Farming for 1.5°

Independent inquiry on farming and climate change in Scotland

A transformation pathway

NOURISH SCOTLAND

NFU Scotland

THE PANEL

Co-chairs

Nigel Miller is a graduate of the Royal Dick School of Veterinary Studies and farms in the Scottish Borders. He is a past chair of FWAG Scotland and was NFU Scotland President during the last CAP Reform. He has been a board member of SRUC and SAC Commercial and today is a board member of the Moredun Research Institute and Chair of Livestock Health Scotland.

Mike Robinson is the Chief Executive of the Royal Scottish Geographical Society (RSGS). Previously he worked with RSPB and Head of Marketing and with the Royal Botanic Gardens. Mike has held more than forty board/advisory roles, including as previous Chair of Stop Climate Chaos Scotland (SCCS). He is a member of the Arctic Strategy Forum & Perth City Development Board & is heavily involved in promoting climate change solutions.

Panel members

Andrew Barbour runs a livestock enterprise with his wife and family in Highland Perthshire. He also has experience in forestry, deer management and aquaculture. He was recently Acting chair of the Deer Working Group.

Russell Brown runs an arable enterprise in partnership with his wife and family in Fife and Perthshire. Russell has been the Chairman of NFUS potato working group and is currently the Chairman of the Scottish Potato Co-op.

Robert Fleming is a livestock farmer in South-West Scotland. Robert sits on the Simplification Taskforce for Scottish Government for CAP reform. He was a former member of the Scottish Cattle Industry Group (SCIG) for QMS, was the host farmer for Agrii's first Forage iFarm and is a 2015 Nuffield Scholar.

Sheila George is the Food and Environment Policy Officer at WWF Scotland. For the last decade she has worked in the NGO sector on landscape-scale conservation delivery, nature-based solutions, land-use and environment policy.

Deborah J. Long is Chief Officer at Scottish Environment LINK, the umbrella organisation for Scotland's environmental charities. Deborah was director of Plantlife in Scotland and ran a Europe-wide project on sustainable food growing.

Dave Reay is Executive Director at the Edinburgh Centre for Carbon Innovation, Professor of Carbon Management at the University of Edinburgh and Director of Policy at ClimateXChange. Dave is an advisor for the Scottish Government on rural policy and climate change and his latest project involves managing his farm on the West Coast of Scotland to sequester a lifetime's carbon emissions.

Pete Ritchie is Executive Director of Nourish Scotland, which he co-founded in 2013. He also runs Whitmuir Organics with his wife and is a trustee of the Food Ethics Council. Pete is a first-generation farmer and was previously founder and director of Scottish Human Services.

Geoff Simm is Director of the Global Academy of Agriculture and Food Security at the University of Edinburgh. Geoff's research is in sustainable farm animal breeding and sustainable agri-food systems. He is a Fellow of the Royal Agricultural Societies and a Fellow of the Royal Society of Biology.

Sarah Skerratt is the Director of Programmes at the Royal Society of Edinburgh. Previously she was Professor of Rural Society and Policy Director of Policy Engagement at Scotland's Rural College (SRUC).

Philip Sleigh farms in partnership with his wife, in the North East of Scotland. Their enterprise includes crops and pigs. He is a past board member of NFUS and currently sits on the boards of Scottish Pig Producers and QMS.

John Smith and his wife run a herd of pedigree Holsteins rearing replacements and some dairy beef on the Kintyre peninsula. John is a past chair of Scottish Association of Young Farmers Clubs and more recently spent 7 years on NFUS board of directors chairing the legal and technical committee for 5 years and the Milk Committee for 2 years.

Steven Thomson is a Senior Agricultural Economist at SRUC with particular experience in agricultural and rural policy analysis and has been involved in assessing agricultural change, particularly in reference to the Common Agricultural Policy (CAP), for a number of years.

Secretariat

Keesje Avis is clerk of the Farming 1.5 Inquiry, employed by Nourish Scotland. Over the last 18 years she has worked on agricultural and climate change policy from the local to the international level. She and her husband run a climate friendly smallholding and rural business in Perthshire.

Ruth Taylor is the Climate Change Policy Manager at NFU Scotland. Before joining NFU Scotland, Ruth worked at the Scottish Parliament on environment and rural affairs policy.

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EXECUTIVE SUMMARY

Everyone and every sector must deliver on Scotland's climate change ambition to be net zero by 2045, at the latest, and to support nature's recovery. Farming, uniquely, has the opportunity to not just improve its own performance by reducing emissions from agricultural activity, but to impact positively on wider societal emissions through good soil and land management, by locking up carbon in trees and soil, and by supporting ecosystems. Without the engagement of the agricultural community, with its ability to absorb emissions and not just cut them, it will be impossible for Scotland to deliver against its targets. This engagement must have political and financial recognition.

The more that emissions from farming can be reduced, the less agricultural land is needed to offset its residual emissions and the more is available to offset historic and other unavoidable emissions from the Scottish economy (or the rest of the world). If the industry embraces this opportunity and accepts the challenge, it will be able to claim a progressive central role and be seen to be offering leadership in a field in which it has – until now – been seen to be a reluctant player.

The risk of climate inaction has especial significance for farmers as they stand on the front line of the impacts of intense weather events, unreliable weather patterns and rising temperatures both on their produce, but also on their infrastructure. By acting now, the industry can make itself more resilient to these impacts as well as contribute to the needs of urban areas at risk of flooding and heat stress.

At this critical global juncture for climate change, as the world turns its attention to Glasgow for the UN's Climate Change COP next year, the choice is a stark one. Decisions now and for the next few years are pivotal. Does the sector choose to portray itself as a climate change victim or villain, or is it ready to embrace its role as a champion of positive and responsible action?

The Farming for 1.5°C Inquiry has brought together farmers, practitioners, scientists, researchers, environmentalists, policy experts and campaigners. They have been charged with finding consensus on a path to net zero for Scottish farming that still delivers a robust industry, that is integral to the culture, nature and prosperity of Scotland.

The inquiry explored and identified key expertise and advice; and with their collective experience, tested the practicality and applicability of current and future measures. The inquiry aims to recommend appropriate adoptable action in the short term; identify system changes in the medium term and to outline longer-term land use changes. This is to help deliver a holistic net-zero pathway and to identify how government and others need to support the industry to become the champion of climate change that Scotland needs.

This is a heavy responsibility on farmers, farm managers and crofters. Firstly, they need to revolutionise current practices to reduce agriculture's impacts on the climate, and maximise sequestration through changes to management practices, to reduce the need for a complete land use change. The "pay back" for pushing management standards will be the space to farm.

Secondly, a positive attitude towards the multi-use of land needs to become the norm so as to sequester carbon and build biodiversity. These 'multi-functional' land uses include integrating agroforestry and agroecology, using wetlands as part of natural flood protection networks and building long term multispecies pastures, and restoring peatlands to keep carbon in the soil and

boost biodiversity. Planting trees also has an important role – as farm woodlands, hedges and shelter belts as well as larger blocks of forestry.

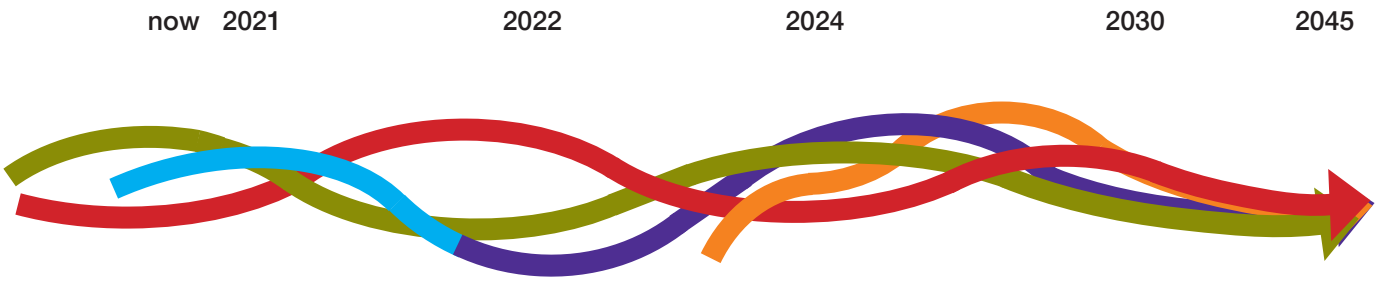
Together these two themes of practice and attitude change can support sustainable land use and food production, create space for sequestration and nature and provide management outcomes to protect and build biodiversity and underpin rural economy and communities. Yet these changes require robust, long term commitments in energy, land, time and money. Historically, agricultural policy has changed on 5-year cycles. As climate change requires long term solutions, agricultural policy will need to provide a longer-term stable roadmap, until at least 2035, to give confidence to the industry that their decisions today will still be policy relevant in the future. This needs to be aligned with long term visions for the associated auditing and monitoring systems that can keep pace with the changes.

These themes support five phases that make up the transformation pathway. This report sets out three sequential phases that build on the foundations of the previous interventions (Phases 1 to 3). Alongside this runs two further non sequential phases of whole farm and land use change (Phases 4 and 5).

The early phases use existing delivery and support vehicles and include baseline data collection, which will need consistent updating to reflect changing action, science and context. Phases 2 and 3 in particular are interlinked as best practice is first extended across farming practices (Phase 2) and then ramped up to maximise greenhouse gas reductions using contracts (Phase 3).

These are supported by wholescale change in farming advice, training and knowledge development throughout. Phases 4 and 5 support greater sequestration and biodiversity across Scottish farmland. Some farmers may choose to start this journey from day 1, while for others it is driven by requirements under Phase 3 so is built into their medium and long-term planning. Further detail will be provided in our next report.

The transformation pathway phases



Phase 1: Culture change

Phase 2: A farmer's mitigation menu

Phase 3: System change to low emission production

Phase 4: Whole farm change

Phase 5: Land-use change

The inquiry proposes an emissions reduction plus sequestration pathway, with targets and whole farm plans of action for each of the three key greenhouse gases. It is only by capping and reducing these gases that a holistic reduction in agricultural emissions will be seen.

These changes collectively represent as great a change to Scottish farming within a generation as the change from horses to tractors. They can and must be achieved fairly. Farmers who want to play their part in this transformation can and must have profitable businesses and good livelihoods if Scotland is to have a just transition to net zero.

The key principles for Scottish agricultural transformation are

1 Everyone needs to play their part, including all farmers, land managers and rural businesses, agricultural suppliers and buyers. Scottish farmers have the opportunity to be the champions and not the victims of climate change. As an industry, agriculture needs to be ambitious in its aims to meet net-zero milestones.

2 This wholescale change should be supported with the creation of a Transformation Steering Group, with high level representation from across government departments, key stakeholders, including working farmers, and scientists.

3 A new approach to knowledge sharing and technical support is a key priority.

4 Identifying and enthusing industry leaders, influencers, and innovators coupled with a communication strategy to reach all farmers will speed up change.

5 There needs to be political and technical clarity about what is expected of Scotland's agricultural land and businesses outside of agriculture's own need to reach net zero.

6 Emissions should be reduced through improving agricultural and carbon efficiency with better soil management at its core, coupled with national capping and on farm reduction targets for each of the three key greenhouse gases.

