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A CLIMATE OF POSSIBILITY:

Harnessing Scotland's natural resources to end our contribution to climate change

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Report prepared for WWF Scotland by vivid economics January 2019

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WWF SCOTLAND FOREWORD

A CLIMATE SAFE FUTURE FOR PEOPLE AND NATURE

Climate change is one of the biggest threats faced by people and nature. This century has already seen 17 of the 18 hottest years on record alongside more and more climate-related impacts at home and abroad. In Scotland, 2018 marked a year of extremes, from the Beast from the East to summer heatwaves placing strain on farmers, vulnerable people and wildlife. And that's just with 1°C of warming.

The warning signs are clear - if we fail to tackle climate change we will face costs and consequences. That's why the 2015 Paris Agreement marked a global milestone – the world committed to keeping global warming to well below 2°C, aiming for 1.5°C, working to strike a balance between greenhouse gas (GHG) emissions and removals by sinks by the second half of this century – known as the net zero goal.

Following the publication of the Intergovernmental Panel on Climate Change (IPCC) report on 1.5°C in 2018, the science is clear that we must limit warming to 1.5°C. This can sound abstract but limiting warming to 1.5°C compared to 2°C means 1.3 billion fewer people exposed to extreme heatwaves, and 60 million fewer people to droughts. It means the chance to protect up to 30 per cent of coral reefs versus the near certainty of destroying all of them – an ecosystem on which up to a billion people depend. It means an ice-free Arctic only once every 100 years as opposed to every 10 years.

Progressive nations, regions and businesses are now setting deadlines to hit net zero emissions in response. People want to see more action from leaders and corporations, and are already acting themselves. Scotland has a chance to be part of this club of climate-neutral leadership, seizing the opportunity to innovate climate solutions and inspire others to step up their action to protect our environment.

SCOTLAND'S NET ZERO HOUR HAS COME

2019 marks the tenth anniversary of the Scottish Climate Change Act, and is the right time to reflect on how far we've come and how much more we need to do to play our full part in tackling climate change. We've already reduced emissions by around half compared to 1990 levels and made truly incredible progress in cutting the carbon from our power sector. But there's more to do to ensure people across Scotland are living in warm, low carbon homes, that we can breathe clean air on our daily commute to school or work, that our farmers are producing the best of low carbon food and rewarded for the work they do to restore habitats, plant trees and improve the health of their soils. A new iconic legal target to end our climate impact - by reaching net zero GHG emissions - would be a powerful catalyst to accelerate this transition.

The Wealth of Our Nation

Scotland is a country laden with natural advantages for net zero. From our abundant renewable energy resource, to our large land area suitable for carbon sinks such as forests and restored peatlands, to our history of innovation and skilled workforce, this report shows we can hit net zero before other UK nations and be among the global leaders on this issue.

Net Zero is Feasible

THIS REPORT SHOWS WE CAN HIT NET ZERO BEFORE OTHER UK NATIONS AND BE AMONG THE GLOBAL LEADERS ON THIS ISSUE

The Scottish Parliament is currently debating a new Climate Change Bill to deliver on the Paris Agreement. The Bill proposes increasing Scotland's 2050 target for emissions reduction from 80% to 90% on the advice of the Scottish Government's statutory advisors, the UK Committee on Climate Change (CCC). Back in 2017, when this advice was published, 90% was seen to be at the very limits of feasibility. But that was a snapshot in time. The 2018 IPCC report affirmed that it is technically possible to limit warming to 1.5°C if there is enough political and societal will. The CCC will update their advice this year at the request of the Scottish Government. New science, falling technology costs, innovation, new policies and more evidence on carbon sinks all now indicate that we can go further than 90% - up to or even surpassing 120% by 2050.

This report by Vivid Economics sets out new pathways for Scotland to achieve net zero, expanding on the CCC analysis. It shows that Scotland can hit net zero before 2045, with a sensible approach to rapidly increasing carbon sinks and deep cuts to emissions. This could even be within reach sooner with further action, for example on sinks or dietary change. And by 2050, the target date under the Scottish Climate Change Act, Scotland could be removing far more emissions than it creates, making a significant contribution to UK efforts. Even if we have weaker than expected deployment of carbon sinks, Scotland still has multiple options to meet net zero by 2050.

The pathways set out here will inevitably evolve over time and may end up looking different. We have no crystal ball - the report simply demonstrates what's possible today from a technical and economic perspective. Innovation and technology development can be swift and unpredictable – as has been demonstrated with Scotland's renewable electricity revolution. So too can behaviour change and social transformation[1].

What is essential is that we confront this challenge head on by setting the right target for the Climate Change Bill, and accelerating policy action to end our climate emissions once and for all.

Deep Emission Cuts are Necessary Across All Sectors

The report shows that reaching net zero will require deep emissions cuts in all sectors.

The power sector, transport and buildings sectors can all reach zero or near-zero emissions.

Emissions in industry can be reduced by at least 60% without reducing productive capacity.

