SHERPA
Rural Science-Society-Policy Interfaces

MAP Position Paper

# CLIMATE CHANGE AND ENVIRONMENTAL SUSTAINABILITY

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Find out more about the two UK-based Multi-Actor Platforms:

Rural Scotland: https://rural-interfaces.eu/maps/united-kingdom-scotland/

River Dee Catchment: https://rural-interfaces.eu/maps/united-kingdom-dee-catchment/

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# Acronyms

| | |
|---|---|
| AECS | Agri-environment Climate Scheme |
| BEIS | UK Government's Department for Business, Energy & Industrial Strategy |
| CCC | Climate Change Committee |
| CCRA3 | Climate Change Risk Assessment 3 |
| CO2e | Standard unit for greenhouse gas, used to determine and quantify the greenhouse gas impact of different GHGs |
| COP | Convention of the Parties. The 'Parties' are the governments which have signed the UN Framework Convention of Climate Change (UNFCCC) |
| CRISPR | Clustered regularly interspaced short palindromic repeats |
| EEA | European Environment Agency |
| EU | European Union |
| GHG | Greenhouse Gas |
| IPCC | Intergovernmental Panel on Climate Change |
| IUCN | International Union for Conservation of Nature |
| MAP | Multi-Actor Platform |
| NPBSG | National Participatory Budgeting Strategic Group |
| NCAPP | Natural Capital Pilot Programme |
| NGO | Non-governmental Organisation |
| NTS | National Trust for Scotland |
| OECD | Organisation for Economic Co-operation and Development |
| Peatland Action | Programme of peatland restoration coordinated by NatureScot, linking funds for site restoration to survey and monitoring |
| PTSD | Post-traumatic Stress Disorder |
| RLUF | Regional Land Use Framework |
| RLUP | Regional Land Use Partnership |
| SEFARI | Scottish Environment, Food and Agriculture Research Institutes |
| SHERPA | Sustainable Hub to Engage into Rural Policies with Actors |
| SIMD | Scottish Index for Multiple Deprivation |
| SIMRA | Social Innovation in Marginalised Rural Areas |
| UNECE | United Nations Economic Commission for Europe |
| UNFCCC | United Nations Framework Convention on Climate Change |
| UNISECO | Understanding and improving the sustainability of agro-ecological farming systems in the EU |

# Headline Messages

The COP events are waymarkers on a long-term international process of tackling climate change. Policy, science and society have different ways of contributing to that process. A challenge for each grouping is to show leadership within their areas of competence.

Political interests need to provide global leadership in setting the visions, and making the decisions necessary for tackling climate change, many of which will require trade-offs between competing priorities. Tackling climate change is requiring policy action across environmental, social and economic dimensions. Compartmentalising issues will make their resolution harder, or impossible: the climate change and biodiversity crises are interlinked, as are climate justice and social justice.

In Scotland, public attitudes are continuing to show increased recognition of the level of urgency of tackling climate change, and indications of some support for particular types of interventions and changes in behaviour, which are required. Scotland has natural and socio-economic opportunities with significant potential to follow pathways towards net zero Greenhouse Gas Emissions by 2045.

In Scotland, many policies of relevance have been operating for at least a decade (e.g. as set out in the series of Reports on Proposals and Policies; Climate Change Act 2009), and others are more recent (e.g. Regional Land Use Partnerships). Assessments of support schemes, such as the Agri-Environment and Climate Scheme (Pakeman *et al.*, 2021), show some measures have the outcomes intended (e.g. improved habitats for pollinators), but not others (e.g. Wader Grazed Grassland and Moorland Management). Methods of monitoring need to be improved to enable effective assessments of schemes, and targeting of resources. Also of note is the increasing number of rewilding projects, some of which are based on woodland restoration, but also agriculture more broadly. These are examples of entrepreneurs who have aims of supporting public goods as well as operating profitably.

