commitment has potential for wide reach and impact. Leveraging these dynamics requires decisive action on the domestic and international arenas. The UK could pave the way for both in complementing domestic actions with international emissions abatement and by 2050, a net zero scenario domestically may well be ‘net positive’ internationally. The Paris Agreement goals will require all countries to reach net zero by the middle of the century, and for large amounts of removals to continue to happen in the second half of the century. The UK moving faster to zero, and beyond, will give diplomatic space to pressure other countries to make similar commitments by the mid-century mark.

RECOMMENDATION 5: LEVERAGE GLOBAL DYNAMICS

- **Border Carbon Adjustments:** Working with the EU, the Secretary of State for International Trade (**Truss**) and BEIS (**Sharma**) should consider using trade law to prevent carbon leakage and to encourage carbon pricing in other countries.
- **Preferential trading arrangements:** Consider forming bilateral and multilateral preferential trading arrangements for environmental goods and services.
- **Stop UK Export Finance loans or guarantees to fossil projects:** UK Export Finance (**Taylor**) must ensure that UK state or private financial institutions are no longer financing new projects inconsistent with global net zero emissions by 2050.
- **Support climate-compatible growth in developing countries:** The FCDO (**Raab**) should work with the COP26 to deploy carrots and sticks to eliminate fossil subsidies, lift climate ambition and implementation in other nations.
- **Bolder UK targets:** By taking bold action, the UK will have to develop effective policy frameworks which others can copy. More ambitious targets could comprise a 100% reduction by 2040 (90% domestic, 10% international offsets) and 120% by 2050 (100% domestic, 20% offsets) (**Johnson, Sharma, Raab**). Investments in overseas abatement can be used to catalyse and scale up action in other countries.

3.6 Increase business ambition*

3.6.1 Why it matters?

Business ambition is integrally linked to a net zero trajectory. Businesses generate emissions directly, and the products and services they choose to offer have a huge impact on individuals' and households' emissions. Consider that the average new car in 2005 emitted 170 grams of CO₂ per kilometre, while the figure in 2015 was just over 120 grams – a reduction of almost 30 percent in 10 years (DfT, 2015). Businesses who lead in developing and adopting technologies and approaches consistent with net zero make it easier for governments to pass laws and regulations requiring such technologies and approaches to be adopted by all. The recent surge in business leaders' and shareholders' interest in environmental, social and governance (ESG) priorities is a valuable intervention point to be leveraged. Creating a “net zero political economy”, where firms will lobby for change, providing a counterweight to other incumbents lobbying against change, reduces the political cost of action.

* Particular thanks to Tera Allas (in her personal capacity) for her input into this section.

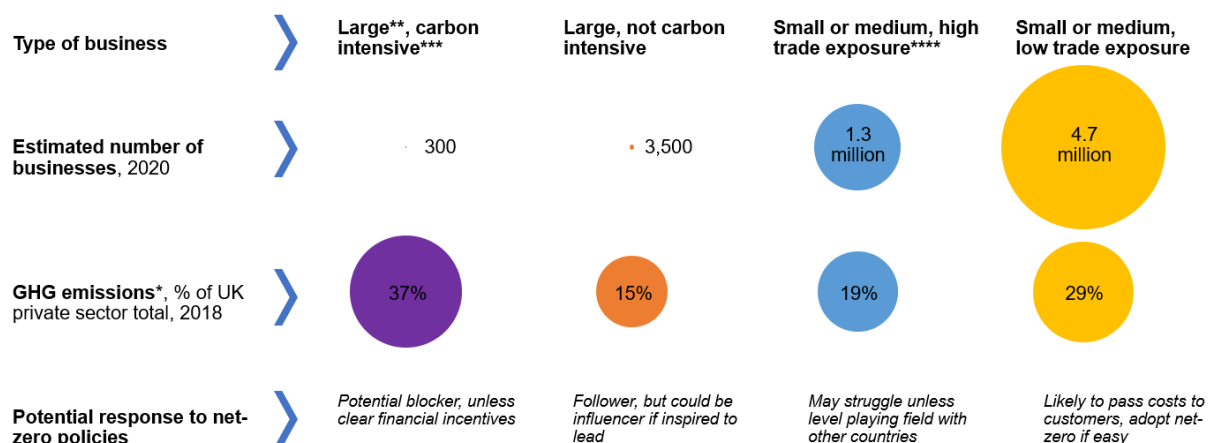
3.6.2 What challenges need to be overcome?