Agriculture can reduce emissions by around 35% while maintaining current production levels. Farms will have a growing and crucial role in deploying carbon sinks to help offset emissions.

Carbon Sinks have a critical role to play in reaching net zero

- A mixed approach to developing Scotland's carbon sinks - pursuing mature options such as tree planting and carefully testing less mature options such as enhanced weathering (applying silicates to soils) – would allow Scotland to achieve net emissions of around -120% relative to 1990.
- This will require strong policy support from the Scottish Government, a strategic approach to managing land use and carbon sinks, and the right policy and financial incentives for farmers and landowners.

Reducing Scotland's net emissions to zero will end our contribution to climate change, help to restore nature and build an innovative, globally-facing economy. We have long known that the economic costs of tackling climate change far outweigh the costs of failing to act and that the benefits for human health, the economy and nature are huge. Reaching for net zero and planning a just transition towards it will allow us to build a healthier, cleaner, flourishing Scotland for all, and strong working relationships with other nations striving for a living planet.

GINA HANRAHAN
Head of Policy
WWF Scotland

THE WARNING SIGNS ARE CLEAR - IF WE FAIL TO TACKLE CLIMATE CHANGE WE WILL FACE COSTS AND CONSEQUENCES.

INTRODUCTION

This project adapts research developed for the UK, to conduct a bottom up study to show how fast Scotland can meet net-zero emissions (by 2050 at the latest) through domestic action.

The Scottish Government introduced a new Climate Change Bill to Parliament in May 2018, to increase the ambition of the 2050 target to 90% by 2050[2] . This legislative process is occurring against the backdrop of the Paris Agreement, which commits the world to the global peaking of emissions as soon as possible and to 'achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century' – the so-called net-zero goal. The need to achieve net-zero has been brought into sharp focus by the latest findings from the Intergovernmental Panel on Climate Change (IPCC), which states that, for no or limited temperature overshoot of the 1.5°C target, global CO2 emissions must reach net-zero around 2050, with deep cuts in non-CO2 gases as well (IPCC, 2018).

THE NEED TO ACHIEVE NET-ZERO HAS BEEN BROUGHT INTO SHARP FOCUS BY THE LATEST FINDINGS FROM THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

Some countries are legislating net-zero, notably Sweden (by 2045) and New Zealand (by 2050, although which gases to include are a topic of debate). In Scotland, the Cabinet Secretary for Environment and Climate Change has committed to legislating for net zero as soon as a pathway is identified by statutory advisors stating that "If the UK Committee on Climate Change advises us that a net zero target is now feasible...we will do it." The UK has not yet committed to a net-zero emissions target, but the Secretary of State has indicated that "The UK will need to legislate for a net-zero emissions target at an appropriate point in the future to provide legal certainty on where the UK is heading" and, together with the Scottish Government, asked the Committee on Climate Change (CCC) to analyse what the 1.5°C target could mean, following the IPCC's Special Report on 1.5°C.

The objective of this work is to provide insight into what achieving net zero greenhouse gas (GHG) emissions implies for Scotland. It builds on the following key evidence sources:

- CCC advice to Scottish Government (CCC, 2017): To support the Scottish Climate Change Bill, the CCC provided supporting analysis and advice, including a 'high ambition' scenario with 90%, reduction from 1990 levels.
- Academic work on greenhouse gas removal (GGR) potential in Scotland: This is primarily based on Scotland specific work by Alcade, Smith, Hazeldine, & Bond (2018) and The Royal Society & Royal Academy of Engineering, (2018) work on GGR across the UK.
- UK scenario for net zero emissions, based on previous Vivid analysis for WWF to illustrate a UK wide net zero pathway (Vivid Economics, 2018). Note, this short report will frequently refer to the more extensive UK wide report which contains further detail and motivation on sectoral trends and assumptions.

The UK and Scotland pathways to net zero are interconnected and mutually reinforcing: Scotland can leverage its greater land area per person to achieve higher negative emissions options and help offset remaining UK emissions; on the other hand, high capex investment in Scotland such as offshore wind and carbon capture and storage (CCS) benefit from a UK wide business case (e.g. exporting electricity across the GB electricity grid and beyond to Europe). Although targets may differ, a coordinated programme of decarbonisation across the UK that capitalises on the strengths of each devolved administration is likely to achieve the best outcome. This also holds true for Scotland's contribution to wider European decarbonisation.

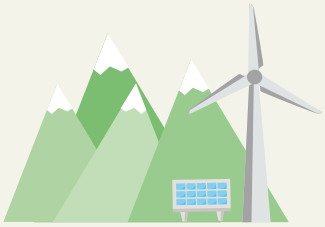
KEY MESSAGES

Scotland is well positioned to reduce its emissions given its natural endowments.