7 An immediate ceiling on agricultural biogenic methane emissions should be set, with decreasing targets with an aim of at least 30% reduction by 2045 compared to today. Improvements in animal health across all sectors and farm sizes, advances in nutrition including the use of feed additives and the development of ruminant genetics have the potential to drive significant reductions in enteric methane. Additionally, the proposed support for low-intensity high nature value grazing systems will result in a further reduction of enteric emissions from the national herd. Progress towards methane reduction targets however can only be safeguarded by managing the total ruminant population. Population growth can negate the value of management interventions and system change.

8 Better nitrogen management is key in tackling excess nitrogen which is producing greenhouse gases, harming ecosystems and costing farmers money. Nitrogen use efficiency must be more heavily weighted in determining both crop requirements and application strategies.

9 Integrating renewable energy with developing technologies to reduce fossil fuel use needs to be supported by rural infrastructure improvements in energy and communications such as broadband and mobile data coverage.

10 Rural policy, including subsidies, advice and regulation need urgent reform to prioritise (re) building biodiversity, alongside targeting greenhouse gas reductions and sequestration, taking account of regional habitat priorities. Better soil carbon management will drive biological activity creating a foundation for biodiversity above ground. This will support both climate and biodiversity targets.

11 A whole farm approach should be adopted to provide a realistic pathway for change and to incentivise the adoption of best practice in production systems, soil carbon management, land-use and renewable energy technology.

12 The change pathway should provide positive system options for all farmers, crofters and land managers and safe-guard rural communities and the food economy.

13 Innovative approaches to multifunctional land use such as agroforestry will add value across a range of priorities.

14 Land use change and sequestration should reflect soil type, topography and both production and biodiversity priorities for the farmer, the locality and Scotland. Regional Land Use Partnerships will have a core role to play in ensuring this. As such their membership must reflect the local community including land managers, farmers and crofters; and the process have roots in the rural community's activities.

15 We need adoption, practical demonstrations, and pilots established as soon as possible to test and explore each of these key principles.

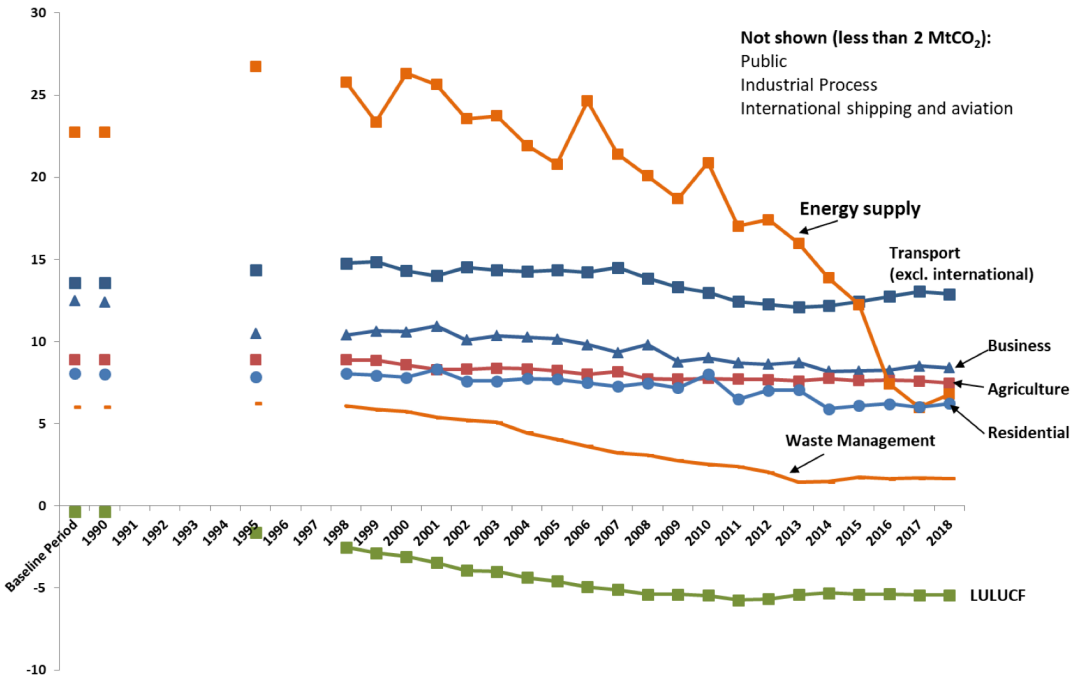
Limiting climate change and restoring nature is essential for human prosperity and equity and underpins a thriving farming sector. Maintaining a healthy planet for future generations is the crucial challenge of the century.

THE CONTEXT

Climate change is a real threat to life as we know it in Scotland. Global temperatures have already risen to 1°C[1] above pre-industrial levels with more extreme events occurring more frequently both at home and abroad. This year alone Scotland has witnessed floods, storms and drought putting Scottish businesses and people at immediate and longer-term risk as previously reliable seasons and weather patterns are no longer dependable. The UK and Scottish Governments have recognised that action must be taken. In 2015, the UK signed the Paris Agreement agreeing to "pursue efforts"[2] to keep warming to "well below" 2°C – aiming to stop at 1.5°C. In the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 Scotland committed to reach net zero by 2045.

Further interim targets are laid out in the legislation with greenhouse gas emissions reductions of at least 54% by 2020[3], 75% by 2030 and 90% by 2040. However, despite reductions across nearly all sectors and particularly large decreases of 70% in energy supply and 72% in waste management, Scotland did not meet its 2020 target[4]. Current policies are not sufficient. Bolder action is needed by

Chart B2. Main Sources of Greenhouse Gas Emissions in Scotland, 1990 to 2018. Values in $MtCO_2e$



[1] European Environment Agency (2020) Global average near surface temperatures relative to the preindustrial period. Accessed 24/09/20 https://www.eea.europa.eu/data-and-maps/daviz/global-average-air-temperature-anomalies-5#tab-dashboard-02

[2] UNFCCC (2020) What is the Paris Agreement? Accessed 24/09/20 https://unfccc.int/process-and-meetings/the-paris-agreement/what-is-the-paris-agreement

[3] Progress towards the targets is measured against 1990 levels of carbon dioxide, methane and nitrous oxide and 1995 levels of hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride and nitrogen trifluoride.

[4] https://www.gov.scot/publications/scottish-greenhouse-gas-emissions-2018/pages/1/

everyone and especially those sectors who have taken the least action. Agriculture has a key role to play. The industry must embrace the challenge, but it needs helps to do so.

The Agriculture[5] sector of the greenhouse gas inventory is the third largest source of emissions[6] in Scotland at 7.5 MtCO2e[7] or 18% of total emissions. If agriculture-related land use changes are also included this rises substantially. There has been a 16% fall in Agriculture sector emissions since 1990, but very little of this has been in the last decade and a much smaller reduction than most other sectors. This has been due to the complexity of the science, a lack of concerted political leadership, marginal profitability in some sectors and little public or private financial targeting. Now, with the right combination of support and knowledge both within and outside the industry, Scottish agriculture can make needed strides in contributing to reaching net zero.

At the same time, Scottish and world nature is under threat. The UN's fifth edition of the Global Biodiversity Outlook report[8] states that "Humanity stands at a crossroads with regard to the legacy it leaves to future generations. Biodiversity is declining at an unprecedented rate, and the pressures driving this decline are intensifying." It goes on to name food and agricultural production in particular is one of the main drivers of global biodiversity loss. The State of Nature Scotland report shows that nature is changing rapidly with 62% of species showing strong changes[9]. Recognising the continuing loss of biodiversity, the Scottish government recently signed the Edinburgh Declaration on post-2020 global biodiversity framework stating that they are "deeply concerned about the significant implications that the loss of biodiversity and climate change has on our livelihood and communities"[10].

The picture on the ground is 67 000 people who are directly employed on farm and engaged in their local communities across the beautiful, and sometimes harsh, Scottish landscape. This diversity of farmers, crofters and rural communities have strong attachments to their farming history, the land and the food they produce. This includes those who have already committed to farming with nature and with climate change in mind, many of whom feel that their actions are not sufficiently captured by the data or remembered in policy.

[5] The "Agriculture" sector under the UNFCCC reporting mechanism includes emissions from livestock, agricultural soils, stationary combustion sources and off-road machinery but excludes carbon stock changes which are included in the LULUCF sector

[6] Scottish Government (2020) Scottish Greenhouse Gas Emissions 2018 available at https://www.gov.scot/binaries/content/documents/govscot/publications/statistics/2020/06/scottish-greenhouse-gas-emissions-2018/documents/scottish-greenhouse-gas-emissions-2018/scottish-greenhouse-gas-emissions-2018/govscot%3Adocument/scottish-greenhouse-gas-emissions-2018.pdf

[7] Million tonnes Carbon Dioxide equivalent

[8] https://www.cbd.int/gbo/gbo5/publication/gbo-5-spm-en.pdf

[9] https://www.cbd.int/doc/nr/nr-06/gb-nr-06-p2-en.pdf

[10] https://www.gov.scot/publications/edinburgh-declaration-on-post-2020-biodiversity-framework/

THE INQUIRY AND THE PRINCIPLES UNDERPINNING THE TRANSFORMATION PATHWAY

Farming for 1.5°C is an independent inquiry, sponsored by Nourish Scotland and the National Farmers Union of Scotland. The panel is innovative in its diversity of expertise of farmers, scientists, environmental non-governmental organisations; and approach, as it seeks consensus on a positive transformation pathway to 2045 for Scottish farming and food production, while safeguarding communities, biodiversity and landscapes. The goal is to recommend a partnership between Scottish Government and the farming community that underpins a dynamic mixed farming economy, delivering significant emission reductions and sequestration, making space for farming, biodiversity and a vibrant rural economy.

The panel has received evidence since mid 2019, to produce recommendations that build on immediately available management options while including developing science and technology. This positive pathway needs to capture the support and energy of those working on the ground across diverse approaches to land use, with the potential to evolve in light of experience and new science.

The following principles have been key to informing the recommended transformation pathway.

1 Everyone needs to play their part, including all farmers, land managers and rural businesses, agricultural suppliers and buyers. Scottish farmers have the opportunity to be the champions and not the victims of climate change. As an industry agriculture needs to be ambitious in its aims to meet net-zero milestones.

The transition of Scottish agriculture to net zero will take much more than mere tweaking current voluntary 'Greening' or paying for on-farm carbon accounting. The development of these tools to be used by all farmers is a first step and is included in the panel's recommendations, but a wide-ranging, deeper, longer-term commitment with visible leadership by government and the farming industry is needed to power the transition to a net-zero future. This transition needs to be supported with policy alignment across all departments, including research prioritisation; informed by social change science; underpinned by tailored advice and adequately financed.

2 This wholescale change should be supported with the creation of a Transformation Steering Group, with high level government representation from across government departments, key stakeholders and scientists including ties with the Rural Land Use Framework and their Partnerships.

The change pathway must link into both the science and the farming communities, with mechanisms to allow the change process to flex to reflect new science, technology, and the development of on farm techniques, practices and culture. The Transformation Steering Group can provide a long-term overview and thus stability to ensure industry commitments that arise from policy commitments in the short term, have long term validity.

3 A new approach to knowledge sharing, and technical support is a key priority; an approach that generates culture change, prioritises community networks, and provides one to one support at several levels.

Change is not easy and places a heavy weight on producers and managers. It is important that farmers have the financial and moral support to buy-in to the process of developing a transformation plan, contributing to the agenda and adding value. This requires a retraining of the trainers, with climate change and biodiversity core to their knowledge.