In addition to recommendations in other sections of this report – for example, on carbon pricing and GHG accounting – there are a number of necessary “kicks” and “shifts” required to accelerate UK businesses action towards net zero.

Effective business-facing interventions will also exploit the highly heterogeneous nature of the UK’s nearly 6 million businesses, as shown in Figure 8. A mere 300 businesses make up 37% of total private sector greenhouse gas emissions. Similarly, a relatively small number of companies are likely to be central to the R&D and manufacturing efforts to enable better commercialisation and deployment of net-zero technologies across all sectors of the economy (HMRC, 2020). Capturing large and innovative businesses’ attention and working together with them to deliver net zero will be crucial to meeting the UK’s ambition.

In contrast, millions of small and medium sized businesses in the UK are unlikely to be fully aware of the UK’s net zero agenda, may not respond to higher energy prices or carbon pricing in rational ways, or may not have access to the financing they would need to make net-zero-consistent investments. Moreover, a large proportion of the UK’s small businesses operate in sectors with limited exposure to energy or carbon prices and limited international competition. Rather than taking action to improve energy efficiency and reduce emissions, they may simply pass the marginally higher prices to consumers. SMEs, therefore may need to be treated more like individuals, accepting their cognitive and behavioural limitations. This may necessitate, for example, the kind of public engagement efforts described in section 3.1 of this report.

Finally, business attention has been diverted into dealing with the immediate and existential crisis created by COVID-19. Continued communication, engagement, support and collaboration will be required to keep net zero high up on businesses’ agendas.



* Estimated based on sector GHG intensity in 2018, sector export intensity in 2017, and business size distribution in each sector in 2020; ** 500 or more employees; *** Sector GHG intensity more than 1 tonne of CO₂ equivalent per £1,000 of GVA; **** Sector exports more than 40% of GVA. Source: ONS, HM Government Business population estimates 2020; McKinsey team analysis.

Figure 8. The UK’s GHG emissions come from four types of businesses

3.6.3 Recommendations

A portfolio of effective interventions for the business sector can be created by segmenting the actors into four categories: *innovators* (sophisticated players whose products and services could significantly reduce emissions across the economy); *potential blockers* (large, high-energy or carbon-intensive businesses with a lot to lose); *influencers* (large, trend-setting or industry-shaping businesses with leaders that others are likely to follow); and *followers* (the rest of businesses that do not have the bandwidth to specifically address climate change but are also unlikely to swim against the tide if others are adopting a net-zero approach).

For *innovators*, a set of effective approaches is set out in the next section 3.7, addressing how to accelerate clean technology development and deployment. Their products and services will be key “shifts” that will enable others in the economy to “flow towards” net-zero (often with limited conscious effort).

As for the UK’s large, carbon-intensive businesses (the *potential blockers*), their small number makes it possible to understand each of their circumstances, risks and transition issues in detail. They will need to be incentivised, financially and reputationally, to rapidly shift towards a net-zero-consistent business model – if they are not on that path already. Articulating what this would look like, and measuring progress, could help build up peer pressure and leverage shareholders’ desire for managing future carbon risk. Government could engage with each of them individually (building on the Net Zero Corporate Plans recommendation in section 3.3).