Priorities for climate mitigation have focused on investing in natural, social and economic capital. The long term nature of the aim, but shorter and immediate term timescales of actions necessitates a diverse range of actions across sectors and communities, with a coherent set of policies (e.g. planning, land use), and a systems perspective to understand the impacts and dependencies of actions on one dimension on another.

There is a need to continue to improve the quality of scientific evidence between the actions to mitigate climate change and the reductions in the emissions of greenhouse gases, and their impact on achieving the Paris Agreement target of limiting global warming to 1.5°C (United Nations, 2015). Understanding the links between those actions and their impacts should form part of a wider strategy for communications to raise public understanding of the magnitude and potential impacts of climate change, and motivating actions that achieve outcomes of climate mitigation or adaptation. Such a strategy requires investment in developing the human capital required to achieve the Scottish target of net zero by 2045, delivered by means tailored to specific audiences (e.g., citizens, civil society, business) through credible and trusted sources. Those investments need to be inclusive, accessible and relevant across gender, age, ethnicity and geography.

Achieving the desired outcomes will only be possible through actions and communications that are tailored to social, economic and geographic contexts. Such tailoring does not mean that the pathways to net zero will be easy or without adverse economic or social impacts, with delayed actions likely to become more difficult and unpalatable. However, account has to be taken to ensure that places, peoples or sectors are not disadvantaged in the transitions to net zero. The approaches taken should treat all places and people with respect and dignity for their initiatives and contributions to an objective shared globally, cultural contexts, and lock-ins to existing ways of operating, and provide protection and support from consequences of changes in work, and ways of life. They should also embrace means of incorporating the strengths of all types of arts for stimulating innovation and communicating ideas in ways that can create high levels of impact.

Step changes are needed in the broadening of capabilities of citizens, communities and businesses in rural areas such that they can be motivated and empowered to take create or take advantage of opportunities emerging (e.g., new and emerging digital technologies and concepts; support for innovation in local areas). Facilitating those step changes requires education, learning, and support mechanisms that are informed and responsive to the needs of rural areas, and are contributors to and users of Open Science. This can also benefit from a coordinated approach to using high impact events relevant to achieving net zero GHG emissions, to raise understanding amongst audiences across Scotland, and motivate actions on the ground.

Key to achieving the targets will be to motivate and empower citizens (as individuals, or with responsibilities under public or private sectors or civil society) to be agents of change, whilst recognising that human capital and the roles of individuals within a community differ. People need to be able to recognise links between investments in mitigation and adaption they make, or are made in their name, and to understand how the outcomes of actions will affect them now, and affect future generations. They also need an honest and transparent assessment of whether or not the actions worked, and evidence of positive, or negative, impacts created by those actions.

Achieving the shared global aims of a just transition to net zero within set timescales (2045 or 2050) will benefit from the transfer of knowledge and good practice, across nations and geographic levels. The approaches adopted for rural Scotland will gain from being open to ideas from other countries and regions, and Scottish approaches can be expected to make significant contributions to planning and travelling along pathways towards achieving the shared ambition.

# 1. Introduction

One key objective of public policy in Scotland is to achieve net zero greenhouse gas emissions by 2045. This is expressed as "ending Scotland's contribution to climate change, restoring nature and enhancing our climate resilience, in a just and fair way." (Scottish Government, 2021a).

The evidence of actual and projected changes in the climate of Scotland, and the prospective impacts on rural areas, set the context for strategies of mitigating and adaption that reduce greenhouse gas emissions in line with international commitments (e.g. Paris Agreement; United Nations, 2015). The agreements at COP26 (Glasgow, UK, November 2021) are steps in the pathway(s) towards net zero and 'keep alive the Paris Agreement target of limiting global warming to 1.5ºC.' The implications of those agreements is a path to between 1.8°C and 2.4°C of warming, above the target of the Paris Agreement of 1.5°C, but marking progress in several areas affecting in particular rural areas. Notable amongst those are: i) the Declaration on Forests and Land Use, which refers to "promoting an inclusive rural transformation", and building resilience, enhancing rural livelihoods and recognising the multiple values of forests; ii) the Global Methane Pledge to reduce global anthropogenic methane emissions across all sectors by at least 30 percent below 2020 levels by 2030 including the "abatement of agricultural emissions through technology innovation as well as incentives and partnerships with farmers"; conclusion of the Paris Rulebook, the guidelines for how the Paris Agreement is delivered; and a US$100 billion annual target for adaptation finance from 2025. Arguably, the most significant statement is the first direct reference to "phasing down unabated coal power" (responsible for 40% of global $CO_2$ emissions), which will focus attention on ensuring just energy transitions for mining communities.