The size of the issue at hand means that knowledge needs to flow in all directions between farmers, policy makers, scientists and communities. Equally this pathway should be kept under continuous review as technology, understanding and practice changes.

4 Identifying and enthusing industry leaders, influencers and innovators, will speed up change if coupled with an in depth and diverse and sufficiently resourced communication strategy to reach all farmers.

5 There needs to be political and technical clarity about what is expected of Scotland's agricultural land and businesses in terms of sequestration targets, outside of agriculture's own need to reach net zero.

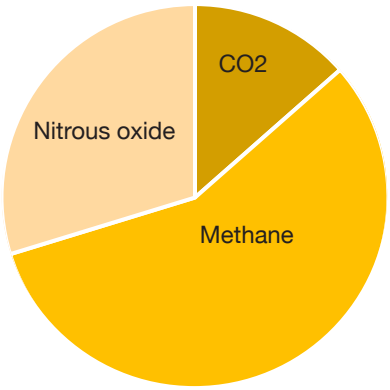
It is not clear whether the sequestration potential on agricultural land is to offset other industries such as aviation and fossil fuels, to offset that farm's emissions or to sequester carbon from historic emissions. It is absolutely essential that the sequestration potential is not double, or triple counted. If it is to offset residual emissions from outside agriculture, they should be paid for by the emissions-producing industries using the Woodland Carbon code, Peatland Carbon code or future carbon credit schemes.

6 Agricultural emissions cannot be simply offset through land-use change. Nor will agricultural emissions reduce to zero. There needs to be a combination of strong effort on both fronts.

Improving agricultural and greenhouse gas efficiency across Scotland has many benefits, including less inherent waste of energy and resources on farm and higher returns for the producer. Better policy, technological and management interventions will improve the carbon intensity per unit of output, allowing for limits due to climatic and biophysical challenges. However, because of the scale of the climate emergency, best practice that improves carbon intensity per unit of product must only be a ramp to overall emissions reductions on-farm and nationwide so as to avoid more painful choices in the future.

Progress on reducing emissions should be made at two levels:

- Greenhouse gas efficiency must be maximised of both the production systems and the whole farm business, underpinned and audited by a standardised calculator where each of the greenhouse gas emissions are broken down to source.



Mix of greenhouse gases emitted by agriculture in Scotland

- At a national level there should be reduction targets for each of the three key greenhouse gases. This is then translated to farm level through greenhouse gas contracts that define management intervention packages, taking into account the other principles highlighted.

In order to support better farmer understanding and in turn appropriate on-farm management, that in turn results in a reduction in national emissions, methane and nitrous oxide should be managed separately, rather than always reduced to carbon dioxide equivalents (CO_2e).

7 Methane can, and must, be reduced from Scottish livestock. This should include deer, including wild deer, as they are also ruminants.

Agriculture is the largest source of methane emissions in Scotland and it is a powerful greenhouse gas. Due to its short (~10 years) life in the atmosphere, the reduction of methane can contribute to reduced human-induced warming (relative to the enhanced warming caused by current methane emissions)[11]. Following evidence from the team at Oxford university, this difference in behaviour in the atmosphere of methane has led the panel recommend there is detailed examination on methane emissions, and considerations how its true global warming potential are imbedded in national policy and on farm actions – according to GWP*. This is to ensure appropriate understanding and action on farm leads to national target achievement and thus meets international requirements. The panel emphasizes that without significant reductions in methane emissions, Scotland (and the rest of the developed world) would need to hit net-zero carbon dioxide emissions around a decade earlier than planned - so by the mid 2030s - to still have a good chance of aligning with the Paris climate goals.

Much climate change and agriculture policy has been based on the outcomes of Marginal Abatement Cost Curves (MACCs), which use the carbon equivalence metric. Due to the point above, we are recommending that these are reworked focusing on methane separately. Specifically, a biogenic methane target for Scotland could then form the emissions envelope for a 'Methane MACC' and help identify least cost mitigation measures that are not distorted by the relatively short atmospheric lifetime of methane. The panel understands the utility of MACCs but would recommend that they are used in conjunction with the latest social science research on human behaviour in determining policy implementation and expected outcomes. It is also crucial that the results take into account the need to both improve the carbon efficiency of a product or farm business and to reduce total greenhouse gas emissions.

There is potential across all Scottish farm types and sizes for significant improvements in animal health. Better animal health can support both reproductive and production performance and optimise population outputs. It is a management factor that underpins carbon efficiency, economic efficiency and welfare and therefore delivers positives for producers, consumers and climate change. Creating and managing high health status flocks and herds is key to realising the benefits of precision nutrition, anti-methanogens and genetic progress. Health status is an important production baseline.

In climate change terms, animal health management impacts at two levels:

- Direct impact on emissions - where interventions achieve the same total farm/system/enterprise output with less input (e.g. through more efficient growth by reducing liver fluke) or through reducing the premature culling of breeding stock, such as due to lameness or reproductive failure.
- Indirect impact on emissions - where health management improves the greenhouse gas intensity of production (kg carbon dioxide equivalent per kg product) but may increase both production and total emissions (e.g. reproductive diseases; neonatal mortality).

Animal health reduces avoidable losses from systems. In some cases, this reduction may be outweighed by the increase in total output but at the very least greenhouse gas emissions intensities improve.

[11] Cain, M., Lynch, J., Allen, M.R. *et al.* Improved calculation of warming-equivalent emissions for short-lived climate pollutants. *npj Clim Atmos Sci* **2,** 29 (2019). https://doi.org/10.1038/s41612-019-0086-4

Clearly there are some cross-linkages but designing health strategies to support climate change targets requires direct and indirect impacts to be taken into account. Studies[12] have indicated a 10% reduction in greenhouse gas emissions is possible by moving to "high health status" flocks and herds. A target of 10% is currently credible, but ill defined.

Up to now, few livestock genetic improvement programmes have directly targeted greenhouse gas emissions. Though there has been an indirect benefit from reduced emission intensities from breeding programmes targeting animal or system productivity or efficiency, there is an opportunity now to maximise Scottish scientific leadership in the development, testing and implementation of climate change breeding indexes. These can directly address reduced emissions, alongside production efficiency and fitness characteristics, and develop new genomic approaches that target rumen microbiome composition and host genetics with a view to reducing methane emissions[13]. Progress has been made[14], particularly in cattle genetic evaluations however the sheep sector should also be a priority.

8 Nitrogen is a fundamental component of productive agricultural systems, and it makes the sky blue. Yet the build-up of reactive nitrogen in the environment represents one of the biggest threats to sustainability of modern time[15]. Reactive nitrogen is one of the most significant threats to global biodiversity[16]; nitrous oxide is now the principal cause of stratospheric ozone depletion; and it has a global warming potential of 298 times that of carbon dioxide[17]. In Scotland opportunities must be taken to tackle excess nitrogen as a climate, nature and health issue in an integrated way and urgently. Due to its importance to agriculture and the threats from nitrogen to the climate and nature, the panel recommends nitrous oxide is singled out, like methane, so that the relationship between on-farm use and its wider implications are better understood and acted upon.

Ammonia is not a greenhouse gas, however its impacts on ecosystems and human health require appropriate management. Ammonia can also indirectly increase nitrous oxide emissions via deposition. Likewise, leached nitrate poses ecosystem and human health risks, but can also result in nitrous oxide emissions. Measures to address greenhouse gas emissions in agriculture should therefore be informed by the pollution swapping risks posed by reactive nitrogen (e.g. slurry management to reduce methane resulting in increased ammonia emissions and vice versa).

9 Direct carbon dioxide emissions from agriculture are dominated by transport and heavy machinery, while soil carbon emissions are reflected in the Land Use, Land Use Change and Forestry sector (LULUCF) emissions sector. The electrification of on-farm machinery and optimising its use through precision farming can be cleverly integrated with on-farm renewable energy production to reduce direct carbon dioxide emissions. Improvements in on-farm fossil fuel use need to be reflected in their reporting.

[12] Skuce P.J., Bartley D.J., Zadoks R.N. & MacLeod M. (2016) Livestock Health and Greenhouse Gas Emissions. Climate Exchange. https://www.climatexchange.org.uk/media/2031/livestock_health_and_ghg.pdf

[13] Roehe R, Dewhurst RJ, Duthie CA, Rooke JA, McKain N, et al. (2016) Bovine Host Genetic Variation Influences Rumen Microbial Methane Production with Best Selection Criterion for Low Methane Emitting and Efficiently Feed Converting Hosts Based on Metagenomic Gene Abundance. PLOS Genetics 12(2): e1005846.

[14] Auffret Marc D., Stewart Robert, Dewhurst Richard J., Duthie Carol-Anne, Rooke John A., et al. (2018) Identification, Comparison, and Validation of Robust Rumen Microbial Biomarkers for Methane Emissions Using Diverse Bos Taurus Breeds and Basal Diets. Frontiers in Microbiology: 82642

[15] Rees RM (2020) panel evidence session

[16] Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) 'Models of drivers of biodiversity and ecosystem change'. Accessed 7/9/20

[17] Skiba, UM., & Rees, RM. (2014). Nitrous oxide, climate change and agriculture. CAB Reviews, 9. https://doi.org/10.1079/PAVSNNR20149010

In moving to a new power model for agriculture, clear targets are required to drive technological progress but also to inform investment decisions. Policy must recognise the challenges for small producers and crofters where older machinery, often operating low hours per year, are vital tools. Some form of transition support or conversion to alternatives should be available.

10 Agricultural climate change policy, funding, advice and farmer action all need to prioritise (re)building biodiversity, alongside targeting greenhouse gas reductions and sequestration, taking account of regional habitat priorities. The resilience of Scotland's nature underpins farming now and under future climate scenarios.

Tackling particular emissions such as nitrous oxide and ammonia and supporting diversity through agroforestry integration, will have immediate biodiversity benefits that in turn will support adaptation to the effects of climate change. Rather than a "nice to have", integrated rural and climate change policy must see a healthy and wildlife rich environment and attractive landscapes as vital assets to society and essential for underpinning economic activity such as food production, farming, forestry, agri-tourism and tourism more widely[18].

Changes to regulations, funding and attitudes (regardless of motivation), have implications for the people involved in, living around and supporting Scottish agriculture. The needs and expectations of rural communities need to be taken into account to ensure a just transition to a net-zero future. The creation of Rural Land-Use Partnerships and Frameworks have the potential to positively involve these communities and produce locally appropriate actions. However, care must be taken to ensure they are properly financed and have sufficient authority. It is crucial to ensure alignment with national and international frameworks and priorities.

11 A whole farm approach should be adopted to provide a realistic pathway for change and to incentivise the adoption of best practice in production systems, soil management, biodiversity support, land-use and renewable energy technology.

Agriculture has to refocus from purely production-centred business thinking to understand the broader impacts of its actions but also the untapped opportunities currently on-farm. There is sequestration potential in woodland, hedges and peatlands; sequestration and biodiversity potential in scrub areas, peat moorland, acid grassland, and herb-rich pastures; energy production in on farm renewables and community commitments for employment, recreation and culture. However, internationally agreed climate change audit standards capture agricultural emissions but exclude land use sequestration and renewable energy on agricultural holdings.

Progress on managing and developing both sequestration and biodiversity assets on-farm is a core policy goal and should be audited through a living farm mapping process.