For less carbon- or energy-intensive large organisations, industry- or nation-wide joint declarations, within a shared framework, could elevate these issues to board level and ensure that their strategies are brought to line with net zero. COP26 is a critical opportunity for creating such commitments. In addition, sharing of best practices and positive case studies (along with the recommendations in section 3.8 relating to Paris-aligned accounts and audits), could be a sufficient “kick” to build climate awareness into day-to-day decision making. For example, across all industries, many GHG mitigation actions have a positive NPV. But how many UK Chairs and CEO’s realise this and strive to capture the win-wins available?

Identifying the *influencers* among leading UK businesses (whether carbon-intensive or not) should be a priority, in order to create a longer-term movement that is independent of the government of the day. Such businesses, and business leaders, if identified early enough, could play a critical role in coordinating, agreeing, and embedding the actions mentioned in the previous paragraph. They would also act as important role models for *followers*.

Finally, for British businesses to transition long-term, it must be made clear from the political leadership that net zero is here to stay.

RECOMMENDATION 6: INCREASE BUSINESS AMBITION

- **Identify and engage with key businesses:** Government should identify and name the top 100 businesses that are critical to achieving net zero in the UK. These businesses should be directly engaged with, using a clear relationship-management approach, to ensure they drive net zero (**Sharma**).
- **Circumvent resistance:** Businesses who lose from the transition will need ruthless regulation (and scrutiny) and/or some support for their transition. One-to-one business negotiations by the government (e.g., to “save” a fossil-intensive asset) should have net-zero among their top 3 priorities.
- **Support climate innovators:** In addition to recommendations in the next section, government should use its procurement, convening power and networks to secure demand, contracts and credibility for the UK’s climate innovators.
- **Elevate climate leaders:** Identifying businesses that shape industries (due to their size or leadership) and celebrating and amplifying their successes can help other businesses understand the urgency and importance of net zero. They can also provide critical momentum for COP26.
- **Require consistent GHG reporting:** All large businesses should be required to disclose progress towards their business being consistent with a net-zero future (in line with recommendations in section 3.8).

3.7 Accelerate clean technology*

3.7.1 Why it matters?

Reaching net zero requires a variety of technologies and varying combinations of these across sectors. The past decade has witnessed a rapid development and acceleration of low- or zero-carbon technologies. Innovation is path dependent (Aghion et al., 2019) and rates of learning in existing technologies is not completely unpredictable over time (Farmer and Lafond, 2016). Further, uncertainty over “winning” technologies tends to reduce with more experience. Combining this fact with classical portfolio theory implies that an optimal technology portfolio will be highly diverse in the early stages of the transition, with gradual concertation on “winners” as experience accumulates (Way et al., 2019).

Technologies interact, which can be beneficial once the transition is underway. Figure 9 makes the point that more and cheaper batteries, more and cheaper solar, and more and cheaper electric vehicles can feed upon each other, with advances in one area accelerating progress in another. However, these interactions can also make technological systems vulnerable to bottlenecks or immature solutions in supply chains. Half of the required emissions reductions

* Particular thanks to Laura Cozzi, Michael Liebreich, and Peter Bruce for their input into this section.

need to reach net zero require technologies which are “not yet commercially viable” (IEA, 2020a), specifically technologies in land-use, carbon capture, utilisation and storage (CCUS); clean hydrogen and hydrogen-derived fuels and bioenergy (IEA, 2020a). Bringing these solutions to the ‘hardest-to-abate’ sectors and making them viable and accessible is difficult. Innovation and R&D is also vital to support the commercialisation in processes such as long-distance transport, high temperature production industries and energy storage sectors.

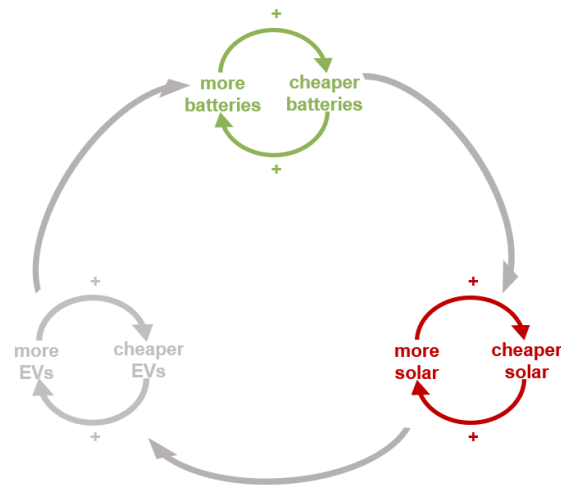


Figure 9. Learning and network effects in clean technologies are powerful amplifiers