The principal strategic approaches being taken in Scotland are set out in the Climate Change Action Plan Update (Scottish Government, 2020a), consistent and contributing to those of the United Kingdom, European Union and globally. Rural areas are significant contributors towards those strategies, notably in climate mitigation (e.g. woodland expansion, peatland restoration, renewable energy generation, and broader environmental management), and adaptation by community and business initiatives. New forms of governance are being designed, the aims of which are to provide mechanisms of tackling climate change (e.g. Regional Land Use Partnerships, RLUPs) through place-based planning, investment in natural capital, through and with engagement and participation of communities and civil society. At all levels, and throughout the processes of transitions, they must be fair and just, respecting the contexts and needs of different places, communities and sectors of society.

The SHERPA UK Multi-Actor Platforms (Rural Scotland and River Dee Catchment) have brought together some of the most recent evidence of relevance to the discussion, and reflected on those strategies, the nature of the transitions required to achieve climate neutrality, identification of gaps in policy, practice and knowledge, and topics requiring particular attention.

## 2. Climate Change and Projections

The Met Office (2021) report that average temperatures in the UK for 2008 to 2017 were 0.3°C warmer than those for the period 1981 to 2010, and 0.8°C warmer than the period from 1961 to 1990. There has been an increase in annual average rainfall over the UK. This is most notable for Scotland, with an average of 11% more precipitation for the period 2008 to 2017 compared to 1961 to 1990, and 4% wetter than 1981 to 2010.

The UKCP18 (2018) provides comprehensive estimates of projections of climate change for the UK. Figure 1 shows representations of the geographic distribution of temperature and rainfall for the UK under a high emissions scenario, referred to as 'Business as Usual' (RCP8.5), from the Regional projections (12 km) of the Met Office's Hadley Centre climate model (RCP8.5; Met Office, 2021).

Each projection (Figure 1a, b) shows reductions in winter rainfall around the Moray Firth, including Caithness and east Sutherland. Amongst other implications, reduced rainfall in Caithness and Sutherland could slow the rate of rewetting of peatlands and thus the restoration and mitigation of GHGs from the significant peatland resources in these areas (see Section 5.2). That slowing could be exacerbated by the higher temperatures projected for these areas.

Both projections are for increased rainfall in areas such as Angus and the Solway coast of Dumfries and Galloway, the former of which could be expected to have implications for the enhanced production of soft fruit in Scotland, and the latter may aid the rewetting of peatlands. However, in each case higher temperatures are likely to create challenges for both such land uses.

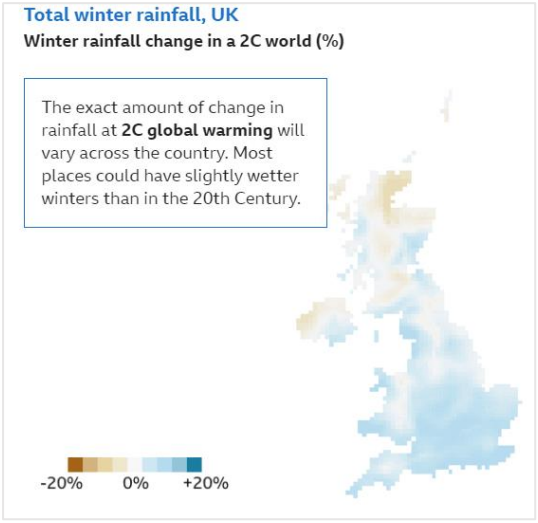


**Figure 1 (a)**. Percentage change in winter rainfall across the United Kingdom, under a 2°C global warming (source: www.bbc.co.uk/news/resources/idt-d6338d9f-8789-4bc2-b6d7-3691c0e7d138)