Taking a whole farm approach, as mentioned in the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019, will better foster farmer engagement, resilience and action. This holistic approach needs to be matched in agricultural policy mechanisms, by the support provided by advisors and training and by the way data is managed on-farm and between agencies. At the moment, if farmers improve sequestration on a farm (counted in the LULUCF inventory) or produce renewable energy (counted in the energy inventory), it is not recognised at either the enterprise level through the carbon calculator or at a sectoral level at the national scale. This is a disincentive to act.

[18] 'Renewing Scotland's Rural Areas' Revisited How to transition from the CAP to a new regime of rural support (2020) Scottish Environment LINK Food and Farming Group; https://www.scotlink.org/files/LINK-Future-of-Farming-and-Rural-Land-Management_March2017.pdf

12 The change pathway should provide positive system options for all farmers, crofters and land managers and safe-guard rural communities and the food economy.

Both production centred systems and extensive or low intensity approaches (including High Nature Value systems, organics and other agroecological or regenerative practices) have roles in Scotland future agriculture. They all need to be supported by excellent advice, farmer community groups and opportunities for continuous professional development.

13 Multi-functional land use can add value across a range of priorities.

Agroforestry is one example that can support both biodiversity and improve sequestration value to the agricultural landscape while contributing to agricultural output, but it needs both political and appropriate financial support.

Less intensive farming methods such as organics, agroecology, regenerative farming, pasture for life and high nature value farming all have an important role to play in producing a diverse range of foods, contributing to localisation of food systems, supporting nature and mitigating climate change. These methods need championing at the highest level and seen as part of the solution, rather than merely as an alternative to the norm.

14 Some form of land use change and/or sequestration is required by all and should reflect soil type, topography and production, rural community and biodiversity priorities. A suite of options should be available, including not just woodland creation, but also for example herb rich pasture, thin peat grassland, moorland, peatland, wetland, scrub and agroforestry.

More research and action are needed on permanent grasslands and moorland so that their sequestration potential and current storage capacity is identified[19]. This is not to delay action but to inform it as well as to halt any reductions in current levels. Practices such as surface improvement, direct drilling, zero and minimum tillage, intercropping, rotations, producing more biodiverse swards, and the integration of agroforestry where possible will increase sequestration, biodiversity, resilience and maintain production. Equally stopping carbon loss from these soils is an immediate win.

Tree planting has a role in supporting and developing biodiversity and sequestration. Optimising planting design, species mix, planting/extraction systems, and encouraging a diversity of products is important to secure biodiversity, community and sequestration outcomes. It also has the potential to add economic value to lower quality grazing or scrub land. This has potential benefits for owners, but the panel recognised that there are potential difficulties delivering this on tenanted land. Rural Land Use Frameworks and Partnerships have an important role to play in this.

[19] Miller G (2020) Scottish Environment, Food and Agriculture Research Institutes fellowship Blog – 29 June 2020

RESPONDING TO THE COMMITTEE ON CLIMATE CHANGE

The Committee on Climate Change is the leading UK body dedicated to working out how the UK can reach net zero and they have mapped out targets for agriculture and land use to do so[20]. Their recommendations create a benchmark for both the reduction of emissions and the development of sequestration capacity; changes, which when linked with the decarbonisation of other sectors, will deliver the UK's international climate change obligations. The Climate Change Committee's template uses land use change as a sequestration vehicle to balance emissions from a range of sectors.

Clearly there is a political dimension as to how sequestration obligations are shared across the UK; however, it must be accepted that any alternative transformation pathway must have the potential to deliver the headline reduction in emissions and create significant sequestration capacity to contribute to Scotland and the UK's targets. Scottish agriculture must fulfil the target of meeting net zero by 2045 at the latest.

The foundations of the Committee's recommendations are built on maintaining per capita food production through the intensification and concentration of food production systems on productive land classes and the freeing up of lower grade land for sequestration. That process of freeing up agricultural land is also supported by a projected dietary change away from red meat and dairy products. The UK report indicates that commercial forestry will be the main sequestration vehicle in Scotland which is likely to carry the majority of the projected UK tree planting targets.

The Farming for 1.5°C Inquiry accepts the thrust of the Committee on Climate Change's recommendations and the sign-posted significant reduction of greenhouse gas emissions. There are however significant concerns that the implementation strategy will create a negative impact on the rural economy and fails to protect or build biodiversity. The Land Report indicates that upgrading existing systems through best practice and mitigation measures has the potential to reduce emissions by 20%. In contrast the WWF report indicates potential savings of 38%, and greater ambition to take early wins reduces unwelcome pressure on system and land use changes.

The Committee on Climate Change's Land Use report[21] advises an increase in tree cover from a current 20% of land in Scotland to 30% by 2050 with a further area dedicated to biomass for energy with carbon capture (BECCS). As agricultural land makes up 75% of Scotland, this change in use has massive bearings on farmers and the potential for food production. The panel's interpretation of the Committee on Climate Change's advice is that it provides a simpler quick fix solution, relying heavily on land use change, in particular commercial forestry and BECCS. If action focuses on that alone there would need to be around 15 000ha per year of woodland expansion to 2050 and beyond, around about the equivalent of 25% of Scotland's enclosed land. The panel is concerned that that type and level of land use change will have negative implications for agricultural activity, jobs, rural communities and landscapes without addressing biodiversity goals.

The Farming for 1.5°C Inquiry transformation pathway is weighted differently and diverges from that mapped out by the Committee on Climate Change.

[20] https://www.theccc.org.uk/wp-content/uploads/2020/01/Land-use-Policies-for-a-Net-Zero-UK.pdf
[21] https://www.theccc.org.uk/wp-content/uploads/2020/01/Land-use-Policies-for-a-Net-Zero-UK.pdf

THE TRANSFORMATION PATHWAY

The transformation pathway includes a number of phases – culture change, a mitigation menu that develops into including greenhouse gas contracts, whole farm management change and land use change. Due to the speed at which response is needed, it is crucial to get pilot schemes up and running as soon as possible. These can test and encourage innovative ways of working across different strands of agriculture and constructively learn from the practices that do and don't work, both of which are key to informing a successful post 2024 Scottish agricultural policy. Advice and understanding must equally continue to progress as the science develops and the industry responds.

PHASE 1: CULTURE CHANGE

Approach	Examples	Timeline	Mechanism
Culture Change	Creation of Transformation Steering Group by 2022 Improved baseline data and understanding Soil Carbon Survey as standard in soil testing with advisory support Identification and recruitment of industry innovators and influencers Engagement with teaching and learning facilities and the SAYFC to highlight the opportunities and challenges ahead for our next generation of agricultural employees/managers etc at every level of the industry.	Beginning as soon as possible	Nationwide soil testing programme with first round completed by 2024 Farm Carbon audits of all farms with first round completed by 2024 Farm mapping to be upgraded to capture biodiversity features and sequestration resources on farm by 2024 Support for innovation Retraining of trainers, including development of a Carbon and Nature Accreditation to be further supported by ecological experts. Advisors need to look at identifying trade-offs Establishment of pilots covering each of the principles outlined in this report begun as soon as possible.

Communication and knowledge sharing

The scale of the task at hand demands a fundamental change of direction and ethos from the top to the bottom of Scottish Government and Scottish Agriculture. Farming for a Better Climate and the Climate Change Champions have worked hard to create change but with little relative budget or political enthusiasm, while the Farm Advisory Service was never designed or funded to produce large scale change. Yet, by maximising closer links between and with Scotland's excellent institutions that feeds into more holistic one-to-one training of farmers and land managers, the change required is possible.

Although the Agricultural Productivity Working Group's principal perspective was of improving agricultural productivity, many of their recommendations are relatable in this context. They recommended "defragmenting the landscape of knowledge exchange, providing more opportunities for farmers and growers to learn from the best and facilitating investment in capital, skills, training and continuous professional development[22]."

The communication and knowledge sharing aspect of change management is crucial in not only reaching all who are directly involved on the land, but also in gaining the trust and support for change at farm and croft level, which is critical in meeting climate change targets. The strategy outlined places industry representatives at the centre of prioritising and targeting climate change knowledge sharing budgets.

[22] The Agricultural Productivity Working Group (2020) Food and Drink Sector Council https://www.fdf.org.uk/publicgeneral/APWG-report-feb20.pdf

The priorities include:

- All those involved in land management, regardless of gender and age, including part-time producers and those carrying heavy workloads as solo operators, need to be reached. A significant part of the delivery budget should be inclusive and operate at a local or catchment level, establishing a sustainable network within the community.
- The need to diversify the sources of expertise, opening up new approaches to the climate challenge and learning from farmers experience and expertise.
- The need to involve those in the farming and rural community as facilitators of local transformation groups and to open the opportunity to gain training in farm carbon auditing. This local approach has the potential to add a new level of local support, create trusted long-term relationships and seed informed advocates of change into the rural community.
- Building on existing trusted relationships as a conduit for information and the provision support systems to these professionals. Veterinarians, agronomists, feed merchants and nutritionists may fall into this category.
- The adapting of the Rural Payments and Services' role to include advisory support. Within the organisation there is an existing understanding of the industry and its pressures, agricultural expertise, communication skills and relationships that reach all producers. The organisation can be a powerful driver for change while creating a new culture of partnership across the industry. One to one support is critical if a change culture is to be adopted positively and all producers are to be reached.
- To use the interest and power of industry influencers.

Key to wholescale change is to replace the current Farm Advisory Service with a new model focused on transformation in terms of resource use, carbon and nature across farming. This could be an Education Trust or a Service and would take control of the Knowledge Enhancement budget, bringing a new approach to knowledge sharing that reaches all. The Trust or Service would identify priorities, coordinate and commission knowledge exchanges utilising a range of experts from across the Scottish research institutes and universities. The aims must be to increase understanding as well as to inspire change, feeding off a wider range of expertise.

This new body should also be tasked with establishing and funding farm/croft Community Resource, Carbon and Nature Knowledge groups, supported by a facilitator. These part-discussion, part-change support groups, would act as a bridge to expert advice, to innovators and early adopters and as a vehicle for case studies and pilots to inform the group members and the wider community. These groups should be inclusive at a local or catchment level and meet and communicate in ways that ensure part-time or one-person enterprises are not excluded. The groups may have a social aspect, which will support trusting relationships and the easier transfer of knowledge. Irish research has shown that "dairy farmers with agricultural education or who participate in farmer discussion groups are more likely to adopt the mitigation practice of extended grazing" highlighting the "urgent requirement for a stronger link between research and knowledge transfer to encourage practice change and the adoption of mitigation measures."[23]

[23] Lanigan GJ, Donnellan T et al (2019) An Analysis of Abatement Potential of Greenhouse Gas Emissions in Irish Agriculture 2021-2030 https://www.teagasc.ie/media/website/publications/2018/An-Analysis-of-Abatement-Potential-of-Greenhouse-Gas-Emissions-in-Irish-Agriculture-2021-2030.pdf

The panel recommends that the group practices should avoid the creation of centres of excellence or activity hubs within the group, instead focusing on a community model that works with and for all within the community. The facilitators' people skills and energy will be vital to be a catalyst for change on all holdings.

The inspiration for this type of knowledge transfer and support network comes from a RISS funded farmer group on Arran, supported by a SAC consultant. Their collaborative rather than competitive approach is expanding on data and processes from the Beef Efficiency Scheme and the Farming for a Better Climate Initiative, with the ambition to involve other local wider actors in the community such as Taste of Arran and Arran Eco Savvy. They are also looking at the link between farm businesses, processors and retailers.