3.7.2 What challenges need to be overcome?

A nuanced understanding of the technological maturity of sectors – and the technological possibilities yet to mature – is required inform government. Currently, the CCC provides advice based on technologies available today to reduce emissions, considering a range of costs and efficiencies based on projected technological progress. More could be done and there are four key challenges to overcome.

First, identifying key unsolved problems, and bottlenecks involved in developing and deploying technologies, is important to devise policy to improve efficiency and performance, scalability and to reduce cost. Problems (or opportunities) might arise when various technologies are combined – until particular neighbourhoods or towns go fully net zero and are forced to solve various technological challenges simultaneously, such knowledge is not available.

Second, uncertainty around the optimal energy mix – for instance the respective roles of nuclear and renewables – may slow progress (Schneider and Froggatt, 2020). Nuclear energy may be suitable in sectors which require constant power access and can make use of residue heat. Intermittent renewables need to be paired with energy storage if dispatchable power is required. They may or may not sit comfortably together, depending on the flexibility of nuclear and the ability to store and dispatch renewable energy at short, medium and long durations. Another example is the precise niches that hydrogen and ammonia (or similar molecular energy carrier) are likely to occupy in a net zero economy.

Third, industries will achieve net zero at different rates. Negative emissions in one sector could be used to offset emissions in others which may require more capital-intensive reform, but the precise role and extent of negative emissions remains uncertain.

Fourth, the workforce to deliver on today's targets are currently being educated and trained, and must be equipped with appropriate skills if key technologies are to be employed. Investments into skills and supply chains are critical to enable the needed scale and speed of action in many areas, including decarbonising heating (Killip et al., 2018; Wade et al., 2016).

3.7.3 Recommendations

There are four main recommendations. First, greater intellectual effort should be invested in charting the course for plausible mixes of net zero technologies, with an understanding of when key choices need to be made. It is pleasing to see that some of this is already occurring in the HM Treasury Net Zero Review. The UK also has a strong asset in its learned societies – not least the Royal Society and the Royal Academy of Engineering – to help understand how the existing ecosystem of fossil technologies can be transformed to an ecosystem of clean technologies.

Second, and relatedly, a set of “pathfinder” projects in specific regions or cities should be supported, perhaps akin to the “Hydrogen Neighbourhood” to be scaled up to a “potential Hydrogen Town” announced in the Ten Point Plan (HM Government, 2020). Piloting select cities or regional actors that leap ahead will enable solutions and barriers to be identified early, providing lessons for others. The pathfinders would seek to identify which technologies are working, which are not, which combinations of innovations provide synergies and which are not complementary.

Third, the UK should prioritise technologies where learning rates appear high, where the UK has a comparative advantage, and in a manner that is coordinated with efforts in other countries. The UK will rely on global innovation to achieve its net zero target, and the speed with which the above technologies are developed and deployed is therefore partially outside its direct control. The COP26 presidency is of particular interest as an arena in which innovation alliances and agreements can be promoted. There are also innovation gaps which the UK can shoulder an international role where it has advantages, for example in floating off-shore wind, nuclear small modular reactors (SMRs), CCUS and hydrogen.