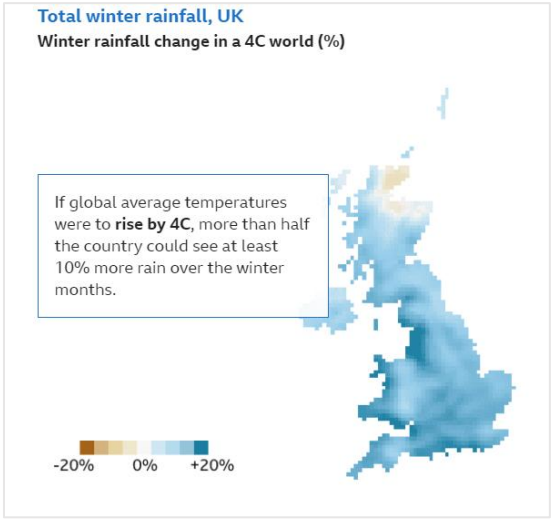


**Figure 1 (b)**. Percentage change in winter rainfall across the United Kingdom, under a 4°C global warming (source: www.bbc.co.uk/news/resources/idt-d6338d9f-8789-4bc2-b6d7-3691c0e7d138)

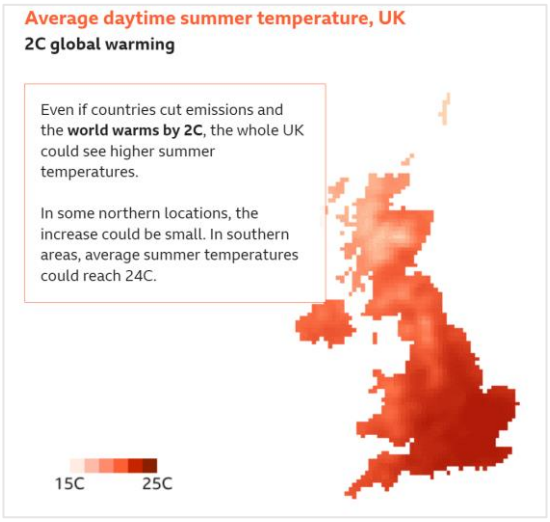


**Figure 1 (c)**. Average daytime summer temperature across the United Kingdom, under a 2°C global warming (source: www.bbc.co.uk/news/resources/idt-d6338d9f-8789-4bc2-b6d7-3691c0e7d138)

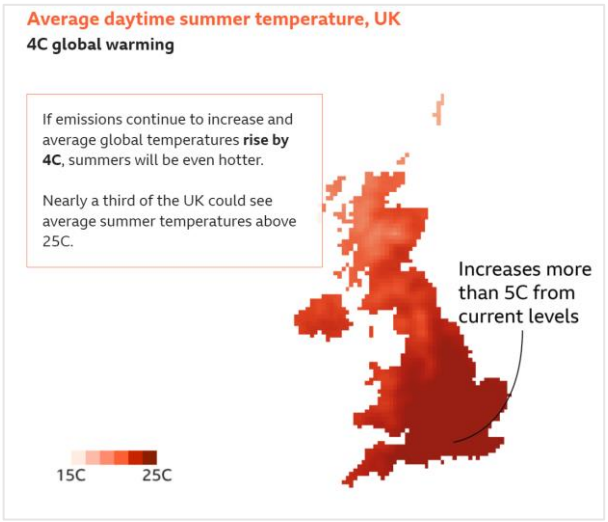


**Figure 1 (d)**. Average daytime summer temperature across the United Kingdom, under a 4°C global warming (source: www.bbc.co.uk/news/resources/idt-d6338d9f-8789-4bc2-b6d7-3691c0e7d138)

Figure 2 shows a summary of the projected rainfall and temperatures, for summer and winter, for a location in central Scotland, with a 2°C and 4°C rise in temperatures since the mid-19th Century. In summary, the projections are for summers to become warmer and drier, and winters to become warmer but considerably wetter.

