UK Net-Zero Advisory Group to the Committee on Climate Change

Chair's Final Report

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April 2019

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1. Summary of recommendations

The UK net zero advisory group was established by the Committee on Climate Change (CCC) to advise them on how the UK can reduce emissions to net-zero, and how the CCC should approach and interpret the modelling of these scenarios. The advisory group reached the following conclusions and recommendations:

1. **A transition to a net zero UK economy is technically achievable**. The advisory group's main concern is about whether this can be delivered – particularly the ability of government to implement the fundamental and wide ranging policy reforms necessary to achieve this goal by 2050.

2. There is a need for a **fundamental change in the UK policy approach to the low carbon transition** – from the current piecemeal approach that focuses on specific actions in some sectors to an explicitly economy-wide approach. This should build on the world-leading Climate Change Act and include:
   - Policy leadership at the heart of government. Whilst BEIS have played an important role so far, for example in leading the Clean Growth Strategy, action to reduce emissions cannot be left to one government department. HM Treasury needs to take a leading role, so net zero becomes an explicit goal of economic policy (alongside other goals such as productivity improvement). Leadership should also mean a much more active role in delivery for all departments and agencies.
   - The promotion of GHG emissions monitoring to the same status as economic monitoring, e.g. by publishing regular emissions metrics alongside GDP and productivity statistics.
   - Ensuring that all policy decisions and sectoral strategies are informed by the requirement for them to contribute to the delivery of net zero by 2050, e.g. through reforms to the 'Green Book'. In a net zero world there is no room for any sectors to remain 'untouched', including agriculture and aviation.
   - A flexible and responsive approach to policy that allows quick action and adaptation to take place if there is insufficient progress towards net zero.

3. **The 2050 target should be implemented as a 100% reduction in GHGs from the UK on a production basis**. This can include a significant contribution from greenhouse gas removal (GGR) options.
   - The use of offsets to achieve a small percentage of required emissions reductions is a possibility, and would provide government with some flexibility. Any offsets should support the international transition to net zero.
   - When monitoring progress towards net zero, production and consumption emissions should be reported at the same time.

4. **All options that can help to meet a net zero target domestically should be explored fully.** Single transition pathways, which rely on all technologies and measures succeeding are too risky and inflexible. They do not take into account the inherent uncertainties that lie ahead. The CCC analysis includes conservative assumptions about demand reduction. Therefore an important source of flexibility could be greater ambition on the demand side.

5. **Net zero should not simply mean a shift in long term aspirations**, with implementation left to future governments and generations. It also requires government and other actors to do things differently in the next five years. For example:
    - The fundamental policy reforms discussed in recommendation 2 need to start now alongside more detailed policies. Whilst prices (including for carbon) matter, the evidence suggests regulations can play an important role in driving rapid change. This means implementing ambitious, economically-efficient regulatory targets to provide long-term visibility to citizens, firms and other decision-makers.
    - There is an early opportunity to maximise the use of readily available GGR options including afforestation, agroforestry and land management.
    - There is also an urgent need to trial, demonstrate and evaluate key technical and social innovations for net zero. Public funding should be prioritised for innovations that can make significant contributions to achieving net zero, and where there is potential for UK global leadership and wider economic benefits. Priorities should include large scale trials of hydrogen; development of CCS transport and storage infrastructure; deployment of BECCS at scale; scaled up demonstrations of direct air capture; and trials of innovations to reduce emissions from aviation.

6. **The costs and benefits of a transition to net zero, including distributional impacts, require much more attention**. This includes maximising the economic opportunities to the UK (e.g. by building leading positions in key industries of the future) and the global leadership benefits of being an early adopter of a net zero target (e.g. via climate diplomacy and expertise on the policy and regulatory reforms required). However it is also essential to ensure the UK implements a 'just transition' to net zero so that costs and benefits are fairly shared between income groups, industries and regions – as well as between current and future generations.

2. Introduction

The UK government has asked the Committee on Climate Change (CCC) to provide advice on revisions to the UK's long term climate change targets[1]. This includes options for achieving net zero emissions target as a contribution to the Paris Agreement's global ambitions.

To inform the CCC's deliberations and its report '*Net Zero - The UK's contribution to stopping global warming*', three advisory groups of independent experts were convened. This is the chair's summary report from one of these three groups: the UK net zero advisory group. The main question the group was asked to answer is 'how can the UK reduce emissions to net-zero and how should CCC approach and interpret the modelling of these scenarios?'. The terms of reference for the group set out its scope, which is to:

- Provide commentary and advice on the general challenges of developing, modelling and communicating scenarios for net-zero emissions, including how these challenges differ from the challenges for scenarios with an 80% reduction in emissions from 1990.
- Provide advice and review on the CCC's proposed methodology for constructing and assessing scenarios for reducing UK emissions towards net zero, including on which aspects are not well suited to quantitative modelling and how these can be treated.
- Provide critical review and advice across a number of specific issues, including:
  a. The approach to greenhouse gas removals
  b. The approach to 'hard-to-treat' sectors, including industry, aviation and agriculture
  c. The role of innovation
  d. The treatment of uncertainty
  e. Timescales and rates of change
- Comment on the nature of the policy challenge in reaching net-zero emissions in the UK, especially how this differs from the challenge for an 80% target.
- Provide critical review and advice on emerging CCC analysis/recommendations related to scenarios for reaching net-zero emissions in the UK.