Engendering wide-reaching change is not simple, nor should it rely on common sense. The approach to knowledge transfer must be informed by the latest social science. This shows that farmers are not homogenous; there are different age groups, levels of interest, ambition and knowledge, all of whom access different forms of information. Further, there should also be space made for knowledge to go up to policy makers and scientists, rather than just down to farmers. In communication with the Farming for 1.5°C Inquiry Dr Dominic Duckett wrote "for change to occur knowledge is best co-constructed rather than communicated….knowledge reform ought not to be a top down process. Institutions usually think they should target farmers while farmers think they should target institutions, especially government."[24] This is supported by a report on the uptake of precision agriculture in Scotland where they found "The farmers who had adopted PATS (precision automated technology) were asked what had influenced their adoption decision. Generally, other farmers, industry salespeople and visits to trade fairs had the strongest effect on their decision[25]."

In an evidence session with a behaviour change and psychology specialist, Dr Amanda Lucas, she outlined that there is an inherent assumption across policies that "as long as it saves money and you provide support, farmers will take 'it' up", also known as "win-win" scenarios. This is based on the belief that humans make decisions individually, are self-interested and are rational. However, research shows humans are social learners - learning principally through conformity with a prestige bias, are more other-centred than self-centred and our decision making is constrained rather than rational[26].

In order to speed up the uptake of new behaviours, the careful use of 'prestige' or opinion leaders is imperative. This means identifying industry leaders, targeting this group, and rather than leaving them to change on their own, guide them in how things can change. Research shows that after which they are highly effective in influencing uptake in others[27]. Many of these 'leaders' will not be in traditional political leadership roles but instead have large social media followings. Maximising the potential impact of these leaders needs the recruitment of communication specialists across all types of media to ensure that all types of Scottish farmer are included.

The creation of 'Climate Change Champions' and sophisticated demonstration sites can create barriers for many in the farming community if they feel they cannot identify with the production approach or the level of investment required. The requirement for whole system change needs

[24] Email communication Dr Domnic Duckett, James Hutton Institute 29/07/20

[25] Barnes A & Eory V Uptake of Precision Agriculture; Scotland Land Economy, Environment and Society Research Group, SRUC available athttps://www.sruc.ac.uk/download/downloads/id/3607/precision_agriculture_update_brief.pdf

[26] Moran, D., Lucas, A., & Barnes, A. (2013). Mitigation win–win. Nature Climate Change, 3(7), 611-613

[27] Muller, E., & Peres, R. (2019). The effect of social networks structure on innovation performance: A review and directions for research. International Journal of Research in Marketing, 36(1), 3-19.

to go beyond talking to the already converted and access the leaders of each individual farming business. This is to not only communicate the need for (in the best-case scenario) accelerated change but also to furnish them with all the information, tools, training and best placed funding and investment to make net zero a reality.

This will involve a large-scale communication strategy. The template of a cooking show reveals one possible approach. Tools and ingredients are shown, the processes and pitfalls are demonstrated, and the results are displayed. Rather than a passive experience, this would be a 'cook-along' using the community groups mentioned earlier. It might mean producing specific step 'Recipe cards' or online portals with the required steps, noting points at which to access personal progress and options to overcome issues already highlighted by others. If these tools were as visual and interactive as possible, there is a greater chance of change within the 10-year horizon that we currently have.

Innovators, on the other hand, are not highly effective at influencing the broader community. Continuing the cookery theme, they would be the Heston's rather than the Jamie's of cookery TV. Yet innovators do need support to try, to fail and to succeed, which can then be translated into wider action. This support would be through the creation of peer groups, using their learning as benchmarking so that policy makers can learn what has worked or what needs to change to make successful innovations more mainstream[28]. It is imperative that questions about how to make change, rather than just what needs to change are considered in the creation of new systems.

Collation and use of data

Throughout our evidence sessions, there was a repeated request for better data collection and better management and use of current data. The Committee on Climate Change found "driving effective use of data including developing Key Performance Indicators enabling better measurement of performance across the sector" as a key driver of productivity[29]. Equally the Agricultural Productivity Working Group[30] identified "Harnessing the power of data and inspiring farming businesses to measure performance" as their number one recommendation to overcoming low productivity. In all cases the ability to provide and access data easily and understanding it are crucial. Benchmarking across systems is also important to measure results and success. However, the high number of part time and smaller scale producers in a Scottish context, must be recognised so they can be included.

Soil health

Improving and maintaining soil health is a fundamental building block to the carbon holding capacity of Scottish soils and its water and nutrient capacity; making it essential to sustainable production, soil biodiversity and as a buffer to extreme climate events. Soils management should become a priority at farm level and be supported by analysis standards, survey work and specialist advisory support. Scotland has some of the world's premier institutions and knowledge on soils that could be much better used and updated to reflect current knowledge and on-farm practice. Using new technology such as drones and expanding testing capacity can inform this. Soil sampling and analysis could be core parts of the new Green Jobs push, aligning with the Green Recovery[31] priorities under "boosting youth employment opportunities in nature and land-based jobs".

[28] Dedehayir, O., Ortt, R. J., Riverola, C., & Miralles, F. (2017). Innovators and early adopters in the diffusion of innovations: A literature review. International Journal of Innovation Management, 21(08)

[29] https://www.theccc.org.uk/wp-content/uploads/2020/01/Land-use-Policies-for-a-Net-Zero-UK.pdf

[30] Agricultural Working Group (2020) Report to the Food and Drink Sector Council https://www.fdf.org.uk/publicgeneral/APWG-report-feb20.pdf

[31] Scottish Government (2020) Scotland's Green Recovery **https://www.gov.scot/news/scotlands-green-recovery/**

Recommendations:

- The establishment of a widely understood and agreed definition of great soil health for different Scottish soils
- Attaining great soil health is a core agricultural policy aim
- The creation of a second-generation model for both soil sampling and analysis that can quantify both field carbon and nutrient status.
- The attainment of great soil health is supported through expert tailored advice, stimulating the uptake of management techniques that minimise carbon loss and maximise carbon storage potential, minimise nutrient loss and improve soil biodiversity.
- The present cost of soil carbon analysis is a significant barrier to uptake and the survey approach would have to offer a lower cost package to create positive buy-in.

Soil data coupled with knowledge on how to use it is key to supporting the Farmer's mitigation menu, greenhouse gas contracts and shifts in farm management. Changes in practice should be results led, with future revisions in policy reflecting successes and failures.

Carbon calculators

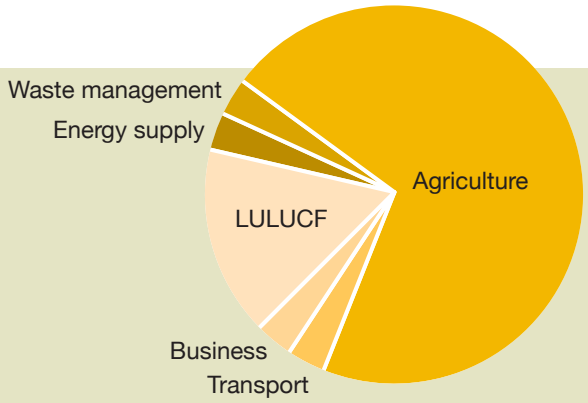
Carbon foot-printing has been a vital bridge between farming and the climate change agenda. It is a powerful vehicle to support the adoption of efficiency measures and mitigation interventions; spotlighting the win-wins that deliver system efficiency and a reduced carbon footprint. The approach has been integral to government climate change initiatives including the Beef Efficiency Scheme and has been adopted by food processors to underpin the green credentials of their supply chain.

The present general carbon foot-printing approach however is not a complete audit system. By prioritising the carbon cost per kilogram of production it masks the emissions of each individual greenhouse gas; figures that are critical to the industries' progress to net zero. Some performance factors that reduce the carbon cost of each kilogram of production also increase total emissions; recognising these conflicting indicators is vital. Carbon foot-printing at both system and whole farm level must be upgraded to capture and quantify both the emissions of the three main greenhouse gases, and in the case of methane adopting GWP* methodology. This issue is explained fuller as part of the greenhouse gas management contracts under Phase 3.

The carbon efficiency of production should also take into account the sequestration directly linked to a production system and indirectly, through farm biodiversity and sequestration features. Finally, the whole farm audit approach should also take account of on-farm renewable energy production. It is important that this data is collated as soon as possible (i.e. in Phase 1) for it to be acted upon in future phases and thus reach the 2030 and 2045 targets.

This more sophisticated approach is a vital part of the change infrastructure and must provide:

- A baseline audit of the production system and whole farm carbon status, including a comprehensive assessment of sequestration.
- An auditing system to support and verify the transformation process.
- A user-friendly interface that includes a decision support tool. This can be used to test the impact of potential management changes, specific interventions and/or land-use change.
- A cross industry tool that all farmers use.



Sources of nitrous oxide in Scotland

Nitrogen, nitrous oxide and ammonia

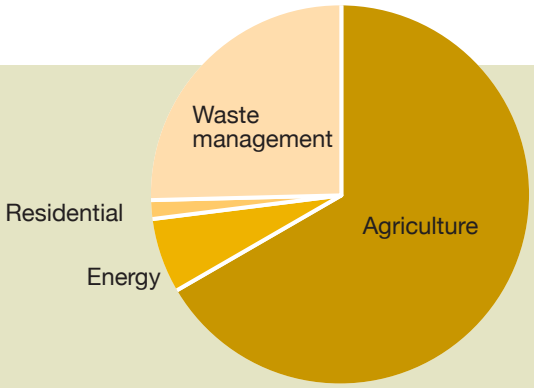
Nitrogen makes up 78% of the Earth's atmosphere and is crucial to life on earth. When combined with oxygen at high temperatures (such as combustion or lightning), several different oxides can be created depending on the number of nitrogen and oxygen molecules. Nitrous oxide is one such example. Nitrous oxide is a more difficult challenge than methane; it is a long-term gas carrying a very high global warming potential of 298, subject to complex flows within the environment and deposition across landscapes and water bodies. It is also now the dominant ozone-depleting substance as it is not included in the Montreal Protocol[32]. Scottish agriculture is the main contributor to nitrous oxide emissions in Scotland, responsible for 2.2 MtCO2e per year or 69% of the total[33] - a 14% reduction since 1990. Synthetic nitrogen fertilisers contribute 1.1MtCO2e. Other sources include livestock manure, biomass burning and fossil fuel burning. Natural sources (bacteria and fungi) can be stimulated through soil cultivation and manure handling.

Simultaneously it is recognised that nitrogen is a core production driver in modern agriculture with ammonium nitrate and urea-based fertilisers doubling yields in many systems. Yet the excess of these fertilisers is responsible for significant emissions, much of it at field level where nitrogen use efficiency is around 50%.

Ammonia is created when nitrogen and hydrogen combine. Reducing the amount of excess nitrogen will also reduce the amount of ammonia.