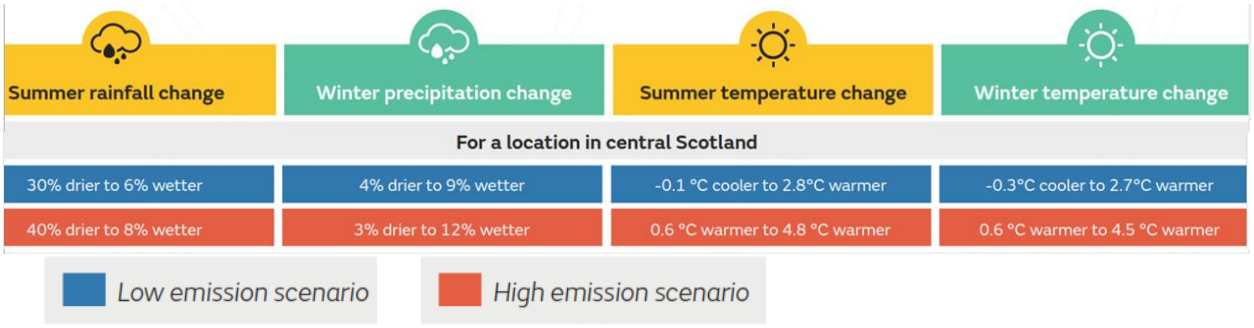


**Figure 2.** Summary of projections of temperature and rainfall for a site in central Scotland under UKCP (Source: Met Office, 2021).

A summary of projected changes is provided in Table 1 for a location in rural north-east Scotland, centred on Inverurie, Aberdeenshire. These projections use the new local (2.2 km resolution) estimates of the UKCP18 (Met Office, 2021).

**Table 1.** Summary of observed and projected changes in metrological characteristics of location in north-east Scotland, Inverurie, Aberdeenshire (source: Met Office, 2021, and BBC, www.bbc.co.uk/news/resources/idt-d6338d9f-8789-4bc2-b6d7-3691c0e7d138)

| Metrological Characteristic | Observed Values (1990 to 2020) | 2°C Rise in Temperatures | 4°C Rise in Temperatures |
|---|---|---|---|
| Hottest summer day | 28.5°C | 30.4°C | 34.3°C |
| Hottest winter day | 16.2°C | 17.2°C | 18.3°C |
| Days above 25°C / month | 0 days | 1 days | 4 days |
| Days rain / month in summer | 12 days | 12 days | 10 days |
| Days rain / month in winter | 12 days | 12 days | 12 days |
| Wettest summer day | 51mm | 56mm | 70mm |
| Wettest winter day | 55mm | 57mm | 58mm |

The SHERPA Discussion Paper cites the Copernicus Climate Change Service in its reporting that for Europe as a whole, 2020 was the "warmest year on record for Europe, and globally, 2020 ties with 2016 for warmest year recorded" (Miller *et al.*, 2021). It also describes the European Environment Agency assessment of observed and projected climate change for the biophysical regions of Europe. For the Atlantic region, which includes the UK, or projects increases in heavy precipitation events, river flows, risks of river and coastal flooding, damage risk from winter storms, and multiple climatic hazards. It also anticipates that demand for energy for heating could reduce due to increased temperatures (European Environment Agency, 2020).

The Third Climate Change Risk Assessment for Scotland (SNIFFER, 2021) sets out the evidence, assessments and interpretations of risks and opportunities of climate change for Scotland, as one of the national summaries for the UK wide assessment (Betts and Brown, 2021). Overall, it concludes that climate change "continues to affect the natural and marine environment across Scotland, as well as its agriculture and forestry, landscapes and regulating services such as pollination." It reports flooding as one of the most severe risks, threatening people, communities, buildings and infrastructure, and the costliest hazard to businesses, and high temperatures as having the potential to "affect a wide range of health and social outcomes."