The net zero advisory group comprised five members, acting in a personal capacity:

- Professor Jim Watson (chair), Director of the UK Energy Research Centre and Professor of Energy Policy, UCL Institute for Sustainable Resources
- Dr Nem Vaughan, Senior Lecturer in Climate Change, University of East Anglia
- Professor Peter Taylor, Chair in Sustainable Energy Systems, University of Leeds
- Michelle Hubert, independent adviser
- George Day, Head of Markets, Policy and Regulation, Energy Systems Catapult

[1] The formal request is set out in a letter from the UK, Scottish and Welsh governments on 15th October 2018: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/748489/CCC_commission_for_Paris_Advice_-_Scot__UK.pdf

This report draws on the views and expertise of all advisory group members, and notes where there were significant differences of opinion. Whilst this is a chair's report rather than a report from the whole group, all members of the group are in broad agreement with its recommendations.

The report includes six further sections. Section 3 sets out some definitions and principles that are important for understanding what the transition to net zero means, and for the implementation of policies and strategies to achieve a net zero target. Section 4 reviews the CCC's approach to modelling the transition to net zero. It considers in particular the additional measures that may be required to increase ambition from current carbon budgets and targets. Section 5 focuses on the scope for reducing demand for energy, products and services. Section 6 explores three sectors that have previously been considered as being harder to abate: aviation, industry and agriculture and land use. Section 7 explores what role innovation can play in helping to achieve a net zero target. Section 8 sets out some implications of a more ambitious net zero target for government policy.

I would like to thank the other members of the advisory group for their extensive and lively contributions to the discussions that informed this report, and for their assistance with some of the report sections. On behalf of the group, I'd also like to thank the CCC staff for their support for the group including advice, briefings and lots of patience at an extremely busy and demanding time; and the members of the CCC for a very useful and productive discussion of the group's draft recommendations.

3. Definitions and principles for net zero

What should the UK target be?

It is important to be clear what net zero means, including the timescale over which it could be achieved. The reason for contemplating a net zero target for the UK is that our current target of an 80% reduction in greenhouse gas (GHG) emissions by 2050 is not fully compatible with the ambitions set out in the Paris Agreement. Whilst this target is consistent with limiting the average global temperature increase to well below 2 degrees, it is not consistent with a limit of 1.5 degrees.

The CCC's analysis from October 2016 shows that the current target could be a fair contribution to limiting the global temperature increase to 2 degrees (CCC, 2016). This assumes that other countries make a similarly fair contribution, and that the UK's average per capita GHG emissions are no higher than the global average in 2050. However, this analysis also suggests that a more ambitious UK target of an 86-96% reduction from 1990 levels by 2050 is required if the global temperature increase is to be limited to 1.5 degrees.

In all cases, the UK's cumulative emissions over time matters - not just the target for 2050. This is illustrated by some of the other allocation methods that could be used to derive the UK's targets from a global emissions budget. For example, the CCC's analysis from 2016 shows that an equalisation of cumulative per capita emissions from 2015 means that UK GHG emissions need to reach zero by 2050.

More recent analysis by the CCC that was shared with the advisory group confirms that a 95% reduction in UK GHG emissions by 2050 would result in per-capita emissions in line with the 1.5 degrees pathways reported by the IPCC . This would include the UK reaching net zero CO_2 emissions by that date. The level of ambition could go further, and require the UK to stop adding to global warming. In the IPCC 1.5C pathways global warming

peaks around 2050. The CCC's analysis indicates that this would mean a reduction in UK GHG emissions of more than 95% by 2050

Based on this analysis and the need to maintain UK leadership, the advisory group's view is that a net zero GHG target should be set for 2050. This should be achieved through an emissions reduction pathway that is compatible with such a leadership role, and should be met by domestic action. Whilst the group is satisfied that this target is technically achievable, the level of ambition it represents should not be underestimated – especially given that the UK is not on track to meet all of our current carbon budgets and targets.

Although offsets could help to meet the target, they should only be used as a source of flexibility if other emissions reduction and removal options fail to deliver on a sufficient scale. Any offsets that are used to comply with a net zero target should be compatible with the ambitions set out in the Paris Agreement.

The advisory group discussed a number of other principles that will be important for the implementation of policies and measures to meet this net zero target. These principles relate to emissions accounting and the equitable distribution of costs and benefits.

Emissions accounting

With respect to emissions accounting, the group agreed that is important to monitor both the UK's territorial emissions and the emissions associated with the goods and services consumed by the UK (consumption emissions). As Defra's annual indicator shows, the UK's consumption emissions are significantly higher than our territorial emissions, though they have also fallen significantly in the last decade[2]. The difference is due to emissions embedded in imported goods and services. Some of the reduction in emissions that the UK has achieved since 1990 have been a result of industrial restructuring – and a shift from domestic production of some goods and services to imports.