Scotland represents, 8% of the UK's population, 32% of the UK's landmass, and 9% of current UK emissions3. Relative to the rest of UK, Scotland has multiple advantages: abundant renewable potential and large land availability to deploy greenhouse gas removal options such as afforestation

To reach net zero, deep emissions reductions are necessary across all sectors. This implies ramping up existing effort in buildings, industry and agriculture, where Scottish emission reductions have been relatively slow (CCC, 2018b). Emission reductions in the CCC's 'high ambition' scenario approach the feasibility frontier, although there are areas where further action is possible.

- Power, transport and buildings: These sectors can all reach zero or near-zero emissions. One example where progress is being made at the policy level is in transport, with the 2032 phase out of internal combustion engine (ICE) vehicles. Further action is necessary in power, with CCS retrofits of existing gas capacity, coordinated with industrial CCS infrastructure, likely the least cost solution. Action in buildings is particularly urgent, to improve insulation and switch to electricity, and potentially hydrogen, as energy sources.
- Industry: Emissions in industry can be reduced by at least 60%. This requires electrification and use of hydrogen as fuel where possible, and deployment of CCS across all large point sources, but is achievable without reducing productive capacity.
- Agriculture: Current production levels can be maintained, but agriculture must deploy virtually all known mitigation measures, which could reduce emissions by around 35%. Furthermore, the agricultural sector will play a key role in large scale GGR deployment, with nearly all farms deploying at least 1 form of GGR by 2050.



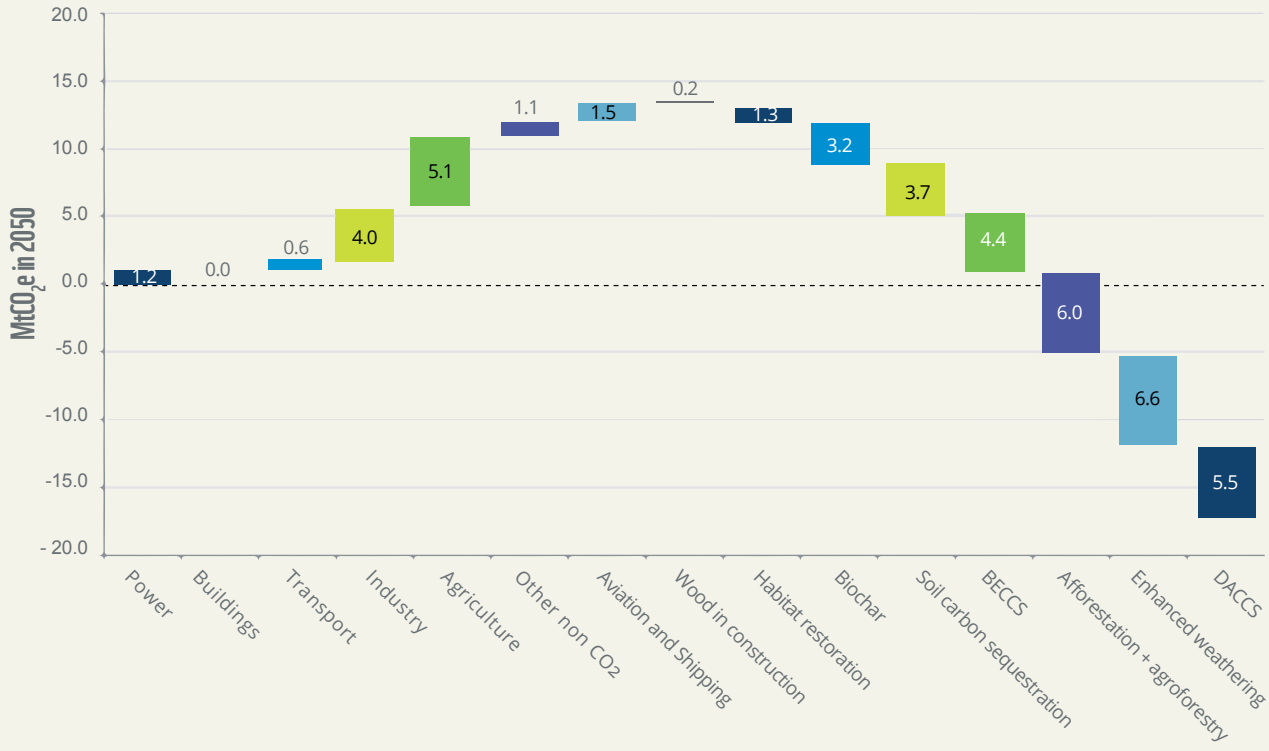
RELATIVE TO THE REST OF UK, SCOTLAND HAS MULTIPLE ADVANTAGES: ABUNDANT RENEWABLE POTENTIAL AND LARGE LAND AVAILABILITY TO DEPLOY GREENHOUSE GAS REMOVAL OPTIONS

There are multiple options for Scotland to deliver and exceed net zero by 2050, even with weaker than expected GGR deployment. Deploying currently known emission reduction measures across its economy, Scotland would emit around 13 $MtCO_2e$ per year in 2050 (Figure 1). Given Scotland's large land area, it can compensate for these emissions through a portfolio of GGR options. Our scenario includes central estimates of Scottish GGR potential across key GGR options, summing to -31 $MtCO_2$ (Figure 3). However, even taking a 'worst case'[4] of deployment potential across all GGR options, 15 $MtCO_2$ can be removed using Scottish resources only, enough to reach net zero GHG emissions by 2050.