Flood events can adversely affect the connectivity of people and places in rural areas. Weak points in the transport and utility networks get revealed, and the resilience of infrastructure and communities is tested. Miller *et al.* (2012) reported on the impacts on mental health and wellbeing of flooding, citing evidence that "… flood disasters, and associated experiences, can have severe and long-lasting social and health impacts, with emotional and psychological impacts often being more severe and longer lasting (e.g. 4 years) than physical damage to property, lives and health." The effects of flooding can include grief and loss (of life or materials assets, such as housing, business premises, crops), uncertainty, emotional exhaustion, loss of hope and meaning and Post-traumatic Stress Disorder (PTSD). Outcomes include adverse impacts on the ability of people to continue to live or work in an area, for direct reasons such as the loss of infrastructure, or indirectly due to inability to obtain insurance cover or perceptions of risk.

SNIFFER (2021) presents risks and opportunities associate with climate change across 61 topics, under headings of natural environment and assets (6 risks, 4 risks and opportunities, 4 opportunities); infrastructure (13 risks); health, communities and the built environment (13 risks, 1 risk and opportunity, 1 opportunity); business and industry (6 risks, 1 opportunity); and international dimensions (10 risks, 2 risks and opportunities, 2 opportunities). Of the 62 topics, 19 were identified as requiring further investigation.

Almost all topics have relevance to rural areas. Details can be read in the set of reports by UK Climate Risk Assessment 3 (Betts and Brown, 2021). In discussion, members of the UK MAPs identified a selection of headings from those reported upon in the CCRA3, and are reflected in the SHERPA Discussion Paper (Miller *et al.*, 2021), and UK MAPs paper on Long Term Vision for Rural Areas (Miller *et al.*, 2020).

**Risks**

- Agriculture: Pests, pathogens, and invasive species, noting that an "increase in the range, quantities and consequences of pests, pathogens and invasive species, will negatively affect terrestrial, freshwater and marine priority habitats species, forestry and agriculture".
- Forestry: Pests, pathogens, and invasive non-native species, noting that these "present serious risks to forest productivity, with consequences for livelihoods and businesses, and for the multiple ecosystem services that forests provide".
- Soils: Pressures on soil quality due to heavier rainfall events (causing erosion, compaction, pollution), increased soil moisture deficits in summer (causing loss of soil biodiversity and organic matter), with adverse consequences for water quality, freshwater biodiversity, and GHG emissions (Neilson *et al.*, 2020).
- Freshwater species and habitats: Changing climatic conditions and extreme events, including higher water temperatures, flooding, water scarcity and phenological shift; and, pests, pathogens and invasive species, noting the vulnerability of species to reduced water availability and higher water temperatures. Other impacts are consequences of changes in snow cover, and thus seasonal runoff on the hydrology and ecology of rivers and lochs, and their associated social and economic functions.
- Landscape character: Changes in landscape character due to climate change (e.g. "biodiversity, soils, geomorphology, hydrological processes, and coastal processes"), mitigation measures (e.g. renewable energy, woodland expansion, peatland restoration), and adaptation (e.g. new land management practices, agricultural systems, changing features of transport systems). Changes in some characteristics of landscapes can then be expected to lead to changes in sense of place and identity, perhaps interpreted in terms of their positive contributions to sequestering carbon.
- Change in demand for goods and services: Providing new products or services in response to needs for mitigation or adaptation to climate change (e.g. repair and maintenance of sites of natural or cultural heritage as a consequence of damage due to extreme events; land management actions for restoring peatlands and nature-based solutions; components of value chains in a circular economy; new carbon neutral or positive products). Such changes in demands can be expected to require associated new skills and investment in enhancing human capital, and consideration of the diversity of composition of society (e.g. cultures, gender, age, ethnicity), and their geographic distribution.
- Food availability: noting that "shoppers in rural locations, with access to smaller and more highly dispersed retail outlets, will be exposed to different risks as availability of food will vary more, as well as its price." Changes in climate can also be expected to impact on the sources and availability of some products (e.g. coffee). Changes in consumer preferences and demand may also lead to changes in markets, with consequences for the viability of individual products.
- Infrastructure networks (water, energy, transport, ICT): Cascading failures, reflecting the risks to individual elements of infrastructure. Examples of such infrastructure at risk are, energy production impacted upon by extreme weather events such as storms, lightening, high winds; transport due to extreme heat, storms, flooding, and exposure to single points of failure, particularly in rural areas, of bridge collapses and landslips cutting communication routes; telephone networks damaged due to storms, with associated loss of access to information through internet communications. Note is also made of the interdependencies of risks, with disproportionate impacts of failures in rural areas, such as the length of detour due to disruption to transport infrastructure (illustrated in Appendix 1; Jaroszweski *et al.*, 2021).
- Human health and wellbeing: High temperatures, flooding and storms, noting impacts on personal safety and human health and wellbeing (e.g. increases in acute mortality due to heat stress; physical damage restricting options for physical exercise) (Kovaks and Brisley, 2021). Other significant consequences are on mental health and wellbeing due to stress created by perceptions of risks on personal safety and assets (e.g. housing), businesses (e.g. properties, fields) and associated issues (e.g. insurance), and stress associated with responsibilities for family, caring, and social support within communities. Of particular note is the importance of providing support within communities before crises arise rather than reacting to crises post-event.