A specific case of this difference that could become more important in a pathway to net zero is the use of biomass for energy production. Biomass is already used at a large scale to produce electricity, using imported biomass fuel. To achieve net zero, it is likely to be necessary to deploy bioenergy with carbon capture and storage (BECCS) to generate negative emissions. If the biomass fuel used in UK BECCS plants is imported, there will need to be international agreements about the attribution of such negative emissions – and the extent to which they could be wholly claimed by the UK.

It is also important to clearly distinguish between the carbon removed by a BECCS supply chain and the amount of CO_2 stored. The amount removed will always be less than the amount stored. This is due to the emission of GHGs due to land use change emissions, farm emissions (e.g. from fertilisers, if used), biomass transport and processing, conversion losses and energy required to capture and compress the CO_2. For example, one analysis of a BECCS supply chain estimates for every 2.1GtC taken up by plant biomass, only 1 GtC is stored (Smith and Torn, 2013). This result is subject to significant uncertainty and will depend on

[2] The latest indicator of UK consumption-based emissions can be found at: https://www.gov.uk/government/statistics/uks-carbon-footprint

previous land use, transport type and distance, type of processing and energy conversion and associated decarbonisation of the power and transport sectors. In some extreme cases, usually arising from poor land use change choices, there can be net positive emissions. A more recent analysis of a set of BECCS supply chains also concluded that the total quantity of carbon removed from the atmosphere are highly case specific (Fajardy and Mac Dowell, 2017). This has significant implications for policy formulation, accounting frameworks and associated regulation, particularly of biomass supply chains within the context of broader land use choices (Gough et al, 2018).

Costs and benefits

The costs and benefits of achieving net zero emissions by 2050 have been covered by a separate CCC advisory group. Nevertheless, this was also an important area of discussion for this advisory group.

A general principle for policies to achieve emissions reduction is to distribute the costs and benefits in an equitable way. This will improve the political feasibility of such policies. Given that achieving a net zero target is likely to require a much more ambitious and systemic policy action (see section 8), this principle is arguably more important if such a target is adopted.

This has a number of different dimensions. First, it means equity between different income groups, regions of the UK and between current and future generations. This suggests that policies to achieve net zero will need to be fully integrated with economic policies (see section 8). It also means that more action is likely to be required to enhance the benefits of those on low incomes who are least able to pay the costs. Second, it means maximising the co-benefits of actions to reduce emissions, and making them more visible to those who benefit from them. This includes, for example, prioritising measures that improve health (e.g. by reducing local pollution), save citizens and businesses money (e.g. by improving energy efficiency) and improve ecosystems (e.g. through nature based solutions).

Third, it also means action to manage the transition for those communities that could be exposed to high economic and social costs because of the need to phase out some industries or infrastructures. This includes identifying opportunities for the transfer of skills and jobs to more environmentally sustainable sectors. The Scottish government's Just Transition Commission[3] has recently been established to investigate how these opportunities can be realised alongside decarbonisation.

Engineering UK has recently published analysis that shows an annual shortfall of engineering graduates and technicians of 37,000 - 60,000 in the near future (EngineeringUK, 2018). Whilst this analysis does not focus on requirements for a net zero economy, any action to redress this shortfall should take into account the skills required to deliver substantial emissions reductions.

[3] https://www.gov.scot/groups/just-transition-commission/

4. CCC scenario(s) for achieving net zero

To understand how a net zero GHG target for 2050 might be met, the CCC have followed a bottom up approach. This examines how to achieve further emissions reductions in specific sectors when compared to their previously published 'central' and 'max' scenarios (CCC, 2016). This has resulted in a new 'further ambition' scenario that was shared with the advisory group (see table 1 below). This new scenario illustrates the opportunities for GHG reductions that could, if realised, deliver a net zero economy. The actual distribution of reductions in 2050 will almost certainly be different in practice due to uncertainties about sectoral growth patterns, and technological and social changes.

Table 1. GHG emissions in CCC central, max and further ambition scenarios

	Emissions in 2050 ($MtCO_2e$)		
	Central scenario	**Max scenario**	**Further ambition scenario**
Industry	61	32	10
Agriculture	45	40	26
Aviation	37.5	33	31*
Surface transport	19	5	2
Buildings	19	4	4
Waste	7	3	7
Shipping	6	4	<1
Power	6	3	6**
F-gases	5	2	2
Land use, land-use change and forestry	-8	-16	-2***
Engineered removals (incl BECCS)	-47	-51	-53
Total GHG emissions	**153**	**61**	**35**
Reduction from 1990	***81%***	***93%***	***96%***
Total CO_2 emissions	***96***	***11***	***-10***

* Does not include a multiplier for aviation non-CO_2 effects

** In the further ambition scenario, the figure for the power sector includes emissions from hydrogen production

*** Reduction in negative emissions reflects changes in the inventory methodology, rather than a change in ambition

The CCC approach contrasts with the more top down approach that could have been taken. For example, an optimisation model could have been used to determine a least cost pathway to meet a net zero emissions goal. One example of this approach uses a UK integrated assessment model (UKTM) to explore more stringent UK emissions pathways in the light of the Paris Agreement (Pye et al, 2017). Whilst the use of an integrated assessment model has some advantages, this particular example illustrates the challenges of modelling net zero emissions pathways. It includes a pathway that reaches net zero CO_2 emissions before 2050. However, the authors note that this pathway 'is at the limits of feasibility'. In 70% of the runs for this pathway, the model fails to find a solution using the technology options that are included, so needs to use an undefined backstop technology.

