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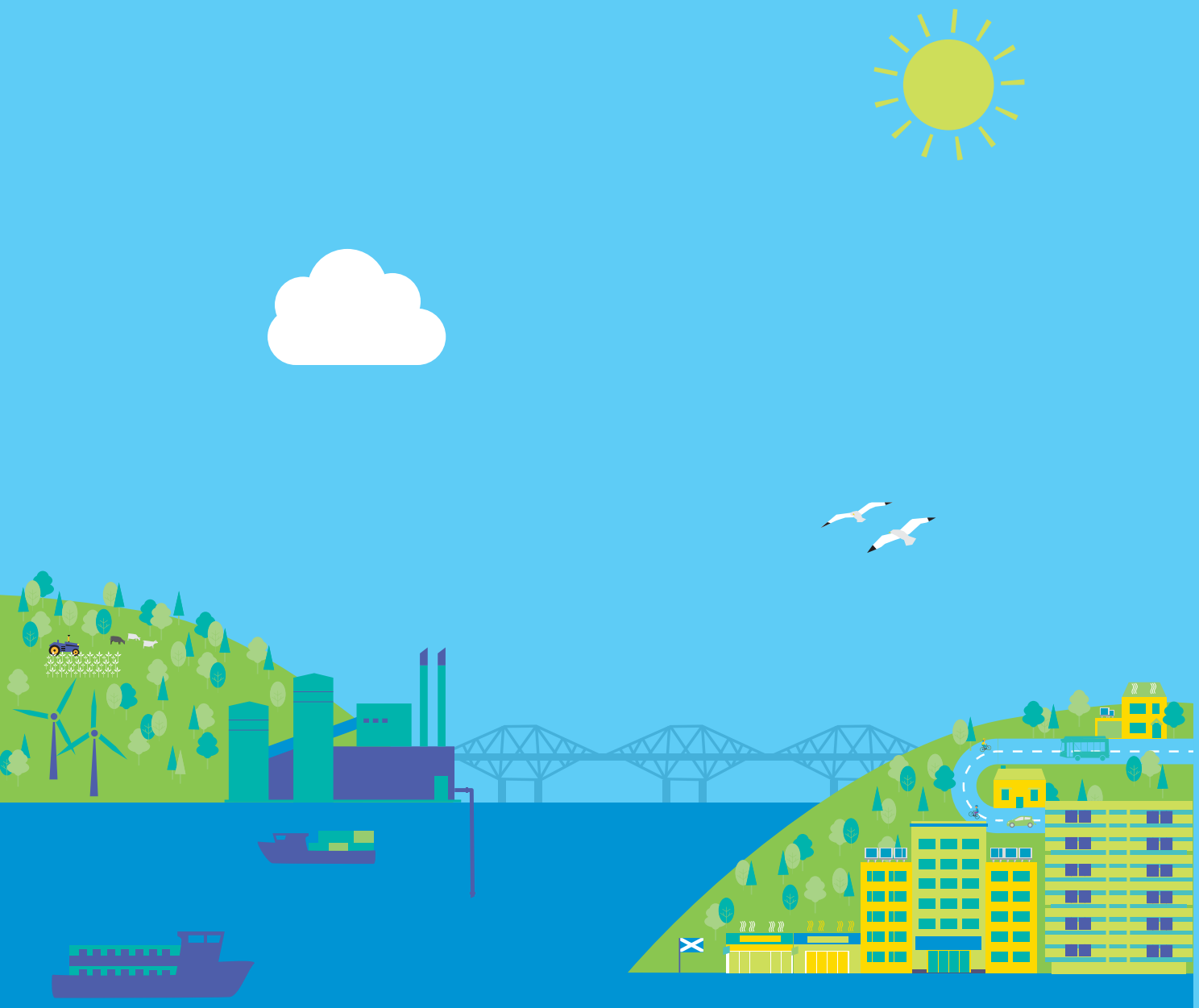

DELIVERING ON NET ZERO: NEXT STEPS FOR SCOTLAND

Report prepared for WWF Scotland by Vivid Economics
October 2019

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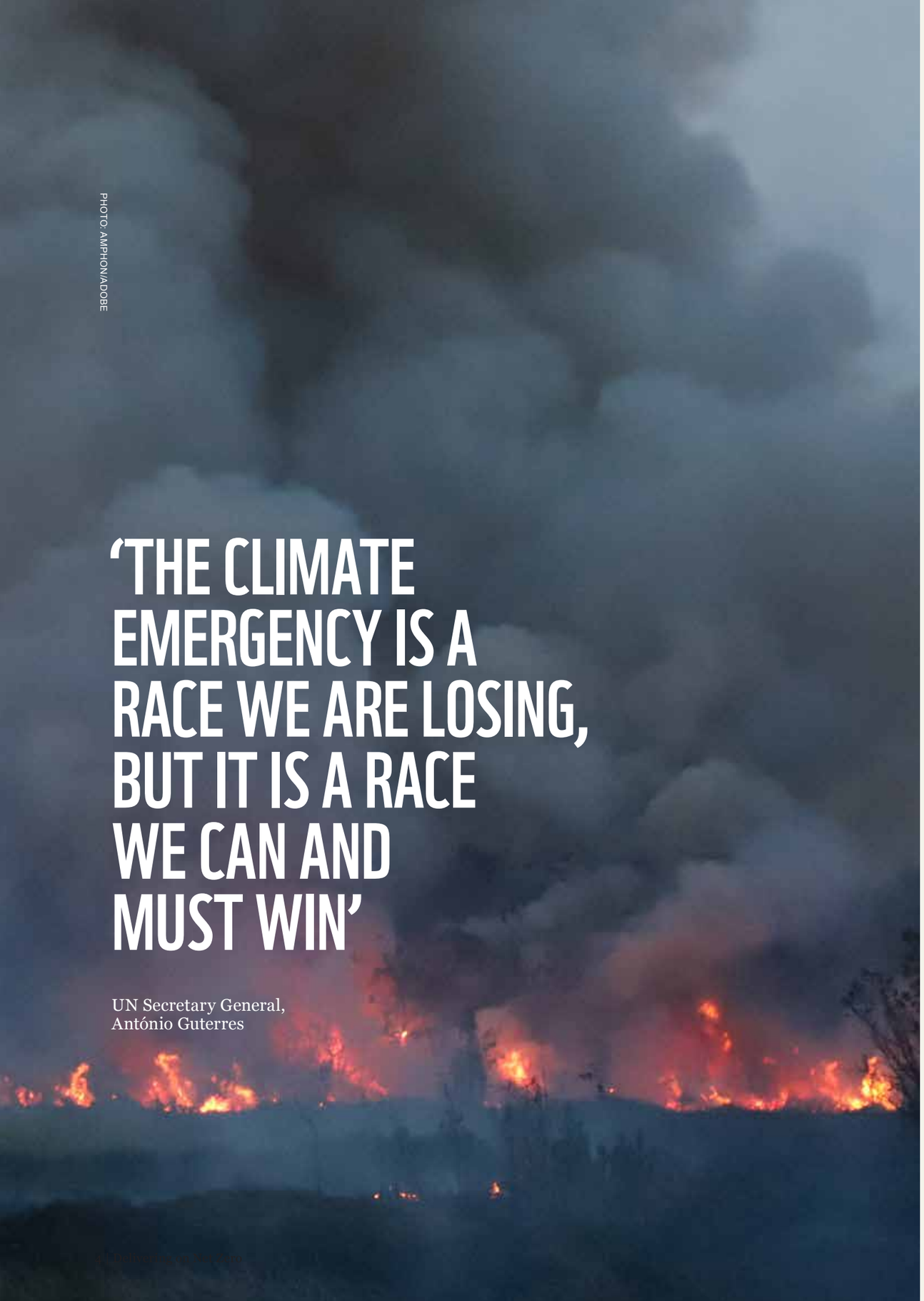


PHOTO: AMPHONADOBE

‘THE CLIMATE EMERGENCY IS A RACE WE ARE LOSING, BUT IT IS A RACE WE CAN AND MUST WIN’

UN Secretary General, António Guterres

WWF SCOTLAND FOREWORD

The impacts of the 1ºC of climate change we have already caused are more visible every day. But there is a cause for hope too, as news of new climate action and new investment reaches us from every corner of the world. There is an urgent moral challenge for Scotland, but there is also a huge opportunity to create a better Scotland if we act with urgency, and keep our nation at the forefront of the global net zero economic transition.

WWF Scotland commissioned this report from Vivid Economics to set out immediate actions, across the economy, that the Scottish Government could take today to accelerate Scotland’s transition to a climate-neutral society. If we are to achieve our challenging climate change targets, and maximise the economic benefits of doing so, we will need to deliver actions like those in this report and more.

There is a clear pathway for Scotland to end its contribution to climate change within a generation and play a full part in keeping global warming to 1.5ºC. But it requires that Scotland’s primary political project is the focussed delivery of the necessary climate actions – accelerating existing programmes, putting in place new investments and regulations, and an immediate end to actions that work against our climate responsibilities.

We hope this report provides content that allows Scotland to vigorously scale up its delivery of climate action in the coming year.

SCOTLAND’S RECORD OF CLIMATE LEADERSHIP

SCOTLAND HAS A PROUD RECORD OF CLIMATE CHANGE LEADERSHIP

Scotland has a proud record of climate change leadership. Our young people have taken to the streets to demand action from their leaders, leading protests by tens of thousands of people, in villages, towns and cities across Scotland. Public polling tells us that an overwhelming majority of the public in Scotland understand the scale of the twin climate and nature crises, are already making significant changes in their own lives, and are willing to accept large changes in public policy in order to protect people and nature from the worst impacts of climate change. Scottish businesses, especially those active in renewables and financing, are investing in the low-carbon transition, and exporting their skills, knowledge and products across the world. Practical community climate projects up and down the country are delivering social change and cutting local climate emissions.

In the political sphere, the Scottish Government was the first government in the world to declare a state of climate emergency, and this year’s Programme for Government committed to making climate action a primary focus for the Government’s work during 2019/20. Our politicians in Holyrood have consistently provided for strong and ambitious climate frameworks. In 2009, Scotland passed what was, at the time, the world’s most comprehensive and detailed climate law – setting annual targets, incorporating international shipping and aviation emissions and requiring regular action plans from government. In the time since that law,

PHOTO: GORDON SAUNDERS/ADOBE

Scotland has revolutionised its electricity generation, abandoning coal and getting to the point that the equivalent of 75% of our power needs are met from renewables. Our previous climate targets have been met, and in that time living standards have been improved and the economy grown.

OUR NET ZERO CLIMATE LAW

Ten years on, the Scottish Parliament has once again passed a climate law that seeks to rise to the climate change challenge our planet faces. It sets challenging and responsible targets. The law requires Scotland to roughly halve its existing emissions between now and 2030, and then continue that progress, achieving net zero greenhouse gas emissions by 2045.

"The new Climate Change Bill showcases the real ambition that the global community requires to limit global warming to 1.5 degrees". Patricia Espinosa, UNFCCC

A pathway of annual emissions targets will keep minds focussed on driving down emissions over that time, and it provides for new delivery action, especially in agriculture and land-use. However, the Bill only provides the launchpad framework for further and concerted action over the coming years.

CLOSING THE DELIVERY GAP

With a comprehensive legislative framework now in place, attention must now be focussed on delivering the necessary transformational policy action.

Existing emissions reductions, whilst impressive, have mainly been achieved in the electricity and waste sectors. To date, there has been a consistent lack of sufficient policy commensurate with targets, in particular in the transport, buildings, industry, and agriculture/land use sectors, where Scotland's delivery gap is most significant.

The Scottish Government has also recognised that we face twin climate change and nature emergencies – Scotland's particular land and natural resources provide the basis from which it is possible for us to tackle these twin crises in conjunction, restoring nature through afforestation and peatland restoration.

The delivery gap is even more pronounced at a UK level. Scotland can make a disproportionate contribution to cutting UK emissions, but the existing devolution settlement means that there are key decisions that need to be taken by the UK Government to unlock our natural resources. This is especially the case in the power sector, where the UK Government needs to provide a route to market for Scotland's renewables resources, if Scotland is going to play its fullest role in helping to decarbonise heating and transport, in Scotland and across the UK.