[32] Ravishankara A.R., Daniel J.S., Portmann R.W. (2009) Nitrous Oxide (N2O): The Dominant Ozone-Depleting Substance Emitted in the 21st Century SCIENCE02 OCT 2009: 123-125

[33] https://www.gov.scot/binaries/content/documents/govscot/publications/statistics/2020/06/scottish-greenhouse-gas-emissions-2018/documents/scottish-greenhouse-gas-emissions-2018/scottish-greenhouse-gas-emissions-2018/govscot%3Adocument/scottish-greenhouse-gas-emissions-2018.pdf pg 12



Sources of methane in Scotland

Methane

Methane is the main net greenhouse gas emitted by Scottish agriculture at 4.2 $MtCO_2e$[34], responsible for 66% of Scotland's methane emissions. Over 100 years or using the GWP100 system, the warming potential of methane is 25 compared to carbon dioxide. It is a potent greenhouse gas. Agriculture, waste management and energy have historically been Scotland's major sources of methane emissions. The modification of landfill management and alternative food waste disposal systems has reduced emissions by 73.7% from waste disposal sites, while the transformation of the energy sector has resulted in a fall of 79.6%. In comparison methane emissions from the agriculture sector have fallen by 18.0%, mainly due to a decrease in livestock numbers but not because of any emissions-specific policies. Scottish agricultural sources include ruminant enteric fermentation and livestock waste management.

Due to its short (~10 years) life in the atmosphere, the reduction of methane can contribute to reduced human-induced warming (relative to the enhanced warming caused by current methane emissions). Without significant reductions in methane emissions, Scotland (and rest of the developed world) would need to hit net-zero carbon dioxide emissions around a decade earlier than planned - so by the mid 2030s - to still have a good chance of aligning with the Paris climate goals. Current methane emissions in Scotland need to be cut.

[34] Scottish Government (2020) Scottish Greenhouse Gas Emissions 2018 https://www.gov.scot/binaries/content/documents/govscot/publications/statistics/2020/06/scottish-greenhouse-gas-emissions-2018/documents/scottish-greenhouse-gas-emissions-2018/scottish-greenhouse-gas-emissions-2018/govscot%3Adocument/scottish-greenhouse-gas-emissions-2018.pdf pg 12

PHASE 2: A FARMER'S MITIGATION MENU

Approach	Examples	Timeline	Mechanism
A Farmer's Mitigation Menu Best practice implementation by all farmers	Soil management Nutrient budgeting and use of nitrification inhibitors Ban splash plate slurry spreaders Use of legumes/ intercropping Manure management Livestock health Feed management Use of improved genetics Decarbonisation of farm machinery Precision farming	As a follow on to current 'Greening' which is due to end in 2021.	Regulation across Scotland Targeted financial support through a mitigation menu Redesigned advisory service and facilitated group learning Farmer education through advice, peer learning and CPD

A MACC is a tool used to better understand the costs of different measures and their potential to reduce emissions or sequester carbon. Agricultural MACCs, developed over the last 12 years (often in Scottish institutions) [35, 36, 37], have recently fed into farmer mitigation menus such as what Teagasc[38] developed for the Republic of Ireland, and WWF Scotland's report collated in "Delivering on Net Zero: Scottish Agriculture[39]". The Irish approach aims to reduce net farming emissions by 30%, while WWF's report suggests emissions reductions of 38% are possible based on conservative estimates of take-up. If there was 100% take-up of all measures, their calculations suggest a 100% abatement.

However, both these templates also include a level of systems and land use change; woodland creation featuring heavily in Ireland and a combination of the conversion of 40% of land to organic management, and 10% of land to agroforestry (not including rough grazing) being a feature of the WWF proposal. Without the recommended creation of 7 000ha/year of woodland (which the Farming for 1.5°C panel believes should be a significant standalone pillar of the transformation plan) the Irish menu system is likely to achieve reductions of closer to 20%, dependent on moderate take up level on farm.

The panel concludes that, in Scotland, an ambitious mitigation menu, with a firm basis in great soil health, can contribute significant reductions in emissions, perhaps 27% or more as new techniques and technology come to the fore. However, a high mitigation score, supported by a positive change in culture, can only be achieved if all producers use the menu. Several of the key climate change measures can also contribute to business efficiency; providing some payback for producers and creating a stepping-stone towards the precision systems that can deliver targeted cuts of individual greenhouse gases. For example, the WWF report found "Improved animal health and breeding, with increased fertility, growth rates and yields, and reduced morbidity/mortality could reduce total livestock numbers needed to deliver the same output and deliver 366 kt emission reductions with 40-50% uptake[40]." From an arable perspective, one of our panel members said "the more resilient you can make your soil the better it is for you. It is bringing all these things together where you maximise good land but make better use of other areas for biodiversity and sequestration."

[35] Moran D et al (2008) UK marginal abatement cost curves for the agriculture and land use, land-use change and forestry sectors out to 2022, with qualitative analysis of options to 2050, Report No RMP4950, Committee on Climate Change, SAC

[36] MacLeod M et al (2010) Review and update of UK marginal abatement cost curves for agriculture. Report to Committee on Climate Change, SAC

[37] Eory V et al (2015) Review and update the UK Agriculture Marginal Abatement Cost Curve to assess the greenhouse gas abatement potential for the 5th carbon budget period and to 2050. Final Report to Defra. SRUC

[38] Teagasc (2019) An Analysis of Abatement Potential of Greenhouse Gas Emissions in Irish Agriculture 2021-2030 https://www.teagasc.ie/news--events/news/2018/reduce-ghg-emissions-.php

[39] https://www.wwf.org.uk/sites/default/files/2019-12/WWF%20Net%20Zero%20and%20Farming.pdf

[40] https://www.wwf.org.uk/sites/default/files/2019-12/WWF%20Net%20Zero%20and%20Farming.pdf, page iii

More efficient use of nitrogen across Scotland, using a mix of solutions, is another area that would reduce farmer expenditure, reduce greenhouse gas emissions, and improve soil and water quality. Estimates of losses of nitrogen to water (132 kt N yr-1), air (80 kt N yr-1) and terrestrial systems (90 kt N through atmospheric deposition) are substantial, and predominantly due to agricultural activities[41]. This reflects an average nitrogen use efficiency of around 50%.

The panel has identified that nationwide "Green Direct Payments" (commonly known as Greening) as currently stipulated under the Common Agricultural Policy can be modified to carry a mitigation menu in tandem with options that support biodiversity[42].

The Greening mitigation menu system should:

- Be mandatory and include options that fit a range of systems, while supporting business efficiency or have a positive cost-benefit so as to support buy-in and generate culture change at farm level. This is to provide a ramp into positive climate change management. Practically this would mean an end to the current exemption for mainly grassland farms.
- Include "an escalator" to ratchet up the number of climate change options implemented over time on each holding, to build positive climate change impact at the same time as building skills and understanding.
- Be designed to allow a self-audit system to avoid the risks of non-compliance. This self-audit system can use examples already in play with dynamic data use and reporting in the business and medical worlds.
- Aim for a national 25% reduction with farm business specific aims.

Marketing standards and/or branding have the potential to incentivise and add momentum to the change process.

Many of the Greening options have implications for nitrogen use. A strategy to reduce excess nitrogen in the ecosystem is a priority, with a targeted approach so as to avoid negative pressures on some sectors. The panel has not formulated a view on what level of reduction is possible without compromising outputs. Yet, from the evidence received, significant savings are possible through the implementation of best practice, developing precision techniques across the farming community, using nitrification inhibitors, increasing the use of nitrogen fixation in rotations and developing plant genetics. With the heavy impact of nitrous oxide, even small cuts in emissions will have a significant and long-term impact on climate change.

The range of potential management interventions can be applied across all systems. The benefits of nitrogen fixing plants are most easily incorporated into grass leys to support grazing systems. WWF[43] reports that 55% of nitrogen fertilisers used in Scotland are on grassland, with dairy farms being very dependent on its use. It is likely that different sectors can contribute nitrous oxide savings at different levels. One of the recommendations from WWF's report is the conversion of 40% of Scottish agricultural land to organic farming. Part of the rationale for the lower expected emissions is due to the difference in approach to inputs as one of the organic certification requirements is a nutrient management plan, an element that could be easily incorporated into all farms' management. Large savings are possible, even in those systems that are heavily dependent on synthetic nitrogen inputs if precision technology is adopted and rotations incorporate a nitrogen fixing phase.

[41] Carnell E.J. et al (2019) A Nitrogen Budget for Scotland https://www.sepa.org.uk/media/468551/nitrogen_budget_scotland_report_.pdf

[42] Please see appendix A for a list of Greening options that the panel submitted to Scottish Government earlier in 2020

[43] WWF (2020) Delivering on Net Zero: Scottish Agriculture https://www.wwf.org.uk/updates/scotlands-agriculture-can-cut-emissions-nearly-40-2045

There is a current call to extend Nitrate Vulnerable Zones (NVZs) across Scotland (and the rest of the UK) to counter excessive nitrogen use. However, the Nitrates Directive's two main objectives to reduce water pollution "caused or induced by nitrates from agricultural sources" and to prevent further nitrate pollution, have not managed to reduce the wastage of fertiliser in Scotland. Across the EU, between 2010 and 2015 there were no further decreases of losses of nitrogen losses from agricultural land[44] despite the implementation of the Nitrates Directive. This is a blunt tool in terms of providing solutions to tackle the climate and nature emergencies. It is moreover a much-maligned piece of legislation within the farming community, as it is seen as a barrier to efficient production with many refusing to accept that farming was responsible for any problems[45].

A new approach to tackle nitrogen should be created for all Scottish farmers, learning from SEPA's experience working with farmers and informed by the Scottish Nitrogen Balance Sheet. The aims should be to:

- Cut waste in the system.
- Increase the efficient use of nitrogen, including biogenic sources such as legumes in grass and arable rotations and inorganic fertilisers.
- Reduce greenhouse gas emissions throughout the process with the contribution of fertiliser manufacturers.
- Support vulnerable ecosystems.

The EU is developing a new tool called "The Farm Sustainability Tool for Nutrients"[46] while New Zealand are investigating a nutrient management tool called "Overseer", both to find new ways of reducing nutrient waste. The keys to the success of these projects are support and advice, streamlined data use and digitalisation.

The uptake of best practice, efficiency interventions and mitigation measures has been at best patchy. A recent report entitled "Boosting Productivity Growth in Scottish Agriculture[47]", found that when compared with comparator high-income countries, Scotland performs as a middle ranking country. This reveals potential for improvement, particularly regarding technology uptake and better farm planning. However, in terms of "economic efficiency" the report found a "diversity of performance" across farm types "with low or negative annual rates of change identified in most sectors". The Greening mitigation menu is a way of breaking through on all holdings; however political, advisory and community support is integral to optimising buy-in at farm level. It is vital that the industry and individual producers embrace the mitigation menu agenda and push the boundaries on take-up so as to overachieve on easy wins, thus reducing the pressure on system change and land use change.

This first strand is an important step but a targeted reduction of greenhouse gases at farm level, to reduce total national emissions, coupled with land use change are also required to transform agriculture into a net-zero economy.