Scotland reaches net zero GHG emissions before 2045 in our scenario, with options to further reduce emissions. This relies on large scale GGR deployment using central estimates. Further policy options, such as incentivising diet change and further optimising land use for GGR could allow an even earlier net zero date.

Scotland plays a pivotal role for the wider UK to be able to achieve net zero GHG emissions. Given its large land availability, Scotland has relatively more opportunity to deploy GGR options compared to the rest of the UK. By 2050, Scotland could produce around 17 MtCO2 of net negative emissions, allowing the whole of the UK to reach net zero by 2050.

FIGURE 1. SCOTLAND'S EMISSIONS IN 2050



Source: *Vivid Economics calculations, based on Alcade et al.(2018), CCC (2017), Vivid Economics (2018)*

OPPORTUNITIES FOR FURTHER EMISSION REDUCTIONS

Scotland's 90% emission reduction pathway implies deep emission cuts across all sectors. As set out by the CCC (2017), Scotland must drastically reduce emissions across all economic sectors.

This implies deep cuts across all sectors, shown in Figure 2, with approximately 34 $MtCO_2e$ reduced from 2016 levels and 60 $MtCO_2$ from 1990 levels. It is achievable while maintaining economic growth, and without reducing production of carbon intensive products. However, a broad suite of supportive policy will be required, to incentivise the required transition and mitigate carbon leakage risk (CCC, 2017).

There are opportunities to reduce emissions beyond the emission reductions already captured in the CCC's 'high ambition' scenario. These reductions are relatively small, 3 $MtCO_2e$, in comparison to the negative emissions contributed by GGR deployment in Scotland, but are significant, nonetheless. If these additional savings are not realised, additional negative emissions are necessary. To illustrate, around 200,000 ha of additional land, equal to 1800 average Scottish farm holdings[5] , could be required to achieve 3 $MtCO_2$ of negative emissions through land use based GGRs.

BY 2050, AGRICULTURE WILL DOMINATE SCOTTISH EMISSIONS, AS EMISSIONS FROM OTHER SECTORS ARE DRASTICALLY REDUCED.

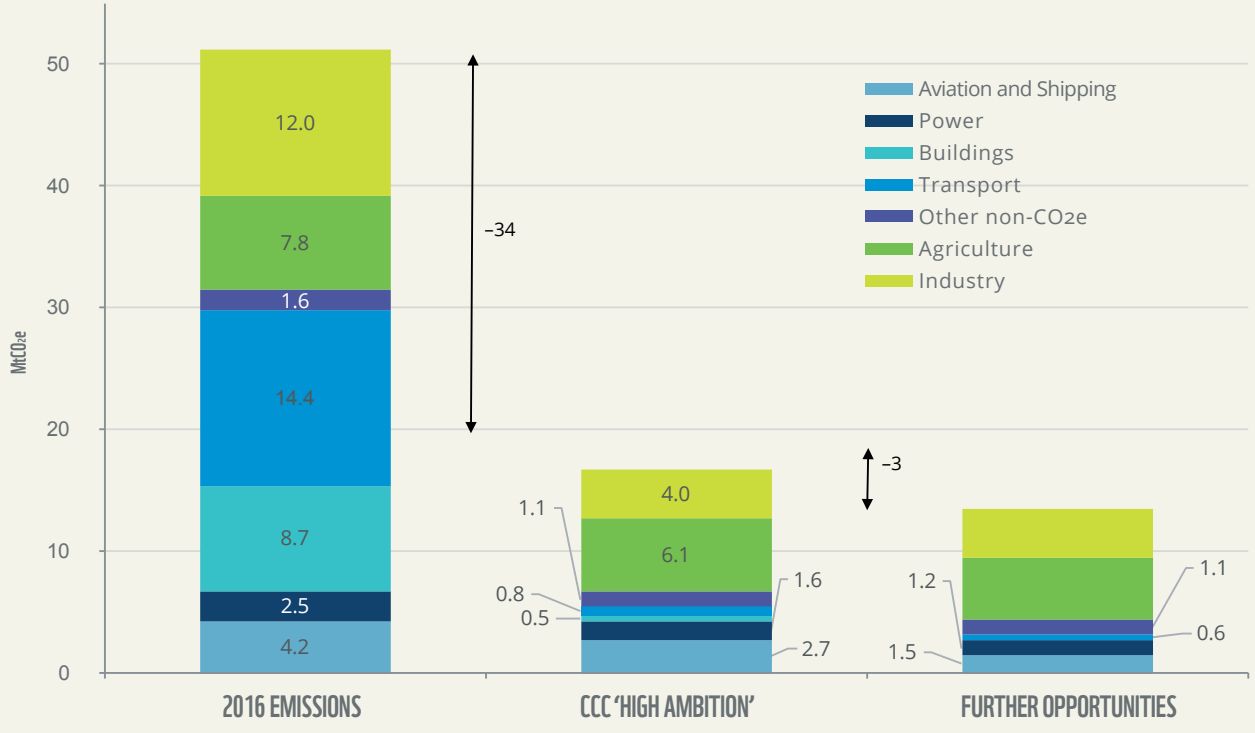
By 2050, agriculture will dominate Scottish emissions, as emissions from other sectors are drastically reduced.