Net zero requires every part of our economy and society to do everything it can to tackle the climate crisis. No industry or activity can have a free pass to continue freely polluting our atmosphere. That means the Scottish Government's plan for reaching net zero must be a comprehensive one – urgently delivering *all* the sector transformations that this report touches upon. Thanks to our world-leading progress in renewable power production, Scotland is further down the road to net zero than many places in the world. This means we have a responsibility to confront other challenges, in industry and land use particularly, that others are yet to reach. We can show how it can be done, and we will see the economic benefits of others following in our path.

This report is the first of a series of reports, briefings and publications that WWF Scotland will publish over the coming year, using a range of methodologies. Taken together, they will set out the full range of urgent and immediate actions that Scotland must take across the economy to tackle climate change.

CUTTING OUR CLIMATE POLLUTION AND BUILDING A BETTER SCOTLAND

There are political choices to be made in the precise delivery of Scotland's transition to a climate neutral economy – the balance of roles for different actors, for example between government and private funders, and how policies are delivered to maximise other economic goals (e.g. job creation) and social goals (e.g. addressing inequality). Climate policy can, and should, protect the most vulnerable, enhance lives and livelihoods, and create a fairer, flourishing Scotland.

But it is urgent. The earlier that transformational policies are introduced, the more ordered the transition will be. The alternative –procrastination on key decisions, waiting for the decisions of others – involves only risks of a delayed, rapid and disordered transition, and lost economic opportunities to lead the way.

With the transition delivered properly, actions delivered decisively, and with appropriate investment, we can deliver a just transition in Scotland. We can cut our emissions from buildings, whilst addressing fuel poverty. We can create a new generation of climate-neutral industry, creating new jobs and attracting inward investment. We can build an efficient transport system, that supports improved health and cleaner air. We can move to a more circular economy, a more efficient economy that treads more lightly on nature, and is less wasteful. Policies can drive social changes, and social innovation can emerge in new ways, reducing our consumption, and allowing us to savour the reusability and longevity of the items we posess. There is no shortage of opportunities for us to build a better Scotland as we address the climate crisis, if the political leadership is there to deliver the necessary acceleration in Scotland's climate action.

Scotland can show the rest of the world that cutting emissions, improving people's lives and restoring nature to good health go hand in hand.

THERE ARE POLITICAL CHOICES TO BE MADE IN THE PRECISE DELIVERY OF SCOTLAND'S TRANSITION TO A CLIMATE NEUTRAL ECONOMY

WHY THIS MATTERS

We are already seeing the impacts of climate change all around the world. Hurricanes have wreaked havoc in the Caribbean. Fires have torn through the Amazon. Scotland has seen new temperature records. Ice at the poles is melting faster than expected. All this with just 1°C of global heating. Existing global commitments to action only add up to sufficient emission reduction to keep average temperature rises to 3°C. Without increased action, things will only get worse.

I believe that there has never been a greater commitment to action on climate change here in Scotland. In the streets, in politics, in business, in people's hearts. Now is the time for us to lead, for us to step up our action to cut emissions and leave our children a better Scotland: one that is prospering, that is in harmony with nature, and that has ended its contribution to climate change.

GINA HANRAHAN
HEAD OF POLICY, WWF SCOTLAND

KEY MESSAGES

Scotland will need to quickly implement new policy actions and funding support to meet the net zero emissions target. Scotland has reduced its greenhouse gas (GHG) emissions more than 40% since 1990. However, Committee on Climate Change (CCC) analysis suggests that current policy is not sufficient to meet the old weaker emissions targets, hence a significant action is required to achieve net zero by 2045.

An immediate increase in the deployment rate of mature low carbon technologies, and broader mitigation options, is required. Scotland's net zero target is 25 years away. This time frame has direct implications on deployment rates of, for example, low carbon heating technologies in buildings. Delaying actions implies a need for costly and disruptive transitions later (for example, a need to scrap gas boilers before the end of their useful life) and shifts risks onto future generations. For less mature technologies, the Scottish Government can invest in the necessary infrastructure (e.g. CO_2 transport and storage infrastructure) in the 2020s, to enable a rapid roll-out through private investment (e.g. in capture plants) in the 2030s.

The Scottish Government is well placed to set Scotland on a path towards net zero. Existing Scottish programmes such as Energy Efficient Scotland, which have driven significantly faster action than the UK average, demonstrate the key role the Scottish Government can play. The recommendations in this report set out areas where Scottish Government can act now, to deliver the major components of the technology scenarios in our previous report, *A Climate of Possibility*[1]. We tailor these actions to build on recent announcements in the Programme for Government and focus on areas where the Scottish Government can have a significant impact. For each sector, the recommendations are designed to:

- Focus on delivering key changes from a business as usual business-as-usual to a net zero pathway.
- Focus on the emitters within sectors where the largest changes are required, e.g. road and marine transport within the wider transport sector.
- Focus on areas where the Scottish Government has the relevant regulatory tools, drawing on international case studies to inform policy design.

A mix of financial support and regulatory action will be required across the economy. The sectors where Scottish Government action can have most immediate impact are buildings, industry, transport and LULUCF. Agriculture also has a key role to play in emissions reductions but the potential measures, costs and impacts and policy framework required to deliver this are the subject of a dedicated report which WWF Scotland has commissioned separately so it is not a key focus of this report. There are also policy options for Scottish Government in power, but key frameworks are either not devolved, or are already set for the short term, and hence these sectors are not the focus of this report.

1 https://www.vivideconomics.com/casestudy/a-climate-of-possibility/

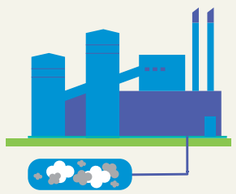
Buildings

- Expand funding for energy efficiency and renewable heat. To reach net zero, additional spending on energy efficiency and low carbon heating in buildings of around £0.9 bn per year is required, compared to business as usual. This includes private and public spending, but a large proportion will likely need to be public spending, particularly in the short term. For renewable heating, multiple £100 million per year of up-front grants, mainly for heat pumps in households are likely necessary. For energy efficiency, a funding increase is required immediately to approximately double the rate of energy efficiency improvements. More detailed work is necessary to estimate the precise public funding levels and targeting across Scotland.
- Deploy local strategies and a national plan to regulate out fossil fuel heating. The Scottish Government should require councils to develop local strategies, that reduce emissions using locally appropriate solutions. Local strategies should include policy levers (e.g. planning), implement national building standards for new homes, and regulations for point of sale for existing homes (set to regulate out fossil fuel heating by a specified date).

THE SIZEABLE VEHICLE FLEETS DIRECTLY OWNED BY PUBLIC BODIES COULD BE RAPIDLY TRANSITIONED TO ZERO EMISSIONS VEHICLES

Transport

- Regulate a zero emissions zone in cities from 2030. This will directly reduce emissions, and indirectly help support low carbon vehicle uptake. Furthermore, zero emission zones provide co-benefits such as air quality improvements. To help support the implementation of the zones, supporting policy should improve the availability and attractiveness of alternative transport modes (e.g. cycling or public transport).
- Publicly procure zero emissions road vehicles (ZEVs). The Scottish Government should leverage procurement rules to rapidly transition the sizeable vehicle fleets directly owned by public bodies (e.g. the NHS) or operating with strong government support (e.g. public transport buses).
- Procure zero emission ferries and develop a coastal shipping emission reduction strategy. Public procurement of zero emissions ferries and financial support for private shipping is necessary, embedded within a wider strategy to develop the required infrastructure.



Industry

- Provide Scottish Government capital funding support for the transport and storage infrastructure to deliver a programme of carbon capture and storage (CCS) projects. A rapid roll-out of CCS in the 2030s requires infrastructure to be constructed in the early 2020s. Public investment of several £100 million is likely required now to achieve this; the investment can be recouped later, with wider business opportunities for Scotland available as an early adopter of CCS.
- Develop a Scottish industrial hydrogen strategy, with grant support for demonstration and commercialisation projects. There are low-regret uses of hydrogen in industry, which will be necessary to achieve net zero. Demonstration of hydrogen in industries such as glass making will help develop low carbon industrial competitiveness in the future.

Land use

- Increase funding for afforestation and closely integrate into regional land use frameworks. Funding should be increased to £60-70 million per year, assuming current planting costs. Large-scale afforestation is necessary, and will require more funding, but needs to be deployed sensitively with consideration for local land use trade-offs. Regional land use frameworks will have key role in helping target future support where it delivers greatest climate and biodiversity benefits.
- Fund demonstration of land-based GGR at scale to establish CO_2 removal monitoring processes, and understand environmental risks. To unlock land-based GGR as a viable option to achieve net zero, demonstration is required now.

LARGE-SCALE AFFORESTATION IS NECESSARY, AND WILL REQUIRE MORE FUNDING

The provided recommendations will require a significant increase in support from the Scottish Government for climate action. Current deployment rates of key technologies such as heat pumps are too low compared to a realistic pathway to net zero, and significant support from Scottish Government is required. While significant, the funding recommendations provided are commensurate with CCC estimates of the resource cost of meeting net zero. However, the funding recommendations in this report are indicative and are not detailed policy cost assessments, which are required to make decisions. To estimate precise costs will require further work (considering wider socioeconomic costs and benefits, distributional impacts, etc.) and depend on detailed policy design.

Further work is required to develop a comprehensive net zero policy framework. To achieve net zero, Scottish Government policy will need to coordinate with local, UK, EU, and global policy developments. The provided recommendations focus on key short-term actions, and are not a comprehensive set of all policies required from the Scottish Government. There are choices about how exactly these policies are delivered, depending on other economic (e.g. job creation) or social goals (e.g. reduced inequality); however, policy changes of the types recommended in this report are all vital to put Scotland on a pathway to net zero.

PHOTO: LUCAS PENG ON UNSPLASH

SCOTLAND'S DECARBONISATION PATHWAY

The contours of Scotland's net zero pathway are well established. Analysis from, amongst others, the Committee on Climate Change and Vivid Economics has set out technological and behavioural options for reducing emissions across the economy. Building on this foundation, the purpose of this report is to identify how the major components of these pathways can be unlocked, and – within that – the role of the Scottish Government.

ALMOST ALL SECTORS NEED TO DECARBONISE FULLY

Almost all sectors need to decarbonise fully, with remaining emissions only from sectors where there is no economically viable technological alternative. To illustrate possible combinations of options, Figure 1 sets out two plausible combinations of mitigation options by 2050, from existing scenarios, which are compatible with Scotland reaching net zero by 2045.

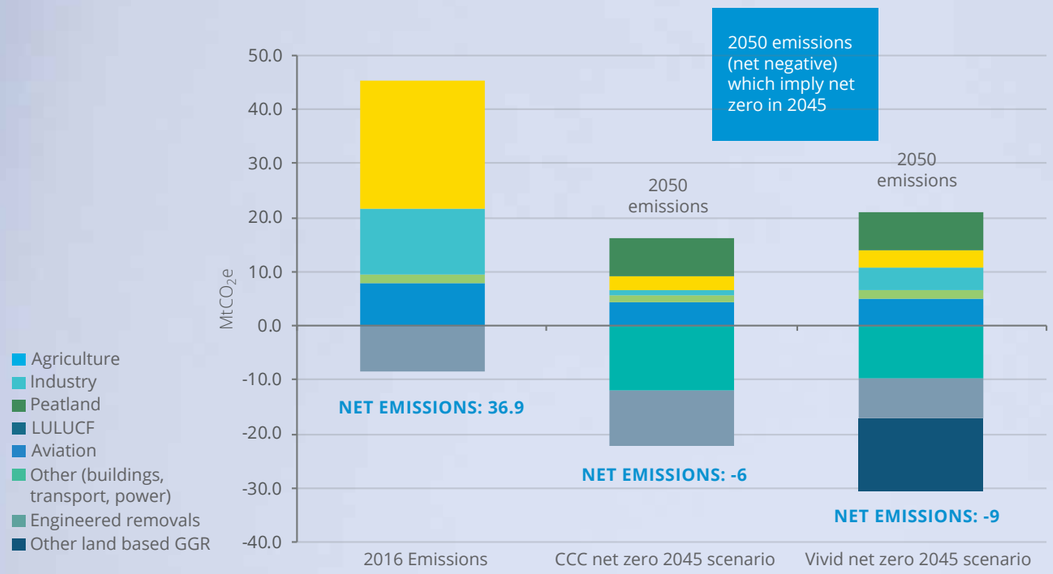
- *Power, buildings, industry, and road transport need will need to almost completely decarbonise*. The carbon budget allows for only negligible levels of emissions in these sectors. In power and industry this is mostly residual emissions from plants with CCS fitted, in buildings it is likely to constitute particularly inaccessible or rural buildings.
- *Agriculture and aviation must cut emissions significantly, but will likely continue to emit*. These emissions arise from in areas where there are currently no viable alternative technologies. For example, agriculture will continue to emit because of fertiliser use and methane emissions from livestock.
- *A significant level of negative emissions are required, from both natural (afforestation etc.) and engineered solutions (e.g. direct air capture).* The most mature options are bioenergy with CCS (BECCS) and afforestation, but there are alternative greenhouse gas removal (GGR) options as well. Deployment of currently immature GGR options (as per the Vivid scenario) could create some flexibility in the decarbonisation pathway.