[44] European Environment Agency (2018) Agricultural land: Nitrogen Balance https://www.eea.europa.eu/airs/2018/natural-capital/agricultural-land-nitrogen-balance

[45] SRUC (2014) Land Economy Working Paper Series; Farmers in Nitrate Vulnerable Zones – What do they think of the NVZ regulation? https://www.sruc.ac.uk/download/downloads/id/2161/80_farmers_in_nitrate_vulnerable_zones_%E2%80%93_what_do_they_think_of_the_nvz_regulations.pdf

[46] https://ec.europa.eu/info/news/new-tool-increase-sustainable-use-nutrients-across-eu-2019-feb-19_en

[47] Barnes A et al (2020) Boosting Productivity Growth in Scottish Agriculture available at https://www.ruralbrexit.scot/resource/boosting-productivity-growth-in-scottish-agriculture-report-for-the-scottish-government/

PHASE 3: SYSTEM CHANGE TO LOW EMISSION PRODUCTION

Approach	Examples	Timeline	Mechanism
Scotland wide system change to low emission production.	Choice of approaches (A or B) to provide all sectors and farm types to contribute through a low carbon pathway. Includes: • High level precision systems • Extensive systems • Feed additives • Climate change breeding index	Following on from Phase 2, to begin with the new agricultural policy framework in 2024	Greenhouse gas contracts, with sequestration, soil management and biodiversity targets

This third phase builds on phases 1 and 2, assumes best practice is in place and relies on the establishment of a respected baseline. To ensure this is a fair reflection of general activity, rather than just one point in time, the baseline could be averaged over 3 years. The greenhouse gas contracts focus on new interventions on land management and/or cropping requirements and introduce sequestration and biodiversity thresholds.

Addressing individual gases allows the impact and persistence of each gas to be factored into a reduction strategy with targeted management measures that are quantified and audited at holding level and understood by the farmers and his/her team. This achievable end point then compounds to a national reduction.

The panel is considering how farmers can individually contribute to the national target of Scotland being net zero by 2045, including by reducing on-farm emissions by at least 50%. A delivery mechanism to do this would be for each farm to adopt greenhouse gas reduction contracts with Scottish Government, with targets for methane, nitrous oxide and carbon dioxide.

The reduction contracts should offer two options to allow producers to adopt a management plan that fits their system and its future development, with a limited number of management interventions. The reduction plan must be clear and simple to audit and implemented without the disruption to normal management priorities.

Options:

- Approach A covering production centred farming, would have a support premium to compensate for costs and controls.
- Approach B includes ‘multifunctional’ farming delivering sequestration, biodiversity priorities and low emission production, and would have an enhanced support premium to reward multifunctional management and constraints on production.

Some of the proposed interventions are still in development and their impact is still being quantified. Anti-methanogens for example, are currently being assessed and are not licensed - a vital development that needs to proceed quickly. New science will emerge; as knowledge progresses interventions and implementation of reduction contracts may evolve or change. Systems must be in place to respond to development and new science. Equally, the importance of rare and native breeds across all farming sectors must be recognised, and diversity protected.

The panel initially separated out methane because of its much shorter life in the atmosphere, thus requiring specific management to both understand its climatic importance as well as to inspire change. As the panel better understood the impacts of reactive nitrogen in its various forms, the case for targeting action here also became clear, however for reasons different to methane. This is predominantly to inspire change. The panel recognises there is potential for overcomplication but equally sees the need for farmers and their advisors to fully understand the implications and trade-offs of action and inaction for their businesses, the climate and biodiversity. This is where it is crucial that the knowledge development that starts in Phase 1 and runs throughout the transformation pathway meets the challenge of a complex problem that needs a combination of solutions, contributing to reductions in both whole farm and national emissions.

Approach A: Production centred management options	**Approach B: Multifunctional farming options**	**Target GHG**
Adopt genetics that drive climate change efficiency and reduce enteric emissions.	Adopt climate change index as core to breeding programmes (rare breed exemption)	Methane
Include approved anti-methanogens over the feeding period. Innovative techniques are likely to provide alternative methods of administration.	Reduce breeding livestock units by 10%	Methane
20% of land managed for biodiversity	50% of land area to sequester or store carbon; 50% of land to underpin biodiversity (these can be overlapping)	Carbon
The incorporation of clover in all grass reseeds or in surface level rejuvenation of pasture		Nitrogen
Adoption of soil fertility/carbon building techniques through the application of manures, compost, or green manures or grazing of break crops or crop residues across 20% of the cropping area		Carbon, nitrogen, methane
Application ceilings created for nitrate and urea application for a range of pastures, conservation grass and crop systems to maximise the contribution of clover, legumes and organic manures	Lower application ceilings created for nitrate and urea application for a range of pastures, conservation grass and crop systems to maximise the contribution of clover, legumes and organic manures	Nitrogen
GPS Guidance Variable rate precision spreading based on mapping or crop monitoring		Nitrogen, carbon dioxide
Adopt crop genetics and plant population targets that optimise uptake and utilisation of nitrogen fertiliser		Nitrogen

Methane

Some reduction in methane emissions can be achieved through a combination of technical changes and long-term advances. Initial data on the impact of the 3NOP feed additive show a reduction in emissions between 25% - 30% depending on the class of animals and system[48], while there is currently a 30% genetic variation in levels of enteric methane emissions within the cattle population[49].

[48] Panel evidence session with Prof Dewhurst 31/10/19

[49] Panel evidence session with Prof Roehe 31/10/19; also see Stewart, R.D., Auffret, M.D., Warr, A. *et al.* Compendium of 4,941 rumen metagenome-assembled genomes for rumen microbiome biology and enzyme discovery. *Nat Biotechnol* **37,** 953–961 (2019). https://doi.org/10.1038/s41587-019-0202-3

Government establishes a national ceiling for methane (i.e. 2020 levels) with a falling target corresponding to reaching nationwide climate neutral greenhouse gas emissions by 2045. As already instigated by the New Zealand government, a specific target for biogenic methane (24-47% reduction by 2050 compared to 2017 for New Zealand) should be considered.

Nitrous Oxide

Numerous savings of nitrous oxide can be achieved through best practice. This can be further improved through developing precision techniques across the farming community, using nitrification inhibitors, increasing the use of nitrogen fixation in both grass and arable rotations and developing plant genetics.

The recommendations in the greenhouse gas contracts above, demand a strict nutrient management system moving from an economically based nitrogen use efficiency to an ecologically based nitrogen use efficiency. This must be supported through excellent advice and evidence beginning in Phase 1.

Carbon Dioxide

Carbon dioxide emissions counted in the Agriculture sector in Scotland are currently 1.0 MtCO2e[50], produced by stationary combustion, mobile machinery, off road vehicles and others. There are also carbon dioxide emissions from agricultural land held within the LULUCF sector. The use of lighting, heating and electricity for animal housing, milk processing, storage, grain drying, irrigation and others also contribute to carbon dioxide emissions, some of which are counted elsewhere in the inventory. They still provide an important contribution to total emissions.

The reduction of carbon dioxide emissions can be achieved through (as examples):

- Better efficiency of current practices thus reducing input and fuel use.
- Precision agriculture techniques reducing the number of passes in a field.
- Use of renewable energy to replace fossil fuels such as solar powered lighting, cooling and heating of animal housing, grain dryers, electric fences or water pumps.
- Electrification of on-farm machinery.
- Use of smaller equipment where applicable.

In many rural areas, transitioning to these activities may require structural support by upgrading energy and communication infrastructure – 3 phase energy and both broadband and mobile capability. The capacity of on-farm wind turbines, solar power and hydro schemes to support farm enterprises with renewable energy is well established by some and must be further encouraged. Further utilising this source of power through hydrolysis to create a hydrogen fuel is at the moment a niche technology. A wider uptake of hydrogen energy technology can provide an energy storage solution for excess generation capacity and contribute to lower emission fuels for farm tractors and vehicles. Achievements in using innovative technology to reduce emissions in the short term, such as the integration of oxy-hydrogen by farmers in Aberdeenshire, need to be expanded across Scotland, to become standard rather than seen as a niche.

[50] https://www.gov.scot/binaries/content/documents/govscot/publications/statistics/2020/06/scottish-greenhouse-gas-emissions-2018/documents/scottish-greenhouse-gas-emissions-2018/scottish-greenhouse-gas-emissions-2018/govscot%3Adocument/scottish-greenhouse-gas-emissions-2018.pdf page 12

Smaller units may struggle to replace machinery as quickly as is needed. There is scope to enhance the role of machinery rings and other collaborative efforts, while ensuring the machinery offered is highly efficient thus contributing to lowering emissions.

Reducing carbon emissions from soils can be supported through better soil health, which underpins much of this report. Minimum tillage is being shown by some Scottish farmers[51] to have benefits to their systems and the climate while saving them money from lower fuel use, lower labour costs and less machinery wear and tear. It must be noted that where improvements in soil carbon stocks are possible (some Scottish soils are already saturated), they take a long time. Focus should be on both the building and maintenance of these carbon stocks.

It should be noted that a number of these recommendations have been echoed elsewhere in the report. Maximising inorganic nitrogen use efficiency for example, will not only lead to reductions in nitrous oxide emissions from the fertiliser, but also carbon dioxide emissions from reduced vehicle and thus fuel use and from the soil due to reduced soil movement. By combining a whole farm approach, with actions for individual gases it is possible to see the synergies and trade-offs and respond appropriately. Yet these actions must be supported with informed advice and training to ensure the best options are chosen.

[51] Panel visit to Durie Farms, Fife 11/12/19

PHASE 4 ENABLING WHOLE FARM CHANGE

Approach	Examples	Timeline	Mechanism
Whole farm change - evolving new land use model to underpin low carbon production, sequestration and biodiversity	Increase diverse approaches to support biodiversity and multifunctional landscapes Agroforestry Organics, agroecology, regenerative farming	Pilot projects start now under both agricultural and forestry schemes to inform post 2024 agricultural and future forestry policy	Opening to new entrants of the Agri-environment and Climate Scheme Organic conversion support Support for other extensive approaches

The options outlined above will reduce greenhouse gas emissions, but Scottish farmers and landowners will need to go further still. Current business models tend to support increasing inputs and outputs; while fixed costs, including loan repayments, encourage businesses to run faster, even if this reduces productivity while increasing production. Changing the farm system - for example changing the core enterprise by converting to organic or introducing agroforestry at scale - can require many years before a new equilibrium is found. The endpoint is a farming system that is more profitable and sustainable while generating fewer emissions, but businesses may need considerable support in the form of grants and loans during the period of change.

The potential for agroforestry

This report uses the widely used definition of 'agroforestry' as the growing of woody perennials on the same piece of ground as an agricultural crop, either livestock or crops[52]. The panel recognises that all woodland types, including hedgerows, can play a role in delivering both carbon sequestration and biodiversity gains on a farm, but agroforestry has the potential to deliver on these goals without significantly reducing and even increasing[53] the productive potential of a farm. Internationally, agroforestry is recognised as a sustainable climate-smart agriculture option that can help deliver on many Sustainable Development Goals and contribute to countries' Nationally Determined Contributions to be submitted to the Paris Agreement.