- Power in Scotland will be nearly zero emissions (1.2 $MtCO_2$), with large exports of renewable energy to the rest of the UK. Like our UK wide scenario and CCC modelling[6] , some emissions from gas generation fitted with CCS are likely necessary to ensure grid stability while meeting increasing electricity demand[7] . Notably, achieving 1.2 $MtCO_2$ of remaining emissions is incompatible with further coal generation in Scotland (even with CCS).[8]
- Transport (0.6 $MtCO_2$) in Scotland will be near zero or zero emissions by 2050. For transport, the 2032 phase out of internal combustion engine (ICE) vehicles, in conjunction with policy to increase electric vehicle (EV) sales, will be a key policy measure to ensure nearly all passenger vehicles are zero emissions by 2050 (CCC, 2018b). In addition, remaining emissions of 0.6 $MtCO_2$ also requires 100% of buses and heavy goods vehicles to be zero emissions.[9]

- Buildings (0 $MtCO_2$) reaching zero emissions implies all Scottish heating must be supplied through a combination of heat pumps, district heating and, in places, use of biogas and hydrogen. This can be particularly challenging and will require significant policy support, especially for rural properties, but achieving full decarbonisation saves an additional 0.5 $MtCO_2$ beyond the CCC 'high ambition' scenario.
- Industry (4.0 $MtCO_2$) will be a significant remaining source of emissions by 2050, despite electrification and use of CCS wherever possible. A key determinant of remaining industry emissions in Scotland is the refining and petrochemical facility in Grangemouth. Our scenario assumes continued production (with CCS fitted); but in the context of a decline in wider UK refining capacity, consistent with broader declines in UK oil production and demand, it is conceivable refining production levels decrease, saving up to 1 $MtCO_2$ (Vivid Economics, 2018).
- Agriculture (5.1 $MtCO_2e$) will likely see significantly smaller falls in emissions than other sectors, reflecting the difficulty in reducing emissions in this sector. Reducing emissions to 5.1 $MtCO_2$ will require farmers adopting virtually all known mitigation measures (Vivid Economics, 2018)[10] .
- Aviation and shipping (1.5 $MtCO_2$) emissions can be reduced to 2.7 $MtCO_2$ through a combination of efficiency improvement, biofuel use, and slowed demand growth (CCC, 2017). To move beyond this, we assume domestic (UK) flights and shipping are fully decarbonised through a combination of electrification, biofuel, and synthetic fuel use.

This leaves remaining emissions of 13.5 $MtCO_2$, accounting for 1.1 $MtCO_2$ of emissions from the waste sector and other non-CO_2, where we do not assume any further reductions relative to the CCC.

Figure 2 Emissions reductions across sectors by 2050



Source: Vivid Economics calculations adapted from CCC (2017) and Vivid Economics (2018)

GGR DEPLOYMENT AND IMPLICATIONS FOR SCOTLAND'S LAND USE

A portfolio approach to GGR – pursuing mature options and testing less-mature options - would allow Scotland to set a robust pathway towards achieving negative emissions by 2050.

GGR options are mostly immature.[11] Estimates for deployment potential is uncertain and, for land use options, vary in the amount of CO2 that can be removed per hectare. Our scenario sets out a portfolio of GGR options deployed at scale, which together achieve -31 MtCO2 of GGR in Scotland. To reflect remaining uncertainty, we do not assume any GGR option is deployed to its maximum potential, broadly taking the midpoint of uncertainty ranges,[12] providing flexibility should options not turn out to be fully deployable.

Land use implications of large scale GGR in Scotland

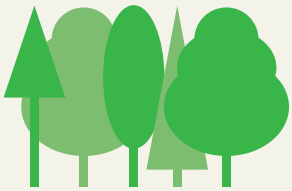
- Scotland currently uses 5.6 Mha for agriculture. By 2050, BECCS and biochar will require a combined 0.2-0.4 Mha, and afforestation will require around 0.5 Mha.
- Scotland has 0.2 Mha of land marginally suited for short rotation coppice (SCP) which can be used for GGR (Alcade et al., 2018). Furthermore, agroforestry could reduce the land requirement for afforestation up to 0.1 Mha, minimising competition with agriculture (CCC, 2018a).
- Overall agricultural production can increase despite GGR deployment, as agricultural productivity improvements from the wider agricultural strategy (National Farmers Union Scotland, 2018) and associated with some GGR practises (The Royal Society & Royal Academy of Engineering, 2018) are expected to outweigh reductions in agricultural land (CCC, 2018a).