To ensure a realistic chance of achieving net zero by 2045, a portfolio approach is required in policy making. Achieving net zero by 2045 in Scotland implies rapidly decarbonising. Achieving the scenarios set out in Figure 1 requires all mature decarbonisation options to be deployed where possible. A policy portfolio means providing incentives for both mature and less certain options, in the knowledge that not all projects and policies achieve their full ambition (and others may over-achieve). This is particularly important in negative emissions policymaking. Greenhouse gas removal is crucial to achieving net zero emissions, and Scotland has large, up to 31 MtCO2/year GGR potential, but it is uncertain.[2] To maximise the likelihood of reaching net zero, the Scottish Government should support a range of negative emissions options. Supporting both the large-scale deployment of mature options (e.g. afforestation and habitat restoration) and piloting less mature options (e.g. biochar and enhanced weathering), in the knowledge that not all may deliver fully.

2 This includes both natural solutions such as afforestation and habitat restoration, as well as engineered solutions such as direct air capture a (DAC) and bioenergy with carbon capture and storage (BECCS)

PHOTO BY J WETA / ADOBE

FIGURE 1. REMAINING EMISSIONS PER SECTOR IN SCOTLAND BY 2050



Source: Vivid Economics, based on emissions data from the CCC and own modelling

SCOTLAND DOES NOT CURRENTLY HAVE SUFFICIENT POLICY IN PLACE TO REACH THE OLD 80% TARGET

New policy commitments are urgently needed to put Scotland on a pathway towards net zero. While making progress, Scotland does not currently have sufficient policy in place to reach the old 80% target (CCC, 2018). To achieve the ambitious net zero target, a broad range of policies are required. The CCC sets out the actions required to meet Scotland's target, or help achieve the wider UK target. The actions can be broadly categorised into 'core' (mature), 'further ambition' (immature but demonstrated), and 'speculative' (not yet demonstrated at scale); see Box 1 for more detail. This report focusses on three categories to increase short-term action, and set Scotland on a path towards net zero:

1. *Increased deployment rates of mature mitigation approaches.* Early deployment of core mitigation options does not only avoid a heavily backloaded level of effort, but also is crucial to enabling additional measures required to reach net zero. For example, achieving net zero will require a larger power system and hence a faster roll-out rate of e.g. wind turbines. The report provides both funding and regulatory recommendations to increase the deployment of heat pumps, electric vehicles (EVs), and other mature low carbon technologies.
2. *Increased development of enabling infrastructure.* Less mature technologies, such as CCS and hydrogen, will need to deploy at a significant scale, particularly to enable the industrial sector decarbonisation needed to achieve net zero. This implies a rapid ramp-up in the 2030's, which will require enabling infrastructure, such as a Scottish CO2 transport and storage backbone, to be constructed in the 2020s.
3. *Increased support to demonstrate and commercialise speculative and further ambition options.* For both further ambition and speculative options, additional demonstration is required before large-scale commercial deployment is realistic. For example, applications of hydrogen in Scottish industry will likely be required to decarbonise, but require further demonstration. Similarly, immature land-based GGR options could significantly contribute to decarbonising Scotland, but require an extended period of demonstration to determine their viability.

PHOTO: ESPENADOBE

Box 1 CCC's classification of mitigation options for Scotland

- Core options broadly reflect previous levels of ambition, and are mostly well established. They include electric vehicles, home insulation measures, heat pumps, industrial energy efficiency, etc. These options will all be required at scale, and should be supported to ramp up rapidly.
- Further ambition options are more challenging and more expensive, but have been demonstrated and are likely to be available with sufficient government support. Options include hydrogen use in industry. If all core and further ambition options deliver at the upper end of what the CCC expects, Scotland can achieve net zero by 2045 with core and further options alone.[3]
- Speculative options are technologically immature and are unlikely to all become available by 2045. They are not necessarily required for Scotland to reach net zero, but some will be necessary to achieve the UK wide net zero target. Speculative options include, for example, large scale synthetic fuel production and immature GGR options such as enhanced weathering. Scotland may not require any speculative options to reach net zero by 2045, but may deploy significant quantities if they prove to be more cost effective than further ambition options, or to help meet the wider UK net zero target.

Source: Based on definitions in the CCC's 'Net Zero' report (CCC, 2019b)

3 A reduction of 104-110% by 2050 under Further Ambition provides confidence that net zero GHG emissions can be achieved in 2050, and can be achieved by 2045 if 110% is achieved by 2050.

IMPLICATIONS OF THE NET ZERO TRANSITION ON SCOTTISH GOVERNMENT SPENDING

The resource costs of net zero are significant, 1-3% of Scottish GDP annually.[4] Significant additional investment, and redirection of existing investment, will be required to meet this cost.

- *Annual investment of around £2-5 billion a year is required for Scotland to fund the costs of decarbonisation.* This cost will also yield benefits, both monetary in terms of green business opportunities, and non-monetary such as cleaner air. Nonetheless, significant additional funding is required compared to business as usual.

Large changes in existing financial flows will also be required. This includes, for example, adjustments to agricultural subsidies (over £200 million a year) to reward delivery of public goods such as GHG reductions and changes in how Scotland's significant annual road infrastructure budget (£831 million[5]) is delivered.

While the resource costs imply a significant investment need, the net zero transition will also create economic benefits, and does not imply a negative impact on Scottish GDP. The resource costs represent the additional lifetime cost of e.g. a heat pump compared to a gas boiler. Summed across the economy, the required investments to meet the resource costs are significant. However, these investments can also yield economic benefits. For example, early decarbonisation investment can enable Scotland to capture low carbon goods and services export opportunities in future. Macroeconomic modelling of the net impact on GDP of the net zero transition has yielded inconclusive results, but suggests the net impact is modest and costs and benefits broadly balance.[6]

WHILE THE RESOURCE COSTS IMPLY A SIGNIFICANT INVESTMENT NEED, THE NET ZERO TRANSITION WILL ALSO CREATE ECONOMIC BENEFITS

The transition to net zero also provides wider benefits not directly captured in GDP:

- *The net zero transition will have positive health and environmental impacts.* For example, measures in the transport sector will improve urban air quality and cycling access and safety, while investment in buildings efficiency will substantially improve indoor comfort. These outcomes directly improve quality of life, but also bring substantial health benefits. This in turn can help reduce healthcare costs, offsetting some of the initial investment costs.
- *The transition can be implemented to support low income households.* Policy to accelerate the net zero transition can have significant distributional impacts. For example, focussing support to improve energy efficiency on low income households accelerates the energy transition while reducing fuel poverty.

4 Across the UK, the CCC estimates the net zero target can be achieved at a resource cost of 1-2% of GDP per year (CCC, 2019b). Scottish costs are expected to be 10-13% of total UK costs (CCC, 2019b); this implies a resource cost of 1-3% of Scottish GDP, a slightly higher % than the UK average .

5 In 2018-19, (Scottish Government, 2017b)

6 Box 7.3 from the CCC's Net Zero report (CCC, 2019b) provides further detail on economic modelling efforts to quantify the net impact on GDP

Public fiscal support is particularly important in the short term to meet net zero resource costs. In most sectors, current regulation and market incentives do not provide sufficient incentive for a rapid transition. While broader policy frameworks are being developed to price (potentially implicitly through e.g. emissions standards) the carbon externality into markets, government will need to provide financial incentives to ensure Scotland is on a realistic net zero pathway. Put differently, public sector funding, including from the Scottish Government, will need to meet most of the resource cost in the short term. In the long run, policy decisions will determine how the resource cost is shared across government, business and households.

A significant spending increase from the Scottish Government is likely to be required. Assuming the yearly resource costs of net zero (e.g. the additional cost of a hydrogen bus compared to an ICE bus) are spread evenly across the public sector, indicative short term Scottish Government spending to meet the resource costs of decarbonisation are £0.7-£1.9 billion per year.[7] This resource cost is on top of redirected public spending towards low carbon investment.[8] For example, redirecting public support for ICE busses towards hydrogen or electric busses. Current government spending (redirected plus additional resource cost) is lower than the estimated Scottish Government spending need on resource costs alone (£0.7-£1.9 billion per year), suggesting Scottish Government spending on climate will need to increase significantly.

This report sets out areas where large spending increases are required. Where possible, we highlight the gap between current and required deployment rates to reach policy targets. This suggests that in, for example, energy efficiency, an additional £100 million per year is necessary. More detailed work is however required to assess funding needs accurately.

7 This assumes climate funding is distributed proportionally to % total spending across Scottish Government, UK government, other UK wide public bodies, and local government. Scottish Government spending is approximately 37% of total public spending in Scotland.

8 Scotland's 2018-19 draft budget allocated £560 million to climate change mitigations (Scottish Government, n.d.). This includes both redirected spending and spending to meet the resource costs of net zero and hence is not directly comparable to the estimate of Scottish Government spending on resource costs.

PHOTO BY STEWART M / UNSPLASH

ACTIONS WITHIN EACH SECTOR

BUILDINGS

The buildings sector needs to almost completely decarbonise, reducing emissions by 87% from today, to achieve net zero by 2045.

The sector emitted 8.7 MtCO2e in 2016, a 23% share of Scottish emissions. Buildings emissions have decreased by 35% since 1990, but have increased since 2014, partly due to relatively cold winters (CCC, 2018). The main driver for the overall decrease has been the switch from oil and coal to natural gas for heating, and improvements in energy efficiency. On average, buildings emissions need to decline 6% annually to meet net zero targets, reaching approximately 1.1 MtCO2e in 2045 and 0 emissions by 2050. Currently, residential buildings are the largest emitter with 73% of the total emissions (Figure 2) and these buildings use 87% of their energy for heating.

TO MINIMISE DISRUPTION AND LONG-TERM COST, EARLY ACTION IS ESSENTIAL.

An increase in action is required now, to accelerate momentum in the sector and ensure a credible pathway towards zero emissions in buildings. The building sector is typically slow to change, given the cost, complexity, and hassle involved with, for example, retrofits while a home is occupied. To minimise disruption and long-term cost, early action is essential. The CCC suggests significant energy efficiency increases in the short term are cost-efficient (CCC, 2019c). Furthermore, low carbon heating installations will need to ramp up now, to avoid an overheated (and hence expensive) market in the 2030s. Rather than an incremental increase in support, a policy framework is required that clearly bridges the gap between current deployment rates and those required to reach the 2045 target. Key ramp-ups necessary include:

- *Energy efficiency retrofits in buildings:* A plausible pathway to net zero likely requires all homes to reach EPC C standard by 2030 (The Existing Homes Alliance, 2019). To reach this a doubling of the 40,000 rate is required (Scottish Government, 2019c).
- *Renewable heating deployment*: At least 90% of homes will need to be fitted with a form of renewable heat by 2050, up from 4% currently (Scottish Government, 2019b).[9] This implies an annual average installation rate of 70,000 renewable heating solutions (e.g. heat pumps).[10] As a point of comparison, annual gas boiler installations in Scotland (new and replacement) are around 20,000.[11]

A holistic approach to achieving zero carbon buildings is required. Households are the key focus, representing the majority of emissions as shown in Figure 2. Modelling suggests the additional yearly resource cost (above business as usual) of retrofits and low carbon heating installation in 2.4 million dwellings to be around £0.9 billion per year (Element Energy, 2019). [12] Delivering the required investment effectively will require detailed urban planning, close collaboration between national and local government, regulation to leverage private investment, and innovative business models from the private sector. The following hence provides two recommendations, one focussed on increasing the short-term deployment of energy efficiency and renewable heating solutions, and a broader recommendation to develop a comprehensive programme to deliver net zero buildings across Scotland.