RECOMMENDATION 7: ACCELERATE CLEAN TECHNOLOGY

- **Strategically support key clean technologies.** Some technologies have predictably higher learning rates than others, even based on limited early data. This can be used to bet on a portfolio of technologies, noting that half of the emissions reductions will come from heating and transport, CCUS, hydrogen and bioenergy, where key technologies are not yet commercial. Globally, wind, nuclear SMRs, CCUS and hydrogen are areas of interest for the UK. Procurement policies and R&D subsidies could be aligned to net zero.
- **Share reliable and up-to-date technology cost information.** Often key institutions are several years behind in their understanding of the costs of different technologies. 2-3 years of progress in wind has been equivalent to more than decades of progress in coal. Making this information available quickly and credibly would reinforce the fact that clean technologies are cheaper and help redirect investment.
- **Fund pathfinder projects in specific regions or cities.** These pathfinders would enable us to learn about what is actually required to make net zero a reality, including the roadblocks and other likely stumbles. They could also help us understand synergies between technologies.
- **Identify key technology ecosystems:** Technologies interact, and key to the shift to net zero is to ensure that the entire ecosystem of technologies is commercially viable. There is value in identifying critical vulnerabilities in a quickly changing global environment post-COVID.
- **Use the UK's COP26 presidency to coordinate innovation leadership.** Collaboration could accelerate the transition through international institutions (IEA, the Clean Energy Ministerial and Mission Innovation) and/or through bilateral partnerships.

3.8 Redirect capital flows*

3.8.1 Why it matters

Inevitably, the more profitable an asset is perceived to be, the more investments it will attract. Existing investments in carbon-intensive assets remain significant, though spending has taken a downturn during COVID-19 (IEA, 2020b). As long as assets are valued without consideration to material climate risk or the emissions they are associated with, incentives to direct capital will be incorrect, with too much capital flowing to fossil assets. Changing accounting requirements is likely to cause a price adjustment of carbon-heavy assets and level the playing field for renewable energy sources.

* Particular thanks to Natasha Landell Mills and the CCC's Advisory Group on Finance for input into this section.

3.8.2 What challenges need to be overcome?

A future low-carbon economy will require capital-intensive investments, but its operational costs are expected to be smaller than those of today's industries. However, market, policy and institutional failures limit access to and delay capital flows needed to stimulate the transition (Robins and Pierfederici, 2020).

One way to target the inertia is to increase transparency and ensure access to information - small yet potentially powerful policy interventions. For instance, the expected life span and future profitability of carbon-intensive assets and the depreciation of value following increased carbon taxes and CCUS expenses, or the competitive advantages of accelerated developments of renewable alternatives, are cause for the readjustment of value. Accounting for these considerations would also change companies' financial statements and provide a more reliable view of entities' profits and capital. This is vital since these financial statements are used by management and investors in their capital deployment decision-making. Where the accounts fail to reflect these material climate risks, capital will be misdirected.

An existing approach to promote better climate risk reporting is the Task Force for Climate-related Financial Disclosures (TCFD, 2020). The TCFD sets out guidelines for the management and disclosure of material climate risk, but not financial statements themselves – and it is these that direct incentives to invest.

Financial statements will not be adjusted to reflect a net zero pathway, and capital will not be redirected, if political leadership on net zero is not perceived as credible (see sections 3.1 and 3.3). Though there are examples of large listed companies acting (see, for instance, BP, 2020; Shell, 2020; Total, 2020; National Grid, 2020), the pace of change is slower than the need. Improving climate risk management is important but likely insufficient for net zero (Caldecott, 2020). By making it mandatory for companies to produce Paris-aligned financial statements, supported by Paris-aligned audits, capital flows will be redirected and companies incentivised to adopt transitions plans.

3.8.3 Recommendations

The CCC's Advisory Group on Finance makes several recommendations with a view to the UK becoming the first "net-zero financial system". We complement those recommendations with consideration on audit and accounting issues. The credibility of our commitment to net zero is related to the alignment of financial statements with that objective. Business leaders can be requested to confirm in their accounts that they have accounted for material climate risk or explain why they have not. Auditors could likewise provide a statement of affirmation that they have considered the Paris Agreement when reviewing company accounts, and have called out any misalignment.