GGR	Total land required (Mha)	Annual MtCO2 abated	Notes
BECCS	0.1-0.2	4.4	All biomass for BECCS in Scotland is sourced from Scotland.
Biochar	0.1-0.2	3.2	All biochar is sourced from Scotland.
Afforestation	0.4-0.5	6.0	This assumes planting rate of 16,000 ha/a as per CCC (2017). Agroforestry could reduce required planting rates (of forests) by around 2,000-3000 ha/a.

OVERALL AGRICULTURAL PRODUCTION CAN INCREASE DESPITE GGR DEPLOYMENT

GGR deployment in Scotland could exceed the -31 $MtCO_2$ included in our scenario. As discussed above, our scenario purposefully takes relatively conservative point estimates for the potential of GGR options. Aside from uncertainty in the tCO_2/ha abated, our scenario makes two key judgements on GGR deployment:

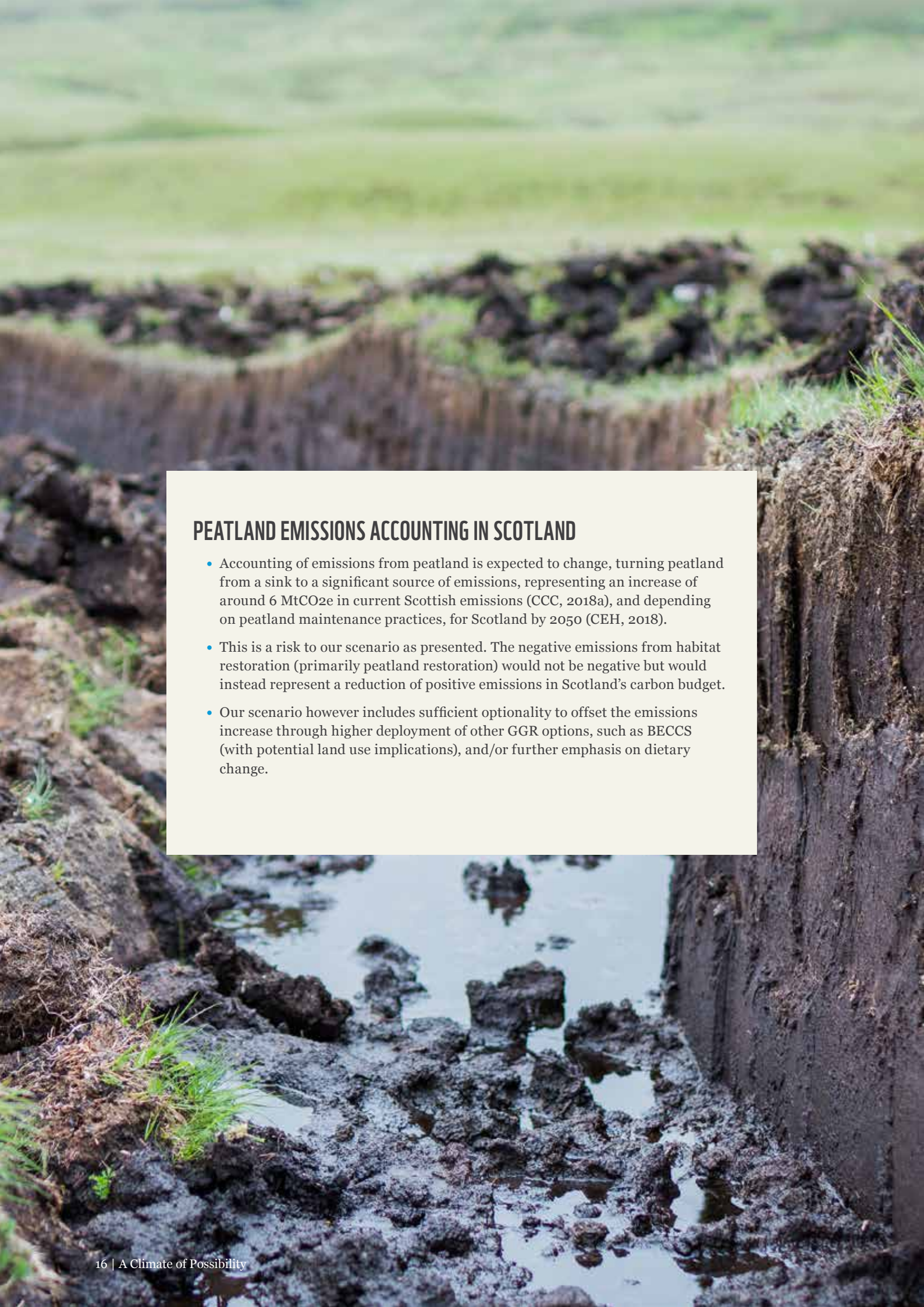
- Land use change: Our scenario has been constructed to limit the impact on current Scottish land use patterns, and reflects a preference towards nature-based solutions[13]. More GGR could be achieved through, for example, more land devoted to producing biomass for BECCS. Nevertheless, our scenario involves up to 0.7 Mha of land changing its primary use. This is a large shift, and the land use implications of GGR should be integrated and balanced with land use demands of agriculture and other policy priorities such as biodiversity conservation and urban development.
- DACCS deployment: We include a modest deployment level given DACCS technological immaturity and related uncertainty. However, Scotland's large renewable capacity and availability of CO_2 storage could allow it to deploy DACCS significantly beyond the -5.5 $MtCO_2$ included in our scenario.