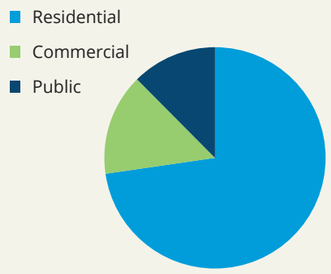
9 The current percentage of homes with renewable heat is a UK wide number.
10 Assuming 2.5 million households in Scotland and 30 years to install renewable heating solutions.
11 Based on annual UK installations of 1.7 million, pro-rated by Scottish percentage of UK households. UK annual sales from (BSRIA, 2017)
12 The resource cost is the cost of installing energy efficiency measures and low carbon heating in all homes, calculated against the counterfactual of fossil heating system and no energy efficiency improvements.

FIGURE 2. BUILDINGS SECTOR EMISSIONS AND POLICY OVERVIEW

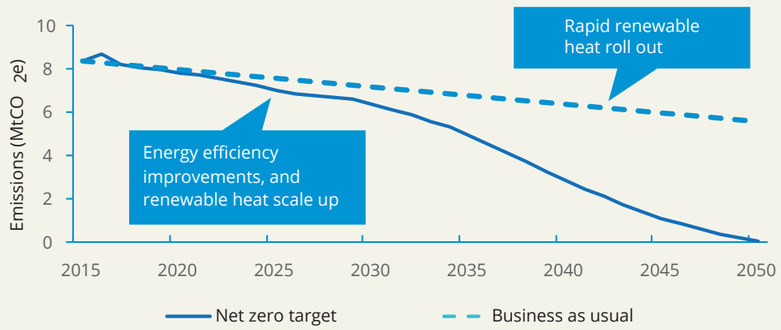
CURRENT POLICY ASSESSMENT (RELATIVE TO NET ZERO)

RAG rating	
Past policy action	Despite significant support, deployment rate insufficient for net zero and 90% target
New policy commit-ments	Significant increase in action required, particularly in renewable heat

CURRENT EMISSIONS 2016 ($MtCO_2e$)



EMISSIONS REDUCTIONS PATHWAY AND KEY COMPONENTS



Note: RAG policy assessment: red = significant additional action required; amber = some additional action required; green = little additional action required. Emissions reductions pathway: The sectoral net zero pathway is based on Vivid modelling and compatible with economy wide reductions of 75% by 2030 and net zero by 2045. The business as usual modelling assumes linear change with a slope equal to average reductions between 2000 and 2016.

Source: Vivid Economics, based on emissions data from the CCC

RECOMMENDATION 1: SIGNIFICANTLY EXPAND SCOTTISH GOVERNMENT FUNDING FOR ENERGY EFFICIENCY AND RENEWABLE HEAT.

Achieving net zero homes by 2045 will require a significant step up in public funding for energy efficiency. As part of the Energy Efficient Scotland programme, the Scottish Government will invest £0.5 billion, £125 million per year, in energy efficiency over the remainder of the current parliament (2018-2021) (Scottish Government, 2019e). However, the Scottish Government has committed to accelerating the improvements of EPC ratings in their Programme for Government (Scottish Government, 2019e). To reach net zero and emphasize early action in the coming decade, EPC C targets should move forward from 2040 to 2030 (Existing Homes Alliance, 2019). This implies 80,000 homes need to be renovated annually until 2030 – doubling the current rate (Scottish Government, 2019c). This suggests approximately a doubling in funding for energy efficiency may be required during the 2020s.

A Scottish heating subsidy, in the form of a one-off payment, should be provided to encourage heat pump installations in households. The current Renewable Heat Incentive (RHI) – a UK government financial incentive – provides quarterly payments over a 7-year period, which fails to address the upfront capital cost barrier. Consequently, only approximately 1,200 heat pump installation were accredited by the RHI in Scotland in 2018/2019. In contrast to the RHI, a one-off payment subsidy exists in The Netherlands. Implementing a similar scheme would require multiple £100s of millions in Scotland, but is likely the only effective policy to achieve the required deployment rates in Scottish households (see Box 3). The funding requirement is many multiples of current funding for the Scottish domestic RHI, which in 2018/19 paid out approximately £20 million (Ofgem, 2019a).[13]

Box 2 Renewable heat incentive (ISDE+) in The Netherlands

- This subsidy for homes and businesses provides funding for heat pumps, biomass boilers, pellet stoves and solar thermal collectors.
- The subsidy provides one off payments. For heat pumps, households can receive a subsidy amount between €1000 and €2500 (£880 and £2200) depending on the kW power and manufacturer price of the heat pump.
- This has encouraged significant uptake, with around 25,000 heat pumps installed with the subsidy in 2018 (TNO, 2018).
- Notably, even this sizeable subsidy has not incentivised up take as the rate required for Scotland to reach net zero. Furthermore, differences in the quality of building stock etc. suggest the subsidy will likely need to be significantly higher in Scotland.

RECOMMENDATION 2: DEPLOY LOCAL STRATEGIES AND A NATIONAL PLAN TO REGULATE OUT FOSSIL FUEL HEATING.

Local heat and energy efficiency strategies can act as the main vehicle for implementation of a Scottish net zero homes programme. Scottish local heat and energy efficiency strategies are being piloted but are not yet widespread. While still in its early stages, the Scottish government has invited some local authorities to develop Local Heat and Energy Efficiency Strategies (LHEES). Devolving heating and energy efficiency strategies to local governments has been successful internationally, as local government can leverage the planning system and knowledge of the local context effectively. In the Netherlands, municipalities oversee the design and execution of energy strategies, while the national government provides financing opportunities and standards to facilitate decarbonisation of the housing stock (Dutch Government, 2019). This devolved policy framework is supplemented by the 'starter motor' approach where the national government accelerates economies of scale in the building sector to bring down costs. In Denmark, a similar devolved framework is in place. Municipalities are responsible for assessing the future heating needs and supplies of their area as well as preparing and updating municipal heat plans that maximise district heating opportunities, which feed into regional heat plans.

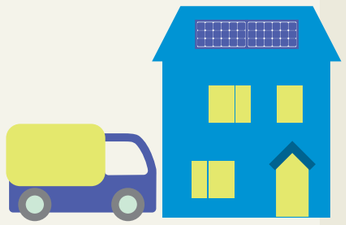
13 This has been calculated using the domestic RHI's annual report for 2018/19, which presents the geographic distribution of accredited installations in that year as well as the total amount of payments made per heating technology. This implies payments of ~£20 million per year to Scotland.For the non-domestic RHI, total periodic support payments cumulated to £2,000 million in 2019. 21% of the total accredited capacity was in Scotland. This means total payments in Scotland over the lifetime of the subsidy were £420 million. The first payments were made in March 2012 (with payments steeply increasing over the years), hence an annual total payment of £52.5 million per year in Scotland. This payment amount was not allocated evenly over the years, as the bulk of payments started in 2016.

The national government supports this structure by granting municipalities autonomy and flexibility, while simultaneously offering a centralised policy and regulatory framework (i.e. tariffs, efficiency requirements, building codes, and a nationwide transmission system) (Chittum & Østergaard, 2014).

To maximise the effectiveness of increased Scottish Government spending on energy efficiency and low carbon heat, the Scottish programme should include:

- *Local strategies*. The Scottish Government should require councils to develop local strategies, which target emissions reductions using locally appropriate solutions and set out policy levers to reach these targets, including e.g. planning permissions and council tax rebates for more energy-efficient homes.[14] Scottish Government funding for renewable heat and energy efficiency should support the delivery of local strategies.
- *Net zero building standards for new builds and low carbon requirements for existing buildings*. Net zero standards for new builds should be implemented as early as practical. For existing buildings, low carbon requirements should be sufficiently stringent to have the effect of regulating out fossil fuel heating by a specified date. This can be achieved through a combination of low carbon requirements on buildings at the point of sale, and supporting regulation such as emissions standards on boilers. Standards will be a key tool to leverage private investment in low carbon heating. However, support should be designed to ensure low-income households are not affected disproportionately.

Early support could be focussed on off-gas and social housing. Installing heat pumps in off-gas areas is a low-regret intervention as it will not have to replace existing on-grid technology (CCC, 2019b). As argued in Box 3, focussing on social housing provides an opportunity for immature supply chains and business models to scale up and become more cost-effective. Furthermore, this would reduce heating bills for low-income households.



Box 3 Energiesprong in Scotland

- Deep retrofitting is expensive and time-consuming, limiting homeowners' enthusiasm to such improvements. Simultaneously deep retrofitting is more efficient than one-off home improvements.
- A successful example of a national net zero programme is *Energiesprong*, a Dutch government-funded innovation programme for large-scale whole house refurbishments. It is simultaneously a funding mechanism and a housing standard and could be supported by zero interest loans.
- *Energiesprong* lowers the costs by aggregating mass demand for retrofits by first refurbishing the social housing sector. This is then followed by the private home-owner market that can access deep retrofits at a lower price. As 23% of Scotland's building stock is social housing, using such an approach will be a good way to build up the supply chain (Scottish Government, 2019g).

14 A council tax rebate was found to be a popular incentivise for homeowners to install energy efficiency upgrades (Citizens Advice Scotland, 2017).

PHOTO BY ERIK VERREPT / ADOBE

TRANSPORT

The Scottish transport sector will need to reduce emissions by about 5% annually to meet net zero targets.

The transport sector is Scotland's largest source of emissions – in 2017, emissions from the sector were 14.9 MtCO2e, 37% of total emissions. This is slightly higher than 1990 levels (14.7 MtCO2e) and includes a 6.2% increase in emissions since 2013 levels (13.6 MtCO2e) (CCC, 2018). This failure to decarbonise has primarily been driven by increased demand for transport, which has offset improvements in vehicle emissions efficiency. To achieve net zero by 2045, emissions from the transport sector must decline to around 3.1 MtCO2e per year in 2045. Most of these emissions will come from aviation, and hence other emissions from transport will need to be fully decarbonised.

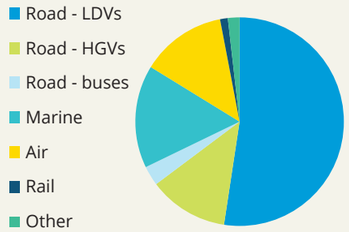
Road transport, followed by marine transport, are the short-term decarbonisation priorities in the transport sector. These comprise 68% and 16% of Scottish transport emissions, respectively, as shown Figure 1. Unlike air transport, there are clear technological alternatives for light duty road vehicles (LDVs), and technologies for heavy duty road vehicles (HDVs) and coastal shipping are quickly maturing. Hence, light duty vehicles are a key short-term priority area, closely followed by heavy duty vehicles and marine transport.

FIGURE 3. TRANSPORT SECTOR EMISSIONS AND POLICY OVERVIEW

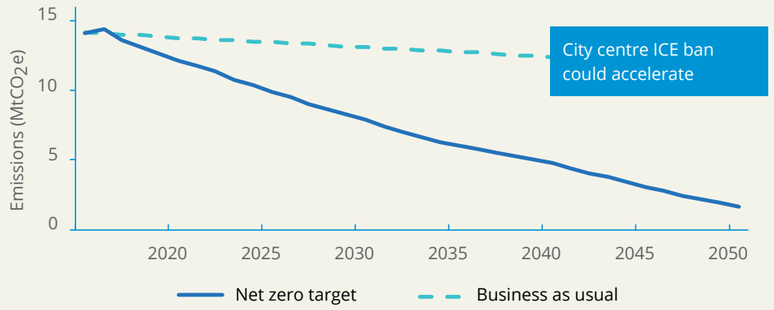
CURRENT POLICY ASSESSMENT (RELATIVE TO NET ZERO)

RAG rating	
Past policy action	Lacking plan for charging infrastructure; EV sales still slow; insufficient for net zero target
New policy commit-ments	Significant acceleration required

CURRENT EMISSIONS 2016 ($MTCO_2e$)



EMISSIONS REDUCTIONS PATHWAY AND KEY COMPONENTS



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Source:
Vivid Economics, based on emissions data from the CCC

The significantly higher upfront costs of zero-emissions transport remains a barrier to its uptake. This is primarily due to a) the immaturity of technology and supply chains relative to fossil-fuel alternatives, b) failure to price in the carbon externality of fossil-fuel alternatives. The Scottish Government is well placed to play a key role in overcoming these market failures.