RECOMMENDATION 8: REDIRECT CAPITAL FLOWS

- **Mandate Paris-aligned accounts:** Asset and liability values should be based on scenarios that are consistent with net zero emissions by 2050. Investors need to ensure that their capital is directed towards businesses that are profitable as the global economy transitions to net zero.
- **Mandate Paris-aligned audits:** Auditors should be required to consider the Paris Agreement and net zero commitments when reviewing company accounts. They should sound the alarm where the accounts are not consistent with these targets, or where they fail to reflect material climate risks.

3.9 Harness legal avenues*

3.9.1 Why it matters?

Legal avenues – legislation, regulation and the courts to judge compliance – have teeth that other interventions do not have. For instance, the UK Supreme Court ruled against a third runway at Heathrow Airport because of a failure to consider the Paris Agreement (Taylor, 2020).

3.9.2 What challenges need to be overcome?

The UK is in the process of drafting its sixth carbon budget – a five-year cap on permissible emissions for the period of 2033-2037. It will be the first carbon budget set within the government’s net zero target. However, estimates from the CCC show that the government is on track to breach both its fourth and fifth budgets (2019b).

3.9.3 Recommendations

Government could establish a team of government lawyers to identify and shape the most significant legal and regulatory interventions to accelerate progress to net zero. This might include consideration of regulation and laws outside the usual territory of climate change. For instance, might a limited ‘climate defence’ be established by the Competition and Markets Authority to protect agreements made in good faith to accelerate net zero from the full weight of competition law? Or should all regulators regard the Paris Agreement, 6th carbon budget and 2050 net zero target in their duties?

Legislation and the courts can also be employed to reduce emissions. Lawyers within civil society might choose to strategically identify and pursue well-founded legal actions to accelerate change towards net zero.

* Particular thanks to James Thornton, Jonathan Church and Thom Wetzler for their input into this section.

RECOMMENDATION 9: HARNESS THE LAW

- **Climate laws:** The Attorney General (**Braverman**) could establish a small team of lawyers to identify and shape the most significant legal and regulatory interventions to accelerate progress to net zero.
- **A climate defence:** The Competition and Markets Authority (**Coscelli**) might consider a limited 'climate defence' to protect agreements made in good faith to accelerate net zero from the full weight of competition law.
- **Regulator duties:** Require all regulators to regard the Paris Agreement, 6th carbon budget and 2050 net zero target in their duties.
- **Strategic litigation:** Lawyers within civil society should strategically identify and pursue legal interventions to accelerate change.

4. Conclusions

The pace of change required to achieve net zero emissions in the UK by 2050 is fast but manageable. In some areas, action builds on current trends and investments where momentum is good and strengthening. Energy and transport provide two examples. In other areas, uncertainty remains and requires resolution as swiftly as possible. The decarbonisation of heat is one such area. Finally, in some areas that are necessary to achieve net zero, action globally has barely begun, such as in CCUS and the harder to abate sectors. It is possible in these areas the UK could be an early mover.

The economics of the transition to net zero has moved in a positive direction and is more advantageous than is widely appreciated. The costs of clean technologies have fallen fast and will most likely continue to do so. The cost of capital is already low, and as risks involved in zero carbon technologies will fall as those technologies mature, as familiarity with the ecosystem of new technologies increases, and as government policy risk fades. Once the transition is complete, the legacy will be a set of clean infrastructures that will offer core services within energy and mobility at very low cost, potentially boosting prosperity and increasingly the inclusivity of society. There is a real sense in which this generation will be the **Victorians of the 21st Century**.

This report has identified a portfolio of 40 different sensitive intervention points across nine categories, namely:

1. Deepen public engagement;
2. Deliver a just transition;
3. Reorganise government;
4. Align incentives;
5. Leverage global dynamics;
6. Increase business ambition;
7. Accelerate technological progress, using “pathfinders”;
8. Redirect capital flows, through accounting and audit interventions;
9. Harness the law, with a government legal team to consider legal and regulatory shifts.