ACHIEVING LARGE SCALE GGR IN SCOTLAND BY 2050 WILL REQUIRE A RAPID RAMP UP OVER THE COMING DECADES.

Achieving large scale GGR in Scotland by 2050 will require a rapid ramp up over the coming decades. This will require strong policy support from both the Scottish and UK governments.

- Incentivisation of landowners/farmers: Virtually all of Scotland's farmers will need to deploy (a combination of) biochar, enhanced weathering, soil carbon sequestration and agroforestry alongside existing food production. Some may switch land use towards bioenergy crops or forestry where appropriate. Farmers will likely need to be incentivised to support the provision of this 'public good'. To target the most cost-effective sites, coordination between Scotland and the wider UK will be important, and could represent an opportunity for Scotland, which is expected to deliver a relatively large proportion of UK wide GGR.
- Scottish land use strategy: Various GGRs have land use implications, but particularly afforestation, habitat restoration and BECCS will require a national approach to ensure land use implications are coherently managed. Development of the Scottish Land Use Strategy (LUS) in 2011 was a key commitment of the Climate Change Scotland Act 2009, recognising the important role that land use can play in climate mitigation and adaptation. Refreshed in 2016, the high-level strategy has proved difficult to translate into change on the ground. However, with full political support and regional delivery, the LUS could provide a mechanism to deliver the strategic and integrated land use and management change required to maximise GGR. Afforestation and habitat restoration fall within existing Scottish strategies and associated targets will need to be made coherent with GGR targets.
- Infrastructure planning and construction: This is particularly relevant for BECCS and DACCS, which require CO_2 transport and storage infrastructure. For BECCS, our scenario includes 1.7 GW of BECCS capacity, with a roll out coherent with Poyry's UK wide BECCS roll out (POYRY, 2016). The required infrastructure should be coordinated across BECCS, gas generation with CCS, and industrial CCS to maximise infrastructure utilisation and minimise costs.



PEATLAND EMISSIONS ACCOUNTING IN SCOTLAND

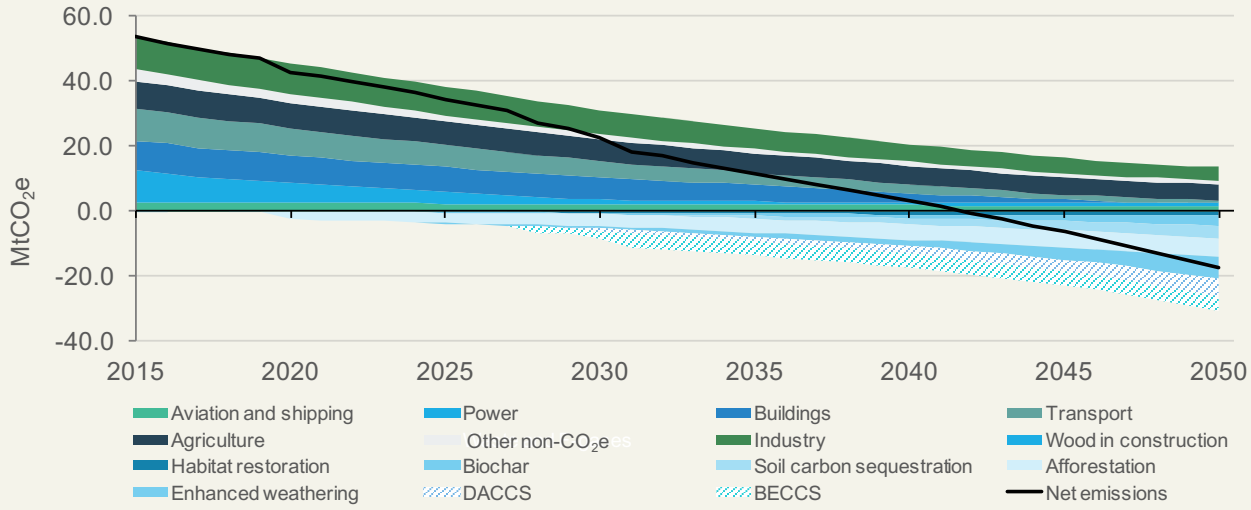
- Accounting of emissions from peatland is expected to change, turning peatland from a sink to a significant source of emissions, representing an increase of around 6 $MtCO_2e$ in current Scottish emissions (CCC, 2018a), and depending on peatland maintenance practices, for Scotland by 2050 (CEH, 2018).
- This is a risk to our scenario as presented. The negative emissions from habitat restoration (primarily peatland restoration) would not be negative but would instead represent a reduction of positive emissions in Scotland's carbon budget.
- Our scenario however includes sufficient optionality to offset the emissions increase through higher deployment of other GGR options, such as BECCS (with potential land use implications), and/or further emphasis on dietary change.