Immediate government action is necessary to ensure the transition to a low-carbon transport fleet by 2045. Transport fleets, particularly maritime fleets, have long replacement cycles; for example, the average age of the Scottish ferry fleet is 17-21 years (Fraser of Allander Institute, 2017), while the average age of the Scottish bus fleet is 8.5 years (Transport Scotland, 2018). As a result, investment decisions today lock in emissions for many years. If zero emission ferries are not procured as standard by the mid 2020's, it is plausible high emissions ferries will have to be scrapped or expensively retrofitted. Similarly, to offer viable low-carbon travel alternatives by 2030, procurement of buses will need to switch to zero emissions quickly.

RECOMMENDATION 3: REGULATE A ZERO EMISSIONS ZONE IN CITIES FROM 2030.

Scottish Government, together with city councils, can encourage city-level Zero Emissions Zones (ZEZs) that phase in bans to internal combustion engines (ICEs) by 2030. Real-world experience has shown that *'pull'* policies (e.g. tax and other financial incentives) typically only result in relatively slow uptake of ultra-low emission vehicles (ULEVs) – despite generous grants in the UK of up to £4,500 through 2018, only 2.1% of all new vehicles registered in the UK in 2018 were ULEVs (Department for Transport, 2019). To complement UK-wide pull policies, the Scottish Government can implement a strong *'push'* policy (e.g. mandates) in the form of a city-centre ban on fossil-fuel vehicles. A ban, with clearly phased stages to provide certainty for businesses and consumers and guide investment, can help signal the need to invest in low-carbon modes of transport (Scottish Government, 2019a).

An inner-city ICE ban can be modelled on existing diesel bans in city centres. Two key lessons can be drawn from existing bans:

- *It is important to phase in the bans over time to afford vehicle owners and stakeholders time to adjust.* Paris's ZCR is incrementally banning all diesel-engine vehicles from the capital with its "Crit'Air" system, which assigns vehicles a score of 0-6 based on their Euro emissions standard, with older, more polluting vehicles phased out sooner.
- *A ban should be aligned with broader 'integrating' policies to support travellers in complying with the ban.* This includes support to enable the use of ULEVs in city centres, and support to increase the attractiveness of other travel modes such as walking, cycling, or public transport. France complements the Paris diesel ban with the highest European rate of EV charging point installations. In London, extensive public transport alternatives provide a viable alternative to ICE vehicles without the need to purchase an ULEV. Furthermore, Transport for London procurement rules are ensuring these alternatives are increasingly low carbon. More broadly, investment in alternatives to ICEs have been shown to be effective to reduce ICE vehicle use. For example, in the Netherlands, increases in cycling infrastructure, such as cycle pathways and free and secure cycle storage, have significantly increased the kilometres travelled by bike, while reducing those travelled by car (CE Delft, 2016). [15]

A city-centre ICE ban would have both direct and indirect abatement impacts, and can play a key role in setting Scotland on a net zero pathway. Urban road emissions accounted for 3.7 MtCO2e in 2017 (Scottish Government, 2018a). A city-centre ICE ban would effectively eliminate these emissions and thus account for nearly 90% of the Scottish Government's stated goal to reduce transport emissions "by 4.2 MtCO2e or more compared to today" (Scottish Government, 2017a). Overall emissions would be reduced by over 9% relative to 2017 levels.[16] Indirectly, the impact may be more significant, as a city centre ban makes ICE ownership significantly less attractive to most Scottish motorists. Furthermore, it will provide a key signpost to EV and fuel cell electric vehicle (FCEV) suppliers in Scotland for the ramp-up in demand, allowing supply chains (dealerships, the secondary market, and maintenance) to coordinate around the expected demand increase. A city centre ICE ban is a strong policy lever to support the rate of emissions reduction required from road transport to reach net zero, but also has wider co-benefits, as discussed in Box 4.

15 For example, a scheme in Apeldoorn providing free and secure bike storage led 11% of travellers to switch from travelling by car to travelling by bike

16 Based on 40.5 $MtCO_2e$ total emissions in 2017, a reduction of 3.7 $MtCO_2e$ would be a 9% decrease.

Box 4 The co-benefits of a city centre ban

- The policy addresses ICE use in areas where negative externalities, such as air and noise pollution, are greatest (Transport and Environment, 2019).
- The policy can encourage more active travel, particularly when complemented with appropriate integrating policy.
- The focus on cities allows rural transport, where EV ownership is less attractive and average incomes are lower, to continue to use ICE vehicles for longer.

RECOMMENDATION 4: PUBLICLY PROCURE ZERO EMISSIONS ROAD VEHICLES (ZEVS).

To immediately increase take-up, the Scottish Government can mandate procurement of zero emissions vehicles for all new publicly owned vehicles or publicly contracted transport services (e.g. bus route operators or waste collection services). A mandate can act in conjunction with existing pull policies, such as the Green Bus Fund, to ensure the required pace of transition.

- *Direct government procurement:* The Programme for Government commits to phasing out the need for new light duty ICE vehicles from 2025 and heavy-duty vehicles by 2030.[17] To meet this commitment, clear procurement standards should be developed now. Vehicle fleets are a significant cost to public bodies, and early sight of the national strategy is crucial to allow for timely adjustment of fleet management strategies.[18] Nevertheless, Scotland should mandate green procurement and provide clarity to public bodies such as Police Scotland and local authorities on the degree of funding support provided by the Scottish Government. The Scottish Government can draw lessons (see Box 2) from countries such as Sweden. From 2010 onwards, the Swedish procurement policy mandates any public vehicle purchased to be an EV or FCEV with a price maximum of £5,000 of the closest ICE equivalent.
- *Green procurement for government concessions:* Aside from direct government procurement of low emissions vehicles, the Scottish Government can strongly incentivise procurement of low emission vehicles by making transport concessions conditional on procurement of low emissions vehicles. For example, Transport Scotland could make its procurement of bus services conditional on an approved fleet management plan from private bus operators, to provide a regulatory complement to existing incentives. As mentioned in the Programme for Government, the Bus Service Operators' Grant (BSOG) already provides an incentive towards low or zero emission buses, reducing the cost for bus operators. Should there nonetheless be an impact on fares, Government should increase the BSOG incentive.

17 With some pragmatic exclusions around specialist and emergency response vehicles.

18 To illustrate, the Glasgow vehicle fleet has an estimated value of £65 million, with an annual revenue cost of £14 million (including new leases etc.). This cost would likely increase in the order of £2-3 million initially, a significant cost for Glasgow council (Glasgow City Council, n.d.).

Public procurement for road transport can meaningfully reduce emissions and create anchor demand for infrastructure such as charging stations. Public vehicle fleets are significant in Scotland. To give an indication: local authority fleets together represent approximately 10,000 vehicles, the fleet of police vehicles contains a further 1,600 vehicles, and the NHS fleet includes 9,600 vehicles.[19] There are 10,000 electric vehicles in Scotland today (Scottish Government, 2019a); thus, rolling-over the publicly owned vehicle stock to EVs (or FCEVs) has a meaningful impact not only on stock, but also the diffusion of supporting infrastructure (charging stations). In terms of emission reductions, the key contribution is likely to be the impact of mandated green procurement on the Scottish bus fleet. If the existing fleet of approximately 4,200 is replaced at a rate of 500 per annum (assuming an average age of 8.5 years) with zero emissions buses, this creates an emissions savings of up to 0.05 MtCO2e each year – 0.4% of all transport emissions.[20]

Box 5 Lessons for Scotland from Swedish Green Procurement policy

- The procurement process was time consuming and it took 12 months to draw up the tenders given the number of parties involved. The government, municipalities and private organisations – a buyers' group of 296 organisations – all jointly determined the vehicle specifications, slowing down the process. This suggests immediate action is required for Scotland to meet 2025 ambitions (European Commission, n.d.).
- The joint procurement with smaller municipalities allowed them to access EV and create economies of scale, as their tender size would normally be too small. It also reduced administrative costs (Clean Fleets, 2013).
- The purchase volume target was unrealistic as EV demand exceeded supply, limiting rebate possibilities, and as some purchasers cancelled their orders (Eltis, 2016).

19 Local Authority fleet is estimated based on Glasgow's vehicle fleet (Glasgow City Council, n.d.). This is scald to all of Scotland using relative population of Scotland and Glasgow. The Scottish police vehicle fleet is based on March 2018 Fleet information published by Police Scotland (Police Scotland, 2018). The NHS vehicle fleet is taken from (NHS Scotland, 2018)

20 Scottish bus fleet size based on Transport Scotland's 2018 statistics, cited above. Turnover is assumed to be linear, with emissions reductions figures based on all new buses being ZEVs.

RECOMMENDATION 5: PROCURE ZERO EMISSION FERRIES AND DEVELOP A COASTAL SHIPPING EMISSION REDUCTION STRATEGY.

Scotland can implement a regulatory framework to encourage maritime operators procure low- or zero-emissions vessels and significantly reduce both shipping and road emissions. Vessels entering the fleet today are likely to be in service for 20-25 years, hence procurement decisions today can lock in emissions for the long term. Scotland is unlikely to impact emissions from ocean-going vessels, as industry-wide energy-efficiency and fuel-switching trends will depend on policy at the international level from organisations such as the International Maritime Organisation (IMO). However, it can significantly influence emissions from its coastal fleet. The current Programme for Government contain few actions for marine emissions reductions; however, we recommend two actions focussed on reducing emissions form coastal/ domestic shipping:

- *Mandate low-carbon procurement of ferries for all new ferries:* As with its public road fleet, the Scottish Government can mandate the procurement of zero-emission ferries in its public ferry fleet. Although the emissions impact will be small (18 ktCO2e per year)[21] it can provide both a business opportunity for Scottish shipbuilding and provide the anchor demand for necessary infrastructure in Scottish ports, such as onshore power supply connections and, in the longer-term, hydrogen landing and bunkering installations, enabling wider coastal shipping to decarbonise. There may also be opportunities to collaborate with neighbours, such as Norway, a leader in the sector. All ferries procured for Norwegian public routes are required to be zero emissions (government funding supports procurement). Over 70 battery electric ferries are expected to be in service by 2022, just under half of Norway's fleet – proving the viability of the technologies (Norwegian Society of Graduate Technical and Scientific Professionals, 2019).
- *Develop a Scottish strategy to decarbonise coastal shipping emissions, including direct financial support:* Local shipping accounts for 1.9 MtCO2e per annum in Scotland, roughly 13% of all transport emissions. Reducing this to close to zero by 2045 is necessary to reach net zero and will require a long-term strategy. This should include targets to increase coastal shipping in the short term and decarbonise over time as fleets renew. Shipping is a fuel-efficient method of moving freight and provides a business opportunity where they replace lorry transport, especially in the Highlands. Scotland could model its plan on Norway's Roadmap for Green Coastal Shipping, which aims to cut domestic shipping emissions by 40% by 2030. The Roadmap, still under development, will include a CO2 fund for the transport sector, investing in necessary port infrastructure, and seeking to further grow the market for green shipping/alternative propulsion (DNV GL, n.d.).

21 According to a 2017 report from Element Energy prepared for Transport Scotland, based on introducing 50% hybrid ferries. Actual emissions reductions would be greater with more stringent procurement regulations.