These “kicks” and “shifts” are largely modest interventions that have been included in this report because they could produce disproportionately large impacts. The themes of the “Ten Point Plan” (HM Government, 2020) are harmonious with those developed here, and several further points in the plan will be needed to get to net zero. There is no certainty that each of the “sensitive intervention points” advanced here will have large effects. But our view is that within this portfolio of cross-cutting recommendations, lie some big opportunities to accelerate progress at relatively modest cost.

4.1 Conclusions for the CCC

The Climate Change Committee plays a central role in the transition to net zero. While many of the recommendations in this report are for government, as a Policy Advisory Group to the CCC, we highlight four recommendations specifically for the CCC:

1. The CCC, joint with BEIS, plays an important role in aggregating indicators of progress and ensuring the public is aware of progress so that democratic institutions can be employed to hold the government to account. The CCC and BEIS could do more to **monitor public and business beliefs, narratives and attitudes**. This should go well beyond surveying for awareness of (arguably) technocratic concepts such as “net zero”, to understanding of which technologies or behaviour changes are socially robust. The rapid pace of change required will only be feasible if it progresses at a rate that is acceptable to communities around the nation.
2. The CCC has an important role in **shaping beliefs and narratives**, ensuring that they are based on facts, and upon plausible and transparent visions of the potential net zero futures that are publicly available for scrutiny. The CCC scenarios contribute to this already, but the scenarios could be more publicly available and digestible, with clearer implications for different communities and households across the country. Scenarios might also highlight where there is genuine uncertainty and set out how and when this uncertainty might be resolved.
3. **Fairness and distributional implications** should be assessed and presented by the CCC; proposals to government must be advanced with a close eye on achieving a just transition. While the political implications of specific alternative pathways to net zero are not a core consideration for a technocratic body, the political and public acceptability of each element of the transition is of immense importance to its feasibility – such considerations must also, therefore, be in scope.
4. Drawing upon the Royal Society and Royal Academy of Engineering and other relevant bodies of experts, the CCC should deepen its understanding of the **palette of different detailed technological possibilities** that are not yet near to market. While time is short, research can further pull down the costs of technologies that we know are required for success, and of course it is also possible that a “**Green Swan**” or two could emerge within the next decade. It is worth the CCC having a deeper understanding of the technological landscape so that advice to government can maximise the probability of a positive “surprise” occurring.

4.2 Recommendations for Government

As we emerge from the second set of lockdowns with the prospect of the wide distribution of COVID-19 vaccines in 2021, the emphasis of economic policymaking will move to implementing a jobs-led recovery and then, in due course, to restoring public balance sheets. It is worth remembering that there are more jobs available in this huge, and necessary, transition than there are in the continuation of the status quo, which could see us “leap from the COVID frying pan into the climate fire” (Hepburn et al, 2020a). When the time comes to raise public revenue, the role of carbon pricing should not be forgotten.

Much of this report is not about specific sectors, or detailed policy recommendations for BEIS alone to implement. Rather, the 40 cross-cutting interventions recommended in this report are relevant multiple Secretaries and Ministers of State, as noted in the relevant boxes. We highlight the three overarching recommendations as follows:

1. **Visionary Leadership.** Achieving net zero will be extremely difficult, if not impossible, without a clearly communicated vision from successive Prime Ministers. Prime Ministers must provide leadership that informs and inspires the public, with the magnanimity to pass the baton in a manner wholly dissimilar to the current transition of power in the USA, so that subsequent leaders can stand on the shoulders of giants.
2. **Inspiring Narratives.** The narratives constructed about achieving net zero must be shared, broad and malleable enough that they can be “owned” by relevant political parties during their term of office. They can accurately point to the meaningful work created by the transition, the huge benefits for health, productivity and well-being of a cleaner and cheaper economy, and the specific place-based opportunities from net zero emissions.
3. **Organised Government.** Achieving net zero is a major managerial challenge. Government is not currently well-organised to deliver. New institutions, teams and structures need to be put in place so that government can take the necessary decisions at Cabinet, engage strategically with the private sector, including key innovators and emitters, and to “get climate done”.

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