SCOTLAND'S PATHWAY TO NET ZERO

Scotland can reach net zero GHG emissions before 2045, with a rapid and large-scale ramp up of GGR to -31 MtCO2 by 2050.

With a roll out at this scale, possibly motivated by a UK wide target, Scotland would deploy enough GGR to offset all its emissions before 2045. By 2050, Scottish net GHG emissions would be significantly negative, reaching -17 MtCO2e.

FIGURE 3 SCOTLAND'S PATHWAY TO NET ZERO GHG EMISSIONS



Source: Vivid Economics calculations adapted from (Alcade et al. (2018), CCC (2017), Vivid Economics (2018)

Scotland plays a pivotal role for the wider UK to be able to achieve net zero GHG emissions. The UK will require around 100 MtCO2 of GGR to reach net zero by 2050 (Vivid Economics, 2018). Scotland's GGR potential suggests a significant proportion of GGR will be deployed in Scotland; as such, our scenario represents Scotland deploying approximately a third of UK GGR by 2050, equal to its share of UK landmass. As shown in Figure 3, such a pathway implies Scotland reaching net zero well ahead of the UK, likely before 2045.

Additional mitigation options, particularly diet change, could help reduce Scotland's emissions further or reduce pressure on other sectors to reduce their emissions. Swapping 50% of meat for plant-based options, in line with WHO recommended levels[14] would reduce agricultural emissions in Scotland by around 2 MtCO2e (Vivid Economics, 2018). Similarly, a concerted effort to support DACCS deployment could plausibly increase GGR in Scotland beyond that included in our scenario. This could either help further reduce Scotland's emissions, or could be deployed in place of more costly mitigation measures to allow Scotland to reach net zero shortly after 2040. Furthermore freeing up land currently used for livestock could increase our opportunity to manage land for mitigation.

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ENDNOTES

1 For a discussion of the power of social innovation and societal shift to accelerate the transition and reduce costs see for instance ECF (2018): Net Zero – From Whether to How: https://europeanclimate.org/a-net-zero-emissions-european-society-by-2050-is-within-reach-but-getting-there-starts-today/

2 https://www.gov.scot/publications/climate-change-emissions-reduction-targets-scotland-bill-business-regulatory-impact/

3 Based on 2016 GHG emission estimates for the UK and Scotland. % calculated excluding aviation and shipping.

4 This represents the low end of estimates from the literature and could be considered a worst case scenario. Note, the scenario does assume GGRs are deployed to potential, just that the potential is low.

5 Based on statistics on the structure of the agricultural farms in Scotland (Scottish Government, 2019)

6 Which has 3 $MtCO_2$ of remaining emissions

7 Based on CCC modelling, we assume 24 TWh of flexible thermal generation is required annually for grid stability. This differs from previous analysis for WWF Scotland.

8 Our scenario saves 0.36 $MtCO_2$ by replacing coal + CCS generation with gas + CCS generation in the CCC's 'high ambition' scenario.

9 Our scenario also assumes all buses and heavy goods vehicles are zero emissions by 2050, which reduces emissions by around 0.2 $MtCO_2$ beyond the CCC 'high ambition' scenario.

10 Our scenario includes an additional 1 $MtCO_2$ reduction beyond the CCC 'High ambition' scenario, based on full implementation of CCC identified measures, and the introduction of inoculations for cattle (Vivid Economics, 2018).

11 Less-mature implies options that are not at a technology readiness level (TRL) of 9 (commercial deployment). Research and deployment will still be required to move these options to a level at which they can be commercially deployed in the UK.

12 Where ranges of deployment potential are provided in the scientific literature, we take the midpoint of the deployment potential range for each GGR, taking land use implications into account. Where available, Scotland specific GGR potential estimates are used (Alcade et al., 2018). If necessary, UK wide estimates (The Royal Society & Royal Academy of Engineering, 2018) are adapted to the Scottish context.

13 Which do not necessarily maximise tCO_2/ha.

14 This goes significantly beyond measures included in CCC modelling, which assumes a price induced shift from red to white meats, but does not include significant overall reductions in meat consumption.

NET ZERO

Scotland will have to aim for a balance between emissions and sinks to play its part in tackling climate change. It can do this by 2045.

-31MTCO$_2$

Scotland could be removing this scale of emissions by 2050 by rapidly increasing its carbon sinks

120%

Scotland can reduce emissions by 120% on 1990 levels by 2050

1.5°C

a safer temperature goal for people and nature