BECCS is included in the model, but is limited to reflect expected constraints on the availability of biomass.

Given these model limitations, the advisory group support the CCC's bottom up approach to analysing additional emissions reductions in the new further ambition scenario. As table 1 shows, this reduces CO_2 emissions to -10 million tonnes of CO_2 equivalent ($MtCO_2e$) by 2050. It also reduces GHG emissions by 96%, to reach 35 $MtCO_2e$ by that date. The main changes from the previous max scenario are further reductions across many sectors – particularly industry and agriculture. However, these are partly offset by a change in accounting methodology for land use, land use change and forestry emissions.

It is particularly notable that the ambition for engineered GHG removals under the further ambition scenario has not been increased significantly. It is lower than the levels included in the recent report by the Royal Society and Royal Academy of Engineering. This includes a scenario that would deliver 130 $MtCO_2e$ of greenhouse gas removals by 2050 (Royal Society and Royal Academy of Engineering, 2018), including 50 $MtCO_2e$ from BECCS and 25 $MtCO_2e$ from direct air capture. It is also lower than the assumptions made by Pye et al (2017) in their net zero scenarios, which include up to 100 $MtCO_2e$ from BECCS in 2050. The technical potential for BECCS in the UK could be higher than this (Daggash et al, 2019). There are many good reasons for being cautious about the extent of engineered removals that may be possible in 2050, including uncertainties about technical change, biomass resource availability and the relationship between carbon removed and stored (see section 3 above).

Overall, the further ambition scenario delivers net zero CO_2 emissions by 2050, but does not deliver net zero GHG emissions by that date. To achieve the latter, further emissions reductions or GHG removals would be required. The CCC have considered some of the options for achieving this, and shared an analysis of potential contributions they could make to achieving net zero with the advisory group.

This highlights an important issue for implementation of the net zero target: the lack of flexibility that is inherent in relying on a single further ambition scenario. Even if further reductions and removals are possible, there is a risk that the target will not be met if some of the measures included in the further ambition scenario (and beyond) are not realised in practice. This also increases the risks to government of adopting a net zero target.

Whilst it is also possible that the scope for reductions and/or removals will turn out to be greater than expected, the advisory group were keen to identify additional sources of flexibility that could reduce these risks. Some specific options that could increase flexibility are discussed in the sections 5-7 of this report. These sections focus on demand reduction, sectors that have been regarded as difficult to abate (industry, agriculture and aviation), and the role of innovation (including options for GHG removal).

The CCC shared their assumptions with the advisory group about the additional emissions reductions required to meet the further ambition scenario, when compared to the central 80% reduction scenario. These include:

- *Surface transport.* The additional reductions focus mainly on heavy goods vehicles. In principle, this could be achieved via the use of hydrogen or electricity from low carbon

sources. Commercial availability of zero emission HGVs is assumed by the CCC from 2030. This is a plausible assumption if there is sufficient attention to innovation, trials and scaling up relevant technologies over the next decade. Whilst hydrogen is thought to be the most likely route for HGV decarbonisation the possibility of electrification reduces the risks that decarbonisation will not be achieved.

- *Buildings.* The further ambition scenario includes the decarbonisation of some of the remaining 20% of homes that are not decarbonised in the central scenario. These are mainly homes on the gas grid with limited space and homes that are more difficult to retrofit. It also includes further emissions reductions from commercial buildings. However, 10% of homes still do not have low carbon heating under this new scenario. This may prove to be a conservative assumption, depending on progress with decarbonisation of heat. There is a lot of uncertainty about which heat decarbonisation pathway(s) will be the most technically, economically and socially feasible in which locations (BEIS, 2018). However, the further ambition scenario makes it more likely that hydrogen will play a role – for example in homes with space constraints and to decarbonise the demand for peak heating. From a technical perspective, the further ambition scenario is feasible – but heat decarbonisation in particular has a long way to go, and requires policy action to demonstrate, test and scale up the supply and demand side technologies required.
- *Shipping.* The CCC envisages that further emissions reductions could be delivered through energy efficiency, operational changes and decarbonised fuels (especially ammonia). Whilst energy efficiency and operational changes could be implemented in the short to medium term, technical solutions to deliver ships that are almost zero carbon are not yet commercially available (Traut et al, 2018). An important risk is that shipping is inherently international, and the drivers for decarbonisation partly depend on global governance (e.g. via the International Maritime Organisation).
- *Power.* The main focus is on reducing emissions from peaking power generation since the assumption is that the power sector is largely decarbonised in the 80% scenario. The CCC's assumptions for achieving this are technically feasible. They depend on using flexible gas plant with CCS for 'mid-merit' power, and burning hydrogen to cover peak demand. This depends on CCS being fully commercialised and hydrogen being produced using zero carbon energy sources. The amount of flexible generation required will depend on the extent of other sources of flexibility which may be cheaper, including demand side response, storage and interconnectors (Poyry and Imperial College, 2017).
- *Land use, land use change and forestry*. Changes in the further ambition scenario are linked closely with assumptions about agricultural emissions (see sections 5 and 6). Additional afforestation to remove CO_2 from the atmosphere is envisaged at a rate of 30,000 hectares per year. This seems feasible since it is similar to the rate of afforestation achieved in the 1980s. The main challenge is whether the land for this will be available, which partly depends on improvements in agricultural productivity and dietary trends. In addition to afforestation, options include changes to farming practices (e.g. better soil and livestock management) and peatland restoration (CCC, 2018b).