Agroforestry can enhance agricultural production depending on planting methods, time scale used and species choice. There are associated reductions in nitrate leaching due to deep root structures[54] while Agroforestry Ammonia Abatement[55] uses both the dispersive effect of a barrier and the uptake of ammonia into the tree canopy to mitigate emissions for example from pig, poultry and dairy units. These contribute to improved water and air quality, while the maintenance of an understory of herbage further supports biodiversity and improves soil structure[56]. Agroforestry can benefit livestock productivity as it can protect better quality pasture, in some instances provide earlier grass growth supporting lambing, improve animal health by providing a diversity in diet (tree fodder), and give protection from adverse weather. Both sheep and cattle have been observed to choose to go under trees when calving or lambing. This behavioural choice results in lower stress thus more fertile, less prone to disease, and has better rumen production[57]. The presence of trees also stops ploughing, an additional mean of protecting soil carbon. In silvoarable systems, shelter belts and alley cropping can reduce soil erosion as well as wind damage to crops and farm buildings. Agroforestry can also

[52] Borelli S, Simelton E et al (2019) Agroforestry and Tenure http://www.fao.org/3/CA4662en/CA4662en.pdf
[53] FAO (2013) Climate-Smart Agriculture Sourcebook pg 20 http://www.fao.org/3/a-i3325e.pdf
[54] FAO (2017) Agroforestry for landscape restoration
[55] SAMBA (2016) Agrofroestry Systems for Ammonia Abatement
[56] Friggens, NL, Hester, et al. (2020) Tree planting in organic soils does not result in net carbon sequestration on decadal timescales. Glob Change Biol.; 26: 5178– 5188. https://doi.org/10.1111/gcb.15229
[57] Langford F (2019) Agroforestry in Scotland FAS podcast. https://www.fas.scot/publication/agroforestry-in-scotland-podcast/

provide a tool for landscape restoration as it can 'enhance physical, chemical and biological soil characteristics, thereby increasing soil fertility, controlling erosion and improving water availability'[58].

The limited experience of agroforestry in Scotland, usually using wide spaced trees, has led to the perception that agroforestry in general will not yield quality timber products, and are instead restricted to firewood. However, the panel holds that suitable agroforestry species can be planted and grown in ways that deliver good quality timber for a range of markets while helping to diversify the types of trees grown in Scotland, with resultant benefits to increasing resilience in Scotland's woodland resource, landscape and rural businesses. For example, if done at scale, birch would have a wide range of uses and thus markets as is seen in Scandinavian countries.

As such, the panel sees the development of agroforestry as central to future agricultural and forestry policy; as an important integration tool to be used in delivering biodiversity gains, particularly when using native trees, and increase carbon sequestration on farms whilst protecting agricultural productive potential. This is despite the limited experience of agroforestry in Scotland. WWF's "Delivering on Net Zero" report suggests a potential of a 570 kt reduction in emissions with uptake by 30% of farmers, assuming 10% of farmland is used for trees. The panel echoes this call for take-up.

In the 8 years since the Woodland Expansion Advisory Group report recommended "better integration between woodland creation and farming" and in the 6 years since agroforestry has been in the Scottish Rural Development Plan, there has been no significant progress on agroforestry in Scotland. Scottish Forestry recently wrote "As part of the Forestry Grant Scheme Stability and Simplicity review it has been recognised that the agroforestry option is not delivering and it will be reviewed – but this is unlikely to be before 2021."[59] This is despite a growing interest in the topic with 50 people signed up to the Rural Innovation Support Service funded Scottish Agroforestry group that started in May this year[60].

According to the literature[61] barriers include farmer perception, landscape aesthetic appeal, and a lack of key policy incentives. Panel experience adds to this list a lack of knowledge on silviculture in the farming community, the perception that trees bring problems to livestock (such as flystrike), a resistance to agroforestry in the forestry sector, until recently the lack of a 'champion' in the NGO sector, inertia and risk averse culture in the Government Forestry Department, much reduced capacity in the 'forestry' academic community (only the University of the Highlands and Islands offers a degree course in forestry), lack of engagement in the agricultural academic community and the lack of obvious drivers to force uptake or development of agroforestry (e.g. the lack of a sequestration element to agricultural emissions calculations). There are also particular current and historical land ownership and tenancy issues[62], which in turn has led to a lack of understanding or commitment to agroforestry.

Yet, agroforestry remains one of the most effective ways to achieve Scotland's climate goals in both mitigation and adaptation[63] across a range of soil types, while improving agricultural and biodiversity resilience and providing a diversity of products.

[58] FAO (2017) Agroforestry for landscape restoration

[59] Scottish Forestry (2020) Email to RISS Agroforestry Group 7/9/20

[60] Frater P (2020) Email to Keesje Avis. 22/9/20

[61] Perks M et al (2018) Agroforestry in Scotland – potential benefits in a changing climate. https://www.climatexchange.org.uk/media/3312/agroforestry-in-scotland-potential-benefits-in-a-changing-climate.pdf

[62] Slee B (2014) Increasing the Integration of Farming and Forestry in Scotland -a summary of recent research https://www.climatexchange.org.uk/media/1848/increasing_the_integration_of_farming_and_forestry_in_scotland_-_a_summary_of_recent_research.pdf

[63] Perks M et al (2018) Agroforestry in Scotland – potential benefits in a changing climate. https://www.climatexchange.org.uk/media/3312/agroforestry-in-scotland-potential-benefits-in-a-changing-climate.pdf

The panel recommends creating a ring-fenced budget for agroforestry with a dedicated 10-year programme to drive it. The panel urges that the creation of these policies allows for innovative designs and takes into account the cultural, tenancy and climatic variances that are particular to Scotland.

Integrating Scottish agriculture and forestry knowledge and understanding will further assist the largescale establishment of a variety of agroforestry models. The panel recommends that agroforestry is considered for the pilot schemes within both the Forestry and Agriculture budgets with a variety of planting styles including 'corridors' of trees, with the joint support and advice of Scottish Forestry, the Woodland Trust and Soil Association.

Extensive farming systems

The WWF report suggests that a 40% uptake of organic farming in Scotland could deliver 730kt CO2e reductions due to a combination of a lack of synthetic nitrogen fertiliser use, a 10% reduction in livestock numbers and the conversion of 20% of tillage land to rotational grassland. Of all the actions examined, this had the highest potential for carbon savings as well as air, water and biodiversity benefits associated with lower inorganic input use. Scottish examples echo these trends[64] with close links to local communities, a growing diverse market both locally and further afield and higher returns due to lower input costs. In 2018 for example, supermarket sales of organic food and drink rose by 3.3%, sales by independent retailers rose by 6.2% and in 2019 home delivery schemes increased by 14.2% with a further 10% expected by 2023[65].

However, the percentage of certified organic farmland in Scotland is 1.6%[66] of total agricultural land with a decreasing trend since 2011 in both land area and number of farmers. This is in stark contrast to the EU's Farm to Fork strategy aim for 25% of total farmland in organic management by 2030. There is currently no policy in place for supporting organic conversion in Scotland post 2020, despite the co-benefits to farmer incomes in the growing UK, EU and global markets. The panel recommends Scotland echoes the direction of travel of the EU strategy aim, as well as putting back into place the support for conversion to organics that has currently been frozen.

There are other also other forms of agroecological and/or regenerative farming already being practiced in Scotland, such as high nature value farming, Pasture for Life, biodynamics and others. These all have lower synthetic nitrogen use, often incorporate rotations in their practices and rely on extensive livestock systems. They all have a role to play in reaching net zero and should be supported. This may require the creation of a new category of production where limits on the use of nitrate fertilisers and other inputs would apply with a focus on the quality production of food, fibre, sustainable wood, and breeding stock as well as managing defined percentages of the holding for both sequestration and biodiversity. This system would have a range of marketable outputs, make a significant contribution to public goods and subject to light touch audit.

The panel has some concern that the sequestration values of some soils under agricultural use and in particular land managed by low intensity grazing, including scrub, are not sufficiently understood nor quantified and are largely excluded from the carbon accounting equation.

[64] Panel visit to Balcaskie Estate, Fife. 11/12/19

[65] Natwest (2020) Agriculture outlook: the organic sector https://natwestbusinesshub.com/articles/agriculture-outlook-the-organic-sector

[66] DEFRA (2020) Organic farming statistics United Kingdom 2019. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/887902/organics-statsnotice-28may20.pdf

PHASE 5: LAND-USE CANGE

Approach	Examples	Timeline	Mechanism
Land-Use Change	Converting cropland and grassland to woodland Restoring peatlands and wetlands 'Smart' land use change	Starting now for some with a view for all farmers to be involved in some land use change by 2030	Regional land-use plans based on best science integrating biodiversity and rural community priorities

For some farmers and landowners this may be a sequential change driven by the need to cut emissions and increase sequestration as part of Phase 3 – something they know to start planning for now. However, there will be others who are happy to consider these options now and they must be encouraged. The use of 'phases' is simply to outline a pathway for everyone to arrive at, not to limit those who want to go faster. Action on peatlands and creating woodlands for example, should happen as soon as possible. The next report will explore this phase in more detail.

INTERIM CONCLUSIONS

This transition pathway hopes to map an integrated, inclusive journey for Scottish farmers and associated communities and businesses. The panel recognises the complexity of the task at hand and the lack of a silver bullet, and yet urges action that begins now, with clear milestones to achieve the 2030 and 2045 targets. The implementation tools will need to be sophisticated and underpinned by clear baseline information to measure success, identify what is not working and drive ongoing change. It has to be a joint effort, across the agricultural industry, rural communities and political landscape. The investments in infrastructure, training and land management will be significant and thus require a long-term stable pathway to follow.

OUR NEXT REPORT

- More detail on methane, nitrous oxide and carbon dioxide contracts.
- More about data including on farm carbon calculators.
- Outputs from a joint Moredun and LHS animal health workshop.
- More detail on agroforestry planting patterns.
- Further thoughts on Phase 5 on land-use change.
- More about future research needs and areas for clarification.
- Case Studies.
- Collaboration – its role in supporting investment and new approaches.

Please visit the Farming for 1.5°C website for more comprehensive panel biographies and links to more of our reports.

ANNEX 1

Suggestions for inclusion within 'Greening' management prescriptions, with ideas on how to provide supporting evidence

	Management Prescriptions	Evidence required
1	Soil mapping/yield mapping and variable rate spreading to target nutrients for at least 50% of crop area	Evidence through record of mapping data
2	Nutrient budgeting [all land parcels receiving more than 75kg/ha N] based on rotational soil testing over a five-year cycle with cropping fields also subject to soil carbon analysis as part of the routine check	Record of soil test results, field budgets and log of fertiliser purchase
3	Application of farm-yard manures or slurry or digestate or PAS100 Composts on at least 25% of cropping area, application rates to be managed as part of a nutrient budget	Delivery notes of off-farm soil conditioners and field level nutrient budget
4	Application of slurry through injection system or trailing shoe	Contractor invoice or photography of farm owned kit
5	Stubble management: Crops harvested before 15th September followed by direct drilled green cover crop [plough down from March 1st or graze off from Feb 15th] or Crops harvested after 15th Sept [no pre harvest herbicide] allow natural regeneration [plough down from March 1st]	Dated photos of each field
6	All grass reseed or over-seeding mixtures to have a minimum of 3.5% clover content	Seed merchant invoice
7	Rotations to build nutrients and soil structure: 20% cropping area to be built up of legume crops including clover mixes, green manures or break crops for grazing	IACS declaration
8	Precision nutrition monitored through performance recording	Ration formulation record through nutritionist or feed merchant [and availability of livestock performance records on farm]
9	Sourcing and use of performance recorded sires	AI record or genetic index of purchased sires [terminal maternal or hill above average for breed]
10	Proactive veterinary health planning built on livestock performance benchmarking and agreed action plan to tackle the herd/flock identified risk priorities.	Vet plan sign off document including priorities selected
11	Organic practices or organic transition as they would already be undertaking at least 5 of the items on the menu	Evidence through certification body/certification
12	Direct drilling/min till or over-seeding practices rather than ploughing on pasture	Photographic evidence/ contractor invoicing/equipment on-farm
12	Intercropping	Photographic evidence/ contractor invoicing
13	Return ⅓ straw crop to the soil either as FYM or through direct chopping	Photographic evidence