INDUSTRY

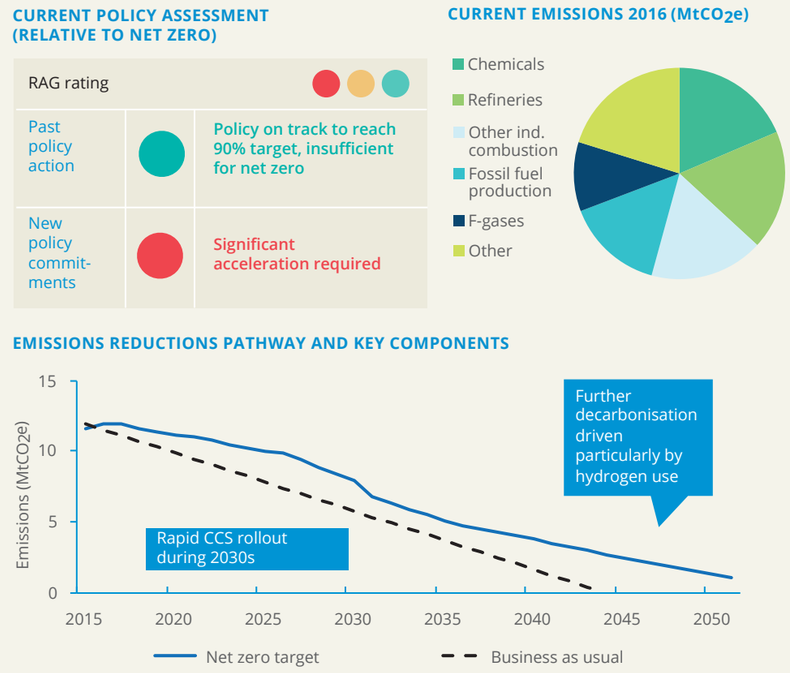
Industry currently emits 11 MtCO2e, which will need to be reduced to approximately 2 MtCO2e by 2045 for Scotland to reach net zero emissions (NZE).

This is a significantly deeper level of decarbonisation than under an 80% target. The key differences between the 80% and NZE targets are:

- The roll out of CCUS technology, which will need to occur earlier, faster, and be more comprehensive.
- The use of hydrogen as an energy source in Scottish industry, which was not necessary under an 80% scenario but will likely be required across several industries to achieve net zero.

Achieving net zero by 2045 requires a step up in policy action. The current Scottish Climate Change Plan (CCP) focusses mostly on continued improvements in energy efficiency measures, and electrification of industrial heat, which could achieve a 32% reduction by 2032 (CCC, 2018). A pathway to net zero can broadly follow this plan in the short term, but crucially needs to prepare for a rapid CCS roll-out in the 2030s to ensure Scottish industry can grow, reduce emissions, and remain internationally competitive.

FIGURE 4. SCOTTISH INDUSTRIAL EMISSIONS OVERVIEW



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Source:
Vivid Economics, based on emissions data from the CCC

The Scottish Government can play a strong enabling role to accelerate industrial decarbonisation. A key policy tool to encourage industrial decarbonisation will be the implementation of market-based carbon prices. Market-based mechanism such as an emissions trading scheme (ETS), border carbon adjustments, or low carbon markets, are best implemented at a UK, EU, and global level to minimise distortions in competitiveness. Nevertheless, the Scottish Government can play a key role in accelerating industrial decarbonisation, potentially improving Scottish competitiveness in the process. Three areas in particular, which the Scottish Government can focus on to complement market-based mechanisms, are:

- *Provision of low-cost capital.* Given energy efficiency measures, although net present value (NPV) positive, typically do not achieve the required rate of return for industrial investment, and public support is often required. The Programme for Government already makes a commitment to utilise the Scottish National Investment Bank (SNIB) to 'ensure transition to net zero'. We recommend a primary focus of the SNIB, particularly in its early years, is to fund industrial energy efficiency projects. This will allow the SNIB to build up a portfolio of low but steady return projects, build its balance sheet, and provide capital for increasingly large projects. Lessons on how to effectively leverage its limited capital, crowding in private capital, can be drawn from the UK Green Investment Bank (Vivid Economics, 2018).
- *Provision of infrastructure with a public benefit:* CCS involves large risks and requires extensive coordination, which the private sector is unlikely to achieve. For this reason, we recommend public investment in CCS infrastructure, as set out below.
- *Provision of a clear, long-term industrial hydrogen strategy:* As it has become clear that hydrogen use in industry will be necessary, the Scottish Government can play a coordinating role of for hydrogen in the Scottish economy. As set out below, we recommend demonstration, in the 2020s, of industrial hydrogen in Scotland, focussing on industries where this is expected to be the lowest cost decarbonisation option.

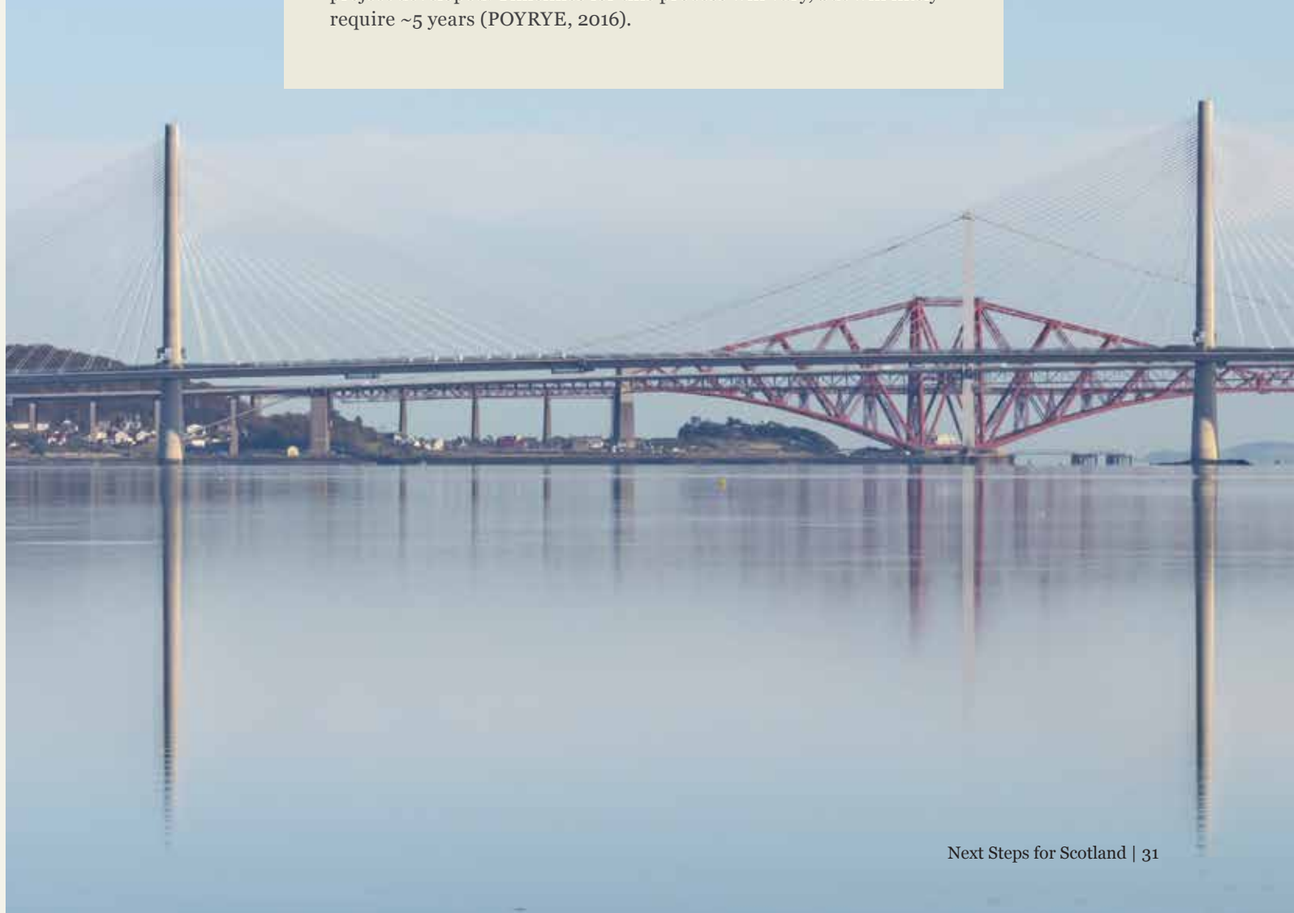
RECOMMENDATION 6: SCOTTISH GOVERNMENT CAPITAL FUNDING SUPPORT FOR THE TRANSPORT AND STORAGE INFRASTRUCTURE TO DELIVER A PROGRAMME OF CCS PROJECTS.

The Scottish Government can drive the development of Scottish CCS by providing capital funding while UK-wide CCS policy is developed. The CCC recommends the development of at least 1 industrial cluster with access to CCS in the UK by 2026 (CCC, 2019a). As set out in Box 4, UK business models are currently under development but are unlikely to incentivise private investment to deploy CCS at scale by 2026 without further government support. Possibly using a public company as a vehicle, the Scottish Government can drive investment in CCS in Scotland, and can help support a project such as Acorn become the first large-scale CCS site in the UK.

PHOTO BY DAVID / ADOBE

Box 6 UK development of CCUS business models

- The UK Government is currently consulting on potential CCUS business models across power, industry, hydrogen production and CO2 transport and storage (BEIS, 2019).
- Emerging findings from ongoing UK Government work on CCUS business models suggest business models for CO2 capture (e.g. a contract for difference) are likely to be split from business models in transport and storage (likely to follow a regulated asset base model).
- Following the consultation, BEIS will work to develop CCUS business models and their implementation including the regulatory framework etc. Considering similar processes in the past, this will likely take ~2 years before the required structures are in place.
- Once these frameworks are in place, CCS business models will need to developed or adjusted to reflect the framework, investors found, and the project developed. Timelines for this process will vary, but will likely require ~5 years (POYRYE, 2016).



The capital investment required in CCS in Scotland is significant, but the Scottish Government could recoup its initial support as UK-wide business models are put in place. While projects such as Acorn can leverage existing oil and gas infrastructure, capital costs are still significant. To give an indication, the capital investment for the offshore transport and store infrastructure for the Acorn project is expected to be approximately £180 million (ACT Acorn, 2019). The initial investment in Feeder 10 and associated onshore CO2 networks is likely to be in the order of £170 million (Brownsort, 2016).[22] To support this investment while a clear revenue model for CCS is lacking, a public interest company, supported by the Scottish Government, could take an equity stake in proposed CCS projects, provide debt investment, or work with the SNIB to develop a tailored financial instrument to leverage private investment as much as possible. By investing through a company, the Scottish Government could recoup the substantial initial investment over time, selling its stake to private actors once UK-wide business models are defined. The early start for Scotland this investment provides is both crucial for its decarbonisation pathway, and can help give Scotland a head start in developing an exportable CCS industry.[23]

Starting the provision of significant capital support now, to ensure the backbone for national CO2 infrastructure is complete by 2030, is essential for a timely scale-up of CCS in Scotland. Private financing for capture plants in Scotland must have an established business model and supply chain to (privately) finance and construct or retrofit multiple capture plants a year. This will require enabling infrastructure to be in place by 2030, with 1-2 scale capture plants connected to demonstrate commercial viability. Aiming for an established full chain project by 2026, and further expansion of the CO2 transport and storage off the back of this, provides a realistic pathway for Scotland to roll out CCS at the required scale for net zero. In the long term, a strategically planned carbon transport and storage network would ensure new Scottish industry (including potential blue hydrogen[24] production) locates with existing CO2 assets in mind, as it would for e.g. access to electricity, for example. Furthermore, it develops the critical infrastructure for Scotland to provide transport and storage for the rest of the UK (and possibly Europe more broadly).

RECOMMENDATION 7: DEVELOP A SCOTTISH INDUSTRIAL HYDROGEN STRATEGY, WITH GRANT SUPPORT FOR DEMONSTRATION AND COMMERCIALISATION PROJECTS.

A Scottish industrial hydrogen strategy should encourage industrial demonstration projects. Achieving net zero implies decarbonising industry more deeply, for which hydrogen is likely to be required. Particularly for industries which require direct firing (e.g. glass and cement production), hydrogen is expected to be the most cost-effective decarbonisation option (CCC, 2019a). Supporting demonstration-scale use of hydrogen, through, for example, grants for on-site electrolyser deployment, in existing Scottish industry will help industry decarbonise while remaining competitive.