5. Reducing demand for energy, products and services

The future demand for energy and other goods and services often receives too little attention in scenarios for decarbonisation. As this report has already noted, addressing this shortcoming could provide a particularly important source of flexibility to help meet a net zero target. For most sectors, additional reductions in demand will mean that less low or zero carbon energy is needed to meet a given target. Where those sectors are particularly hard to abate, such demand reduction can be particularly valuable.

The CCC's further ambition scenario follows this logic by focusing on opportunities to reduce demand in hard to abate sectors (see section 6 of this report). However, there is also scope to extend this to other sectors, where more conservative assumptions have been used. For example, future road transport demand assumed by the CCC is based on 2018 road traffic forecasts, all of which show increased traffic growth by 2050.

CCC reports often discuss 'behavioural change' as one way to help meet climate change targets (e.g. CCC, 2018a). This is different from, though related to, technological change. It focuses on changes in the activities of businesses and citizens that affect their demand for energy and other goods and services. There is often an emphasis on changes in individual behaviours, such as decisions to turn down a thermostat or to use public transport rather than driving. However, the extensive literature on behavioural and social change emphasise that there are significant structural barriers which limit the ability of individuals and companies to change their patterns of consumption (e.g. Jackson, 2005).For example, many households will not be able to afford to invest in low carbon technologies such as heat pumps, or might lack access to charging infrastructure for an electric vehicle. Furthermore, individual behaviours do not only depend on individual attitudes and income. They also depend on social networks and influences.

In the light of this evidence, the advisory group discussed using the term 'social change' instead of 'behaviour change' since this implies both individual changes and broader societal changes. In our discussions with the CCC, it became clear that relatively conservative assumptions are made in the CCC's analysis about such social changes – partly because of the inherent uncertainty about how consumption patterns could change in future. This suggests that more extensive social changes could be envisaged that help to deliver net zero. This could be a particularly important source of flexibility in sectors where emissions abatement is particularly challenging.

The group's discussions about the potential for social change also highlighted an important distinction between emergent social changes that could help to meet emissions targets, and social changes that will require directed intervention (e.g. by government) to counteract their impacts on emissions.

- A good example of an emergent social change that could help achieve net zero is the shift in diets that is starting to gain some momentum, particularly with the reduction in the consumption of meat and an increase in flexitarian, vegetarian and vegan diets (CCC, 2018b). The CCC already assumes a 20% reduction in the consumption of lamb, beef and dairy by 2050, but a further reduction may be possible if dietary changes are more rapid and extensive than they expect. This could also make other contributions to achieving net zero, through associated land use change.

- More directed interventions may be required to counter the emissions impact of social changes such as increases in demand for air travel. Whilst there may be technological solutions to aviation emissions in the long term (see section 6), increasing demand will make achieving net zero more difficult. The CCC's analysis includes limits on demand growth to 60% above 2005 levels by 2050. This is already much lower than the Department for Transport's business as usual projection, which foresees a rise in demand of 90% (Department for Transport, 2017). However, the CCC scenario could have gone further. This would require policies to discourage air travel, make it more expensive, and/or to make alternatives more attractive.

The advisory group also discussed the extent to which the impacts of social change can be analysed in formal models or scenarios – and whether this could explore more extensive changes than those assumed by the CCC.

A recent rapid evidence assessment by UKERC examined how energy models that are used to inform UK government policy incorporate demand side measures (Hardt et al, 2019). It concluded that an important strength of these models is the representation of technologies that can deliver reductions in emissions. However, non-technical drivers of energy demand are usually represented in much more limited ways. Economic, social and behavioural drivers are often included in these models as exogenous assumptions, which are not transparent. Apart from a few exceptions, changes in these assumptions are not explored as potential contributors to climate change mitigation.

If it is more widely reflected, this review highlights an important shortcoming of formal energy and climate change models. The review also discusses three implications that seem particularly relevant to understanding possible pathways to net zero. First, there is an opportunity to open up the use of existing models so that exogenous assumptions about demand can be scrutinised and changed. Second, there is an opportunity to use models that are better equipped to explore the impact of social or behavioural changes (e.g. diffusion models). Third, a mixed methods approach may be more realistic that combines narrative futures that explore social change alongside quantitative modelling of such changes where that is both realistic and useful.

6. Reducing emissions from hard to abate sectors

This section focuses on three sectors that have previously been considered to be particularly hard to abate – and therefore had significant residual emissions in 2050 in the CCC's previous 'max' scenario.

Aviation

The further ambition scenario includes a reduction in aviation emissions when compared to the previous CCC scenario for meeting the 80% emissions reduction target. This previous scenario includes passenger demand growth of 60% from 2005 levels, which would be offset by improvements in airframe and engine technology and some use of biofuels. Demand has already increased by approximately 30% since 2005, so this means a further 25% growth in demand from current levels. The further ambition scenario includes additional biofuels and the introduction of hybrid electric aircraft in the 2040s.

Whilst the CCC are right to be cautious on the timescale for replacing fossil fuels with biofuels and electrification, some advisory group members felt that the assumptions for the aviation sector do not represent a fair share of the reductions required for net zero. Allowing 31 $MtCO_2e$ of aviation emissions in 2050 stands out if most other sectors are required to reduce emissions to very low levels to achieve net zero. This reinforces a need to support low and zero carbon innovations in the aviation sector, and to explore how demand growth can be limited further so that it is below the CCC's trajectory.

The advisory group also emphasised a need for greater equity due to the relatively high proportion of aviation demand from those on higher incomes. The group did not discuss policy interventions to curb demand in detail. However, one option could be to make air travel more expensive, particularly for those that contribute most to demand – for example via a frequent flyer levy (Devlin and Bernick, 2015).

Agriculture

Emissions from agriculture are significantly lower in the further ambition scenario – with a reduction of almost 40% when compared to the central scenario. The CCC expects this change to be achieved by increasing agricultural productivity to release land for afforestation and peatland restoration, shifts in diets away from red meat and dairy and a reduction of food waste (CCC, 2018b). Previous sections of this report have commented on most of these options already. Afforestation should be a priority since it offers a well-known and relatively rapid way to increase GHG removals. The shift towards vegetarian, vegan and flexitarian diets that is already underway means that this social change could contribute additional reductions beyond those envisaged in the further ambition scenario.

Industry

The further ambition scenario from the CCC shows that industry could be less difficult to decarbonise that their previous analyses have indicated. The greater reduction in GHG emissions arises from new work on the decarbonisation of non-intensive industrial sectors (often referred to as "other manufacturing") and from fossil fuel production and fugitive emissions, which were not previously considered due to data gaps. This new scenario foresees the near-full decarbonisation of stationary combustion in manufacturing with hydrogen, CCS, BECCS and electrification all playing a role.

Delivering this greater decarbonisation therefore relies substantially on major infrastructure developments in hydrogen and CCS. Whilst these are potentially feasible, they require major policy and regulatory changes to drive the necessary innovation and investment. Such developments can only partly be influenced by industry itself. The remaining 8 $MtCO_2e$ of GHG emissions from industry include fugitive methane emissions from the gas grid and the uncaptured proportion of CO_2 emissions (when CCS has been applied to large point sources of emissions).

Conservative assumptions had previously been made by the CCC about the role of material efficiency and circular economy approaches to reducing GHG emissions in industry. This role has been explored more fully in the further ambition scenario. It includes the highest

scenario of material productivity in the UK, taken from research by the University of Leeds (Scott et al, 2018).

7. The role of innovation in net zero scenarios

Meeting UK climate change targets will require innovation in low carbon technologies, business models, policies and institutions. Such innovation has already delivered significant cost reductions in some low carbon technologies such as wind and solar PV (e.g. Watson and Gross, 2018). This innovation has been driven by a broad range of government policies in many countries including funding R&D, supporting scale up and demonstrations, creating of markets (e.g. through auctions for renewable electricity) and wider market and institutional reforms.

The CCC's approach to innovation has been to focus on the potential for developing and deploying known technologies. This is partly due to the time it takes for technologies to move from invention to commercial maturity. A systematic evidence review by UKERC that was used in the CCC's advice on the 5th carbon budget shows that this typically takes several decades (Gross et al, 2018). It also suggests that innovation timescales can be shorter for some energy end-use technologies, especially where they are replacing existing products (e.g. LED lightbulbs as a substitute for incandescent or compact fluorescent lightbulbs).

Whilst it is possible that unforeseen technology breakthroughs could lead to unexpectedly rapid innovation or to technological solutions that are genuinely new, the advisory group were broadly in agreement with the CCC's approach. It makes sense to ensure that targets can be met with known technologies, whilst leaving open the possibility that unforeseen innovation could make it easier and/or cheaper to meet targets.

A shift to a net zero emissions reduction target reinforces this message. It also means there is a greater need to understand how innovation could be accelerated, and to broaden the scope of innovations that should be prioritised. A follow up report to the UKERC evidence review has recently been published, which aims to learn lessons about the conditions for speeding up innovations from past experience (Vivid Economics and UKERC, 2019). Whilst more research is required to understand the conditions for accelerated innovation, this more recent report suggests several lessons for government innovation policies. This includes the need for greater government action to co-ordinate the development of new infrastructures, to demonstrate technologies, systems and associated business models at scale and to create markets for net zero innovations.

With respect to scope, the CCC's further ambition scenario requires a much greater focus on greenhouse gas removal (GGR) technologies and measures (Royal Society and Royal Academy of Engineering, 2018). Some GGR measures do not require innovation. Afforestation and changes to land management that increase the removal of GHGs can be implemented over a relatively short timescale. They may be constrained by other factors – particularly competing priorities for available land.