Scotland can draw lessons from other European countries. As the move towards net zero policy gathers momentum, European countries are increasingly developing industry specific and economy-wide hydrogen strategies. The Netherlands has perhaps progressed furthest, setting out clear ambitions and policy mechanisms within its Climate Accord. This provides short-term clarity on how existing industrial hydrogen production and use will be decarbonised using CCS (blue hydrogen), and includes a view to transition to green hydrogen production. More broadly, the Accord includes detail on government support for hydrogen (e.g. green hydrogen demonstration projects), and clarity on long term industrial decarbonisation policy (including an industrial carbon tax), allowing local government and business to plan accordingly (Dutch Government, 2019).

22 This includes £79 million to refurbish the Feeder 10 pipeline, £20 million for a connecting network for Grangemouth, and £72 million for a network in the Fife and upper Forth area.

23 Forthcoming work by Vivid Economics suggests that CO_2 transport and storage alone could add £280 million GVA/year to the UK economy. A large proportion of which could be accrued in Scotland.

24 Blue hydrogen production refers to producing hydrogen at scale from natural gas, with CO_2 emissions captured and stored. It is a way to produce low carbon hydrogen.The main alternative is green hydrogen, which produces hydrogen through electrolysis using electricity as an energy source.

LAND USE, LAND USE CHANGE, AND FORESTRY (LULUCF)

Scotland has a comparatively large land area which requires careful land management and restoration to prevent emissions but could also enable significant greenhouse gas removal.

Using land in the best public interest requires a careful balance between competing (private) economic interests and numerous public costs and benefits. Focussing on land use changes required to achieve net zero, there are three key actions for Scotland:

- Increase the role of land as a carbon sink, primarily through large increases in the rates of afforestation and agroforestry;
- reduce the role of land as a carbon source, primarily by maintaining and restoring peatlands; and,
- make land available to produce biomass for use in, for example, BECCS and the production of biofuels for industry and aviation.

Peatland restoration rates need to double, in line with targets in the Climate Change Plan. In 2017/2018, peatland was restored at a rate of 10,000 hectares per annum (ha/a) (Scottish Government, 2018b). This will need to double to 20,000 ha/a to be compatible with a net zero pathway to 2045.[25] Hence, the ambition set out in the Climate Change Plan to increase restoration rates to 20,000 ha/a is broadly appropriate, although may need to increase depending on the precise definition of the new 2030 target to reduce emissions by 75% by 2030.[26] The funding requirement for peatland restoration remains highly uncertain, with a wide range of costs quoted anecdotally, and costs highly dependent on local conditions (SRUC, et al., 2018). However, historic costs of £830/ha in the Peatland Action Scheme suggest a funding need of £16 million per year to reach 20,000 ha/a. Hence, the Programme for Government funding commitment of £14 million for this year may suffice, but may need to be increased in the long run as average costs per hectare are better understood.

25 Based on 1 Mha total peatland restored across the UK in 2050 (CCC, 2019b). Given 60% of UK peatland is in the UK, and assuming restoration efforts are distributed broadly proportionally, this implies an approximate annual restoration rate of 20,000 ha/a in Scotland.

26 If this target is based on the current emissions inventory, 20,000 ha/a is sufficient. If the target is based on the future inventory (including the improved understanding of peatland emissions), restoration rates should increase.

A sizeable area of Scottish land will likely change end use, which will require careful planning to maximise benefits and minimise costs. Scotland already plants trees at a significant rate, 9,000 ha/a in 2018, however this will need to increase to around 16,000 ha/a (on average) to achieve the carbon sink required for Scotland to reach net zero (CCC, 2019b). This implies an increase to the commitment of 12,000 ha/a in 2020 and 15,000 ha/a mentioned in the Programme for Government. Afforestation alone implies around 0.5 Mha of land use change by 2050, in addition to which land will have to be freed up (0.1-0.2 Mha) to provide biomass for BECCS and potentially biofuel for other end uses. In total, around 9% of Scottish land could change its end use. As a comparator, current Scottish cropland is 0.6 Mha and forest cover in Scotland is approximately 1.4 Mha (Scottish Government, 2018b).

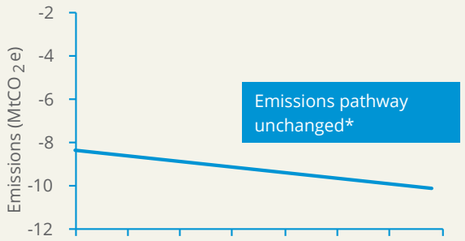
The scale of potential land use change is large and will require careful planning across many stakeholders and levels of government. The recommendations below are hence not an exhaustive list but are intended as key actions relevant to the Scottish Government in addition to those set out in existing Scottish Government plans.

FIGURE 5. LULUCF EMISSIONS AND POLICY OVERVIEW

CURRENT POLICY ASSESSMENT (RELATIVE TO NET ZERO)

RAG rating		
Past policy action	●	Increased action required to meet afforestation and peatland restoration targets, to reach net zero and 90% target
New policy commit-ments	●	Clear long term strategy and increased financial support required

LULUCF EMISSIONS (EXCLUDING PEATLAND)



Note: Current policy assessment: red = significant additional action required; amber = some additional action required; green = little additional action required. Emissions reductions pathway: The sectoral net zero pathway is based on Vivid modelling and compatible with economy wide reductions of 75% by 2030 and net zero by 2045.
* The negative emissions from LULUCF in Scotland have increased relative to previous CCC pathways, however, this is due to changes in the scientific understanding of the CO2 removed by afforestation, rather than increases in planting rates.

Source: Vivid Economics, based on emissions data from the CCC

RECOMMENDATION 8: INCREASE FUNDING FOR AFFORESTATION TO £60-70 MILLION PER YEAR, AND CLOSELY INTEGRATE INTO REGIONAL LAND USE FRAMEWORKS.

Policy recommendations for a net zero path to 2032

Local and regional planning can be aligned with national climate targets by increasing the funding available for afforestation. Regional land use strategies provide a good understanding of opportunities for land use change, and the various co-benefits and trade-offs associated with them. They are essential for managing trade-offs and should be the mechanism by which we identify and facilitate land use management and change, such as woodland expansion, which contribute to sequestration. The devolved approach willneed to be matched financial support from Scottish Government to ensure the required rate of afforestation can be achieved. The main existing grant scheme for afforestation, the Forestry Grant Scheme, will remain in place in its current form until 2024 (Forestry Comission Scotland, 2018).[27] The 2018 budget was £ 46 million, helping to support approximately 9,000 ha of afforestation. The Programme for Government commits an additional £5 million in support; however, it is unlikely a 10% increase in support will unlock an additional 30% of afforestation (the 12,000 ha target for 2020). In the early 2020's the Grant Scheme will likely require £60-70 million per year assuming constant planting costs.[28] We recommend the Scottish Forestry Grant scheme provides this in its current form in the short-to-medium term. However, in the medium-to-long term, alternative funding schemes can be considered. For example, the Woodland Carbon Code (WCC) provides a potential avenue to private sector funding to support afforestation. The Scottish Government, in conjunction with the UK Government, can develop mechanisms to increase private funding flowing through the WCC by, for example, obligating private parties to purchase WCC certificates.

The planned development of a regional land use framework provides an opportunity to develop a national database of afforestation (and other LULUCF) investment opportunities. Detailed land use frameworks can help inform land use trade-offs, between for example, native and non-native afforestation, commercial or non-commercial forestry, etc. To help Scottish Government target funding for forestry, the information from regional frameworks can be collated into a database. For potential forestry businesses, this could be the foundation of a marketplace, providing them with an understanding of the potential (government supported) cashflow from projects. Furthermore, it would enable business and other potential investors (e.g. community groups, NGOs etc.) to target afforestation opportunities with wider co-benefits.

27 The scheme is part of Scottish CAP payments hence some uncertainty remains around future funding arrangements posts Brexit

28 The Scottish Forestry Strategy includes a gradual increase in afforestation to 15,000 ha/a in 2025. This target will need to increase to achieve a net zero consistent planting rate, which implies a need for a significant funding increase.

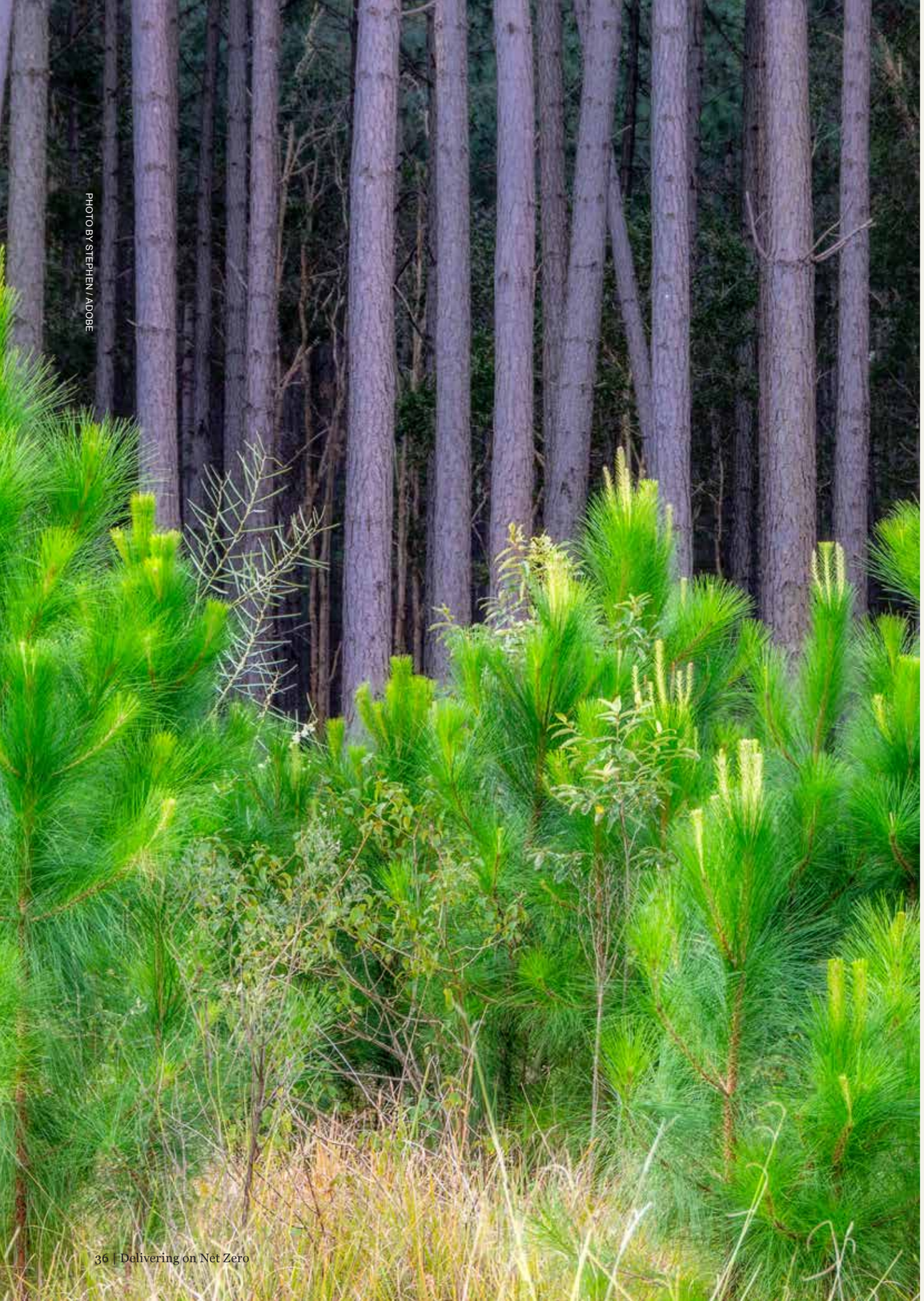


PHOTO BY STEPHEN / ADOBE

Box 7 Regional land use frameworks in Scotland

- Land use involves local actors and has local impacts on e.g. water quality, local flood risk, and the availability of land and forests for recreation, and hence land use strategies are best developed locally/regionally.
- The recent Programme for Government includes a commitment to develop regional land use frameworks, aimed at identifying where 'resource can have the biggest climate impact'.
- The development of regional frameworks has already been piloted in Aberdeenshire and the Scottish Borders. Amongst the pilot outputs are detailed maps, and natural capital accounts (Scottish Borders Council, 2015), providing useful templates on which to build further.
- Detailed regional frameworks provide opportunity to collate a national database of opportunities for land use change (e.g. afforestation), where the value of these opportunities is captured in standardised natural capital accounting frameworks. Furthermore, it would allow Scottish Government to create standardised web-based tools to allow agribusiness to understand the potential revenue streams for various environmental services provided.
- In the long term, such as system may also play a key role in the allocation of agricultural subsidies in Scotland, moving away from the current CAP system towards a system based on payments for ecosystem services.