There is a range of other GGR options that could make a contribution to achieving net zero. Although they are unproven at scale, the most promising options focus on capture and

removal of CO_2: bioenergy with CCS (BECCS) and direct air capture (DAC). A rapid evidence assessment of these two options has been commissioned by the CCC from UKERC. Preliminary analysis from this assessment was shared with the advisory group by the CCC (Daggash et al, 2019).

From an innovation perspective, these two options are at different stages of development. The main components of BECCS plants are readily available now, albeit with high and uncertain costs for a full scale system. Burning biomass in power plants is already happening at a commercial scale, and several large-scale CCS demonstrations are in operation. Some demonstration activities are now combining the two, including a pilot project at the Drax power plant in the UK to capture (but not store) CO_2. It is therefore possible to envisage full scale BECCS plants being brought into operation within the next decade. This will require a shift in focus from governments and industry – away from demonstrations towards policy and institutional frameworks to support deployment. The Parliamentary Advisory Group on CCS chaired by Lord Oxburgh put forward proposals for achieving this (Oxburgh, 2016).

DAC is at a much earlier stage. Whilst small devices have been built by companies like Climeworks and Carbon Engineering, there is a long way to go before DAC can be regarded as a GGR option that is available at scale. In most cases, DAC will also depend on appropriate CO_2 transport and storage infrastructure being available in the right geographical locations. Because DAC is not an energy generation technology, these locations could be a long way from centres of energy demand. Innovation could help to reduce the energy intensity of these technologies and reduce their costs. This is very likely to require significant funding from governments for demonstration and scaling up.

This requirement for government action across the board to support innovations for net zero highlights a further important point. Given constraints on resources, how should the UK prioritise which innovations it should support? Low carbon innovation is often highly international. UK policies have made an impact in some technologies (most notably in offshore wind), but in others UK firms and consumers have enjoyed the benefits of policies implemented in other countries (e.g. policies in Japan, Germany, the US and China that have brought down the cost of solar PV). This suggests that priority should be given to those innovations where the UK can benefit most – both in terms of contributing to achieving net zero, and in terms of potential for wider economic benefits from being a first mover.

The advisory group discussed a range of potential priorities for technological and social innovation in the context of net zero. These include large scale demonstrations of hydrogen systems for heating and industry (where the UK could be a leader in repurposing existing gas networks) and CCS / BECCS (where the UK has significant CO_2 storage capacity and associated skills). There is also a strong rationale for prioritising demonstrations of direct air capture and zero carbon technologies for aviation.

It is important that innovation priorities do not only focus on individual low- or zero-carbon technologies. The advisory group discussions also highlighted the role that social innovation could play – including new business models for resource efficiency in industry, mobility services or the provision of energy services in homes. This also draws attention to the need

for a systems approach in many cases that considers technical, social and policy innovations for net zero in an integrated way.

8. The policy challenge

It is clear from the CCC's analysis that the transition to a net zero economy requires a profound and wide-ranging shift in the UK's emission reduction pathway. This needs to go well beyond incremental changes to scenarios that are compatible with current carbon budgets and the 80% long-term target.

During advisory group discussions, it was repeatedly emphasised that this also requires a fundamental change to the UK policy approach to climate change mitigation. The group noted that there already substantial gaps in the government's plans to meet existing carbon budgets (CCC, 2018a). Therefore, more action is needed across government to ensure that progress is made to net zero on the required timescale. Whilst the Climate Change Act provides the UK with an established legal basis for action to reduce emissions, group members argued that this is not sufficient.

Whilst there was a lively debate within the group about the policy approaches that should be prioritised to achieve net zero, there was agreement that government needs to take an economy-wide approach. This includes:

- Policy leadership at the heart of government. Whilst BEIS have played an important role since it was formed, for example in leading the Clean Growth Strategy, action to reduce emissions cannot be left to this department alone.
- HM Treasury needs to take a leading role, so that net zero becomes an explicit goal of economic policy alongside other goals such as productivity improvement. Monitoring of GHG emissions reductions should have the same status as monitoring of traditional economic indicators. GHG emissions should therefore be reported regularly alongside indicators for GDP, productivity and unemployment.
- All government departments and agencies should be more actively involved in ensuring that emissions are reduced across the economy. In a net zero world there is no room for any sectors to remain 'untouched', including agriculture and aviation. Major policy and investment decisions by government need to be tested for their compatibility with net zero. This could be formalised by modifying the Green Book that is used to appraise government policies, projects and programmes.

With respect to specific policy instruments, there were also some differences of view within the group. There was agreement that an economy-wide approach will require much more than implementing a carbon price and leaving markets to deliver emissions reductions. This view reflects the important role that other policies have already played in delivering energy efficiency and low carbon energy in many countries. These policies include feed-in tariffs and auctions for renewables, and standards for energy efficient appliances and vehicles.

Regulations and standards could play a more important role in driving investment and innovation – particularly to speed up a shift to lower carbon products and services. As the CCC has emphasised in its most recent progress report to Parliament, there is already a need for government to strengthen the future trajectory of standards to meet current

targets. This is particularly the case for buildings and heating systems (CCC, 2018a). Furthermore, there is often a need for more effective enforcement. It therefore makes sense that the government response to the CCC's recommendations is compatible with net zero rather than the current 80% emissions reduction target.

Strengthening of standards and other policies could also be linked to a review of the 'missions' that have already been announced as part of the Industrial Strategy. So far, they include high level targets for phasing out conventional vehicles, for new homes and for the UK's first zero carbon industrial cluster. The adoption of a net zero target could be accompanied by a more comprehensive set of missions that cover the entire economy. Most will need to be much more ambitious that those that have already been announced.

The advisory group also emphasised the important role of the private sector, which will deliver the majority of the investment and innovation required for net zero. Since investment cycles are often longer than carbon budgets and political cycles, businesses will be looking for a policy framework that is long-term, stable and consistent. This will help to foster confidence and drive investment decisions that are compatible with net zero. This reinforces the need to build on existing policies for emissions reductions (where they already exist), and filling gaps with targeted interventions.

Any policy changes or additions must provide sufficient lead-times for businesses, and consider the impacts across a diverse business community. Whilst there will be a need for government to review progress towards net zero and make changes if such progress is not sufficient, review processes should be as transparent as possible. The group also emphasised the need to take a 'whole systems approach' to policy that takes into account increasing digitisation and interdependencies between sectors.

Finally, it is worth reiterating the need to ensure that the costs and benefits of policies are distributed equitably (see section 3 of this report). This includes prioritising policies where there are co-benefits (e.g. to health); taking into account the distribution between different income groups and regions of the UK; providing support for those on low incomes; and anticipating and mitigating negative impacts on particular industries or regions.

References

BEIS (2018) Clean Growth - Transforming Heating: Overview of Current Evidence. London: Department of Business, Energy and Industrial Strategy.

CCC (2016) UK climate action following the Paris Agreement. London: CCC.

CCC (2018a) Reducing UK emissions: 2018 progress report to Parliament. London: CCC.

CCC (2018b) Land use: Reducing emissions and preparing for climate change. London: CCC.

Daggash, H.A., Fajardy, M., Heptonstall, P., MacDowell, N. and Gross, R. (2019) Bioenergy with carbon capture and storage, and direct air carbon capture and storage: examining the

evidence on deployment potential and costs in the UK. Report of a Technology and Policy Assessment evidence review. London: UK Energy Research Centre.

Department for Transport (2017) UK Aviation Forecasts. London: DfT.

Devlin, S. and Bernick, S. (2015) Managing aviation passenger demand with a frequent flyer levy. London: New Economics Foundation.

EngineeringUK (2018) Engineering UK 2018: The state of engineering. London: EngineeringUK.

Fajardy, M. and MacDowell, N (2017) Can BECCS deliver sustainable and resource efficient negative emissions? *Energy and Environmental Science* 10 1389-1426

Gough, C., Garcia-Freites, S., Jones, C., Mander, S., Moore, B., Pereira, C., Röder, M., Vaughan, N.E. and Welfle, A. (2018) Challenges to the use of BECCS as a keystone technology in pursuit of 1.5°C. *Global Sustainability* 1(e5) 1-9

Gross, R., Hanna, R., Gambhir, A., Heptonstall, P., & Speirs, J. (2018) How long does innovation and commercialisation in the energy sectors take? Historical case studies of the timescale from invention to widespread commercialisation in energy supply and end use technology. *Energy Policy* 123 682–699.

Hardt, L. et al (2019) Modelling Demand-side Energy Policies for Climate Change Mitigation in the UK: A Rapid Evidence Assessment. UKERC working paper. London: UKERC.

Jackson, T. (2005) Motivating sustainable consumption: A review of evidence on consumer behaviour and behavioural change. Report for the Sustainable Development Research Network. Guildford: University of Surrey.

Oxburgh, R.(2016) Lowest cost decarbonization for the UK: The critical role of CCS. Report to the Secretary of State for Business, Energy and Industrial Strategy from the Parliamentary Advisory Group on CCS.

Pöyry and Imperial College (2017) Roadmap for flexibility services to 2030. Report commissioned by the CCC. London: Poyry and Imperial College.

Pye, S. et al (2017) Achieving net-zero emissions through the reframing of UK national targets in the post-Paris Agreement era. *Nature Energy* 2, article number 17024

Royal Society and Royal Academy of Engineering (2018) Greenhouse gas removal. London: Royal Society and RAEng.

Scott, K., Giesekam, J., Barrett, J. and Owen, A. (2018) Bridging the climate mitigation gap with economy-wide material productivity. *Journal of Industrial Ecology* 1-14 DOI:10.1111/jiec.12831

Smith, L.J. and Torn, M.S. (2013) Ecological limits to terrestrial biological carbon dioxide removal. *Climatic Change* 118(1) 89-103

Traut, M., Larkin, A. et al (2018) CO_2 abatement goals for international shipping. *Climate Policy* 18:8 1066-1075.

Vivid Economics and UKERC (2019) Accelerating innovation towards net zero emissions. Report commissioned by the Aldersgate Group. London: Vivid Economics and UKERC.

Watson, J. and Gross, R. (2018) UKERC submission to House of Commons Science and Technology Committee inquiry: Technologies for meeting clean growth emissions reduction targets. London: UKERC.