RECOMMENDATION 9: FUND DEMONSTRATION OF LAND-BASED GGR AT SCALE TO ESTABLISH CO_2 REMOVAL MONITORING PROCESSES, AND UNDERSTAND ENVIRONMENTAL RISKS.

Land-based GGR removal options remain speculative, but can play a significant role in achieving net zero emissions. Speculative land-based GGR techniques, such as soil carbon sequestration, enhanced weathering, and biochar, could contribute around 14 MtCO2 of negative emissions in Scotland, roughly equivalent to total Scottish transport emissions today (Vivid Economics, 2019). While significant uncertainty remains around the viability of these techniques, and their environmental impact, the potential emissions savings are significant. Furthermore, when implemented by farmers and remunerated on a tCO2 basis, they could provide a significant additional revenue stream for the agricultural sector as agricultural production on the land can be maintained. While Scotland may not need land-based GGR to reach net zero, it could 'export' the negative emissions to the rest of the UK.[29]

Demonstration of GGR techniques is needed now, if meaningful scale is to be achieved in the 2040s. To establish credible monitoring of the CO2 removed through speculative GGR techniques, a 5-10-year baseline in the Scottish context is required. A long-term baseline is necessary to establish the rate of CO2 sequestration over time, and ensure long-term environmental impacts (both positive and negative) are well understood. This time frame implies that even if demonstration of these GGR techniques starts now, scale-up could only start from around 2030, with meaningful scale likely to require a further decade. Given these GGR options provide optionality in a Scottish net zero pathway, are potentially cheaper than costly abatement options in 'hard-to-treat' sectors, provide potential export benefits, and can have co-benefits, we recommend a GGR demonstration programme is set up in Scotland.

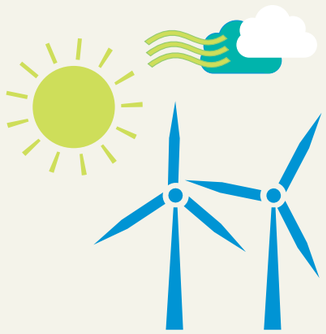
29 This export stream could in the order of £100 million per year in 2045 if Scotland delivers several $MtCO_2$ of negative emissions to the rest of the UK and carbon prices increase as expected to £100 t/CO_2 (Burke, et al., 2019)

PHOTO BY ELLIS FARVEY / UNSPLASH

POWER

Emissions in the power sector do not need to decrease significantly further; however, Scottish renewable generation will need to continue to grow substantially.

By 2035, approximately 175 gigawatts (GW) of new capacity will need to be installed across the UK of which approximately 80 GW will be wind (Vivid Economics, 2019). Scotland is well placed to capture a large share of UK-wide wind deployment, given its excellent wind resource. The recent growth rates in renewable generation are sufficient to deliver a zero-compatible power system in Scotland (Vivid Economics, 2019), and provide an avenue to continue to export electricity to the rest of the UK. While renewable costs continue to decrease substantially, as demonstrated by the latest contract for difference auction (AR3), sustaining recent growth rates will likely require continued support for offshore wind generation, potentially renewed support for onshore wind generation, continued investment in transmission and distribution (T&D) networks, and increased investment in balancing technologies such as batteries and demand-side response.



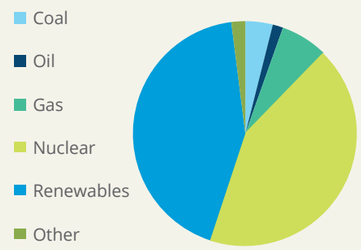
Substantial policy reform in the power sector will be required; however, this will primarily rely on action from the UK Government, National Grid, and Ofgem. A key feature of the future electricity system will be significantly increased variability of generation. The electricity market will need to be partially redesigned to adequately reward flexibility and incentivise the provision of storage and demand-side response. Similarly, transmission and distribution infrastructure will need to be built out to accommodate both increased generation and variability. The Scottish Government can work with relevant BEIS, National Grid, Ofgem, and other UK institutions; however, these changes will primarily be determined at the UK rather than Scottish level.

FIGURE 6. POWER EMISSIONS AND POLICY OVERVIEW

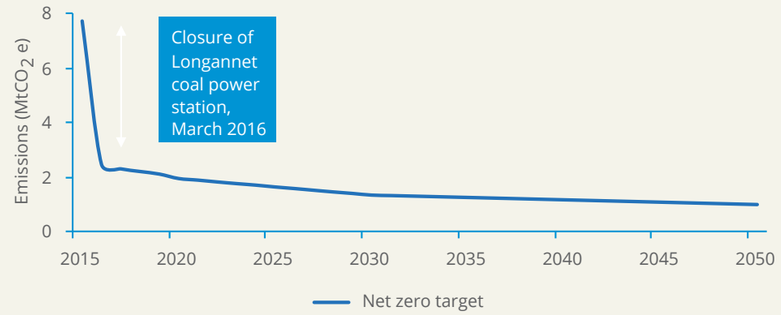
CURRENT POLICY ASSESSMENT (RELATIVE TO NET ZERO)

RAG rating	
Past policy action	Policy on track to reach 90% and net zero target
New policy commit-ments	Design a long term infrastructure plan

CURRENT GENERATION MATRIX TWH



EMISSIONS REDUCTIONS PATHWAY AND KEY COMPONENTS



Note: Current policy assessment: red = significant additional action required; amber = some additional action required; green = little additional action required. Emissions reductions pathway: The sectoral net zero pathway is based on Vivid modelling and compatible with economy wide reductions of 75% by 2030 and net zero by 2045.

Source: Vivid Economics, based on emissions data from the CCC

Nevertheless, the Scottish Government can work with UK institutions to ensure a continued low carbon transition, overall expansion of the Scottish power sector, and focus on Scotland-specific opportunities. The Programme for Government indicates a policy statement will be developed for offshore wind, to complement the existing onshore wind policy statement. The Scottish Government should ensure that jointly these statements continue to provide clear business models for wind developers in Scotland, and devolved powers which impact the route to market, such as planning permissions, will be effectively used in the long term. In addition to clarity for developers of new generators (mostly wind farms), clarity for more niche business models and decisions which will become increasingly important. This includes repowering and decommissioning, and the development of business models which link wind energy generation to hydrogen production, for instance, hydrogen production will be required. For example, Scottish Government could support power purchasing agreements between electrolysers and wind farms.

AGRICULTURE

Scottish agricultural emissions need to decrease significantly faster than current targets. Emissions in agriculture have declined slowly in recent years, and the agricultural share of total emissions has increased from 12% in 2006 to 20% in 2016 (CCC, 2018).

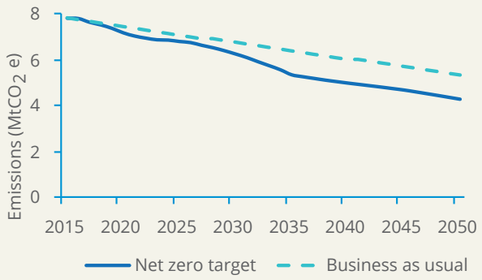
As part of the Climate Change Plan (CCP), Scotland aims to reduce agricultural emissions by 9% from 2018 to 2032 (CCC, 2019b). However, as shown in Figure 7, to avoid requiring rapid declines in the 2030s, emissions would need to be reduced by around 17% in 2032 and by 37% in 2045 (from the 2018 level) to reach net zero in 2045.

FIGURE 7. AGRICULTURE EMISSIONS AND POLICY OVERVIEW

CURRENT POLICY ASSESSMENT (RELATIVE TO NET ZERO)

RAG rating		
Past policy action		Limited action and slow reductions, insufficient toreach 90% and net zero target
New policy commit-ments		Significant action required to achieve long term reductions

EMISSIONS REDUCTIONS PATHWAY



Note:
Current policy assessment: red = significant additional action required; amber = some additional action required; green = little additional action required. Emissions reductions pathway: The sectoral net zero pathway is based on Vivid modelling and compatible with economy wide reductions of 75% by 2030 and net zero by 2045. The business as usual modelling assumes linear change with a slope equal to average reductions between 2000 and 2016.

Source:
Vivid Economics, based on emissions data from the CCC

Public payments for public goods in the agricultural sector is the key policy to support agricultural decarbonisation. Brexit implies payments from the EU's common agricultural policy (CAP) will change. Current policy commits the Scottish Government to providing payments as per the CAP until 2024 to provide stability (Scottish Government, 2018e). However, beyond this rural funding transition period, there is an opportunity to structure funding to incentivise farmers to improve environmental and climate outcomes (CCC, 2019b).

During the rural funding transition period, a ramp-up in emission reduction is required to reach emission targets, and the Scottish Government can help to support action now. In line with the structure of current CAP payments, payments for public goods to farmers are likely to supplement yearly income and hence most naturally support the delivery of public goods through repeated processes (e.g. introduction of precision farming measures). In expectation of a policy which will incentivise mitigation measures with large operational expenditure, the proposed Agricultural Transformation Programme should focus on opportunities which require significant capital investment in the short term, acting as a well resourced Agriculture Modernisation Fund. This could include: development and dissemination of carbon auditing (e.g. AgRE Calc, Cool Farm Tool), nutrient budgeting and farm sustainability tools to support decision making, and investment in institutions to deliver advisory and skills support at farm level.

PHOTO BY DAN SMEDLEY ON UNSPLASH

METHODOLOGY NOTE

To formulate the policy recommendations in this report, Vivid Economics followed the following methodology:

- For each sector, a pathway to net zero was established. This pathway is based on previous work in our *A Climate of Possibility*[30] report. Vivid's pathways were cross-checked against the CCC's recent net zero scenario for Scottish emissions in 2050 (this is net negative in 2050, and compatible with net zero in 2045).
    - Note, the sectoral pathways are consistent with a 75% GHG emission reduction using the *current* accounting methodology. This implies they cumulatively are equivalent to approximately 69% reduction by 2030 in the future inventory (which account for peatland emissions)[31]. Depending on how the new 75% target in 2030 is measured, this implies sectoral emissions reductions may need to be more aggressive than implied by the pathways in this report.
- Based on current sectoral emissions breakdown, and historic emission reductions, the key areas of focus for emissions reductions were identified (e.g. road transport within the wider transport sector).
- Within these areas of focus, the average annual take-up rates of key technologies required to each net zero by 2045 were calculated and compared against historic trends. This allowed for the identification of key areas where significant ramp-ups are required (e.g. heat pump deployment).
- Potential policy interventions are considered based on 2-3 international case studies per sector, and a brief literature review.
- Based on the literature and international example, policy recommendations were formulated, focussing on key policy mechanisms required irrespective of the distribution of powers between Scotland and the UK.
- The policy recommendations were then tested against whether required powers are devolved or reserved to Westminster.
- Final policy recommendations were formulated based on the above and tested with experts through ~2 interviews per sector.

30 https://www.vivideconomics.com/casestudy/a-climate-of-possibility/

31 Based on a letter to the Letter to Environment, Climate Change and Land Reform Committee from the CCC. Available from: https://www.theccc.org.uk/publication/ccc-long-term-targets-report-letter-to-environment-climate-change-and-land-reform-committee/

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2045

Reaching net zero climate emissions by 2045 means quickly implementing new policy actions and funding support

2X

a doubling of energy efficiency funding is required, alongside increased funding for renewable heating

£60-70M

Funding for afforestation should be increased to at least £60-70m per year, to achieve increased planting targets

BY 2030

Net zero emission zones regulated in Scotland's cities, driving low carbon vehicles, public transport and walking