- Services and support: Some members of society are disproportionately exposed to risks with consequential impacts on mental health, such as migrant workers who lack knowledge of how to access support or services (e.g. know of relevant resources in country of origin but not in the UK).

**Opportunities**

- Agriculture and forestry: New/alternative species becoming suitable, noting the potential for enhanced agricultural and forestry productivity due to changed climatic conditions, the introduction of new crops including 'productive' species, and those which are valued for other properties (e.g. woodcraft, amenity value), and species better suited to bioenergy sources. The replacement of the Common Agricultural Policy, now scheduled for 2024, provides an opportunity for Scotland to coordinate land uses, food production, rural communities, nature recovery and climate change in order to reduce emissions. In making these decisions, consideration is required of Scotland's competitive and comparative advantages nationally and internationally.

**Risks and opportunities**

- Natural carbon stores, carbon sequestration and GHG emissions: Exacerbated risks to peatland degradation and carbon losses due to intense rainfall causing runoff, and oxidation due to warmer climates, and loss of vegetation due to wildfires. Opportunities are enhanced rates of carbon sequestration due to milder and wetter bioclimates, allowing high primary productivity.

In responding to the types of risks above, management practices require to be well informed and effective, using contemporary knowledge and techniques. For example, poor land management could exacerbate soil erosion, release soil carbon, pollute water courses and reduce aquatic and terrestrial biodiversity. A limitation to informing policy and management interventions, and of tracking emissions, is a lack of regular and systematic monitoring of soil carbon across diverse land uses, bioclimatic zones, and management practices. This assessment also reflects the evolution of the prospective opportunities and risks through time. For example, it notes that, "while opportunities are possible (such as potentially longer growing seasons), these are not currently being realised due to adaptation barriers, hence this risk increases from medium at present to high in future, with a significant adaptation gap, especially for agriculture."

Berry and Brown (2021), in the Climate Change Risk Assessment on natural environment and assets, report potential synergies between "woodland creation and peatland restoration, low carbon farming, and wetland and coastal/marine habitat and saltmarsh restoration". However, the Climate Change Risk Assessment also observes that there is no systematic national assessment of interdependency risk or a framework to improve resilience at the UK level.

The UK MAP identified the need for a regional and Scottish level assessments of interdependencies of risks, linking the biophysical, economic and social implications of climate change. Those assessments should be designed to inform multi-level planning, at strategic national levels (National Planning Framework 4), and the new regional spatial strategies. They should also form part of the information available to the RLUPs in their consideration of locally significant priorities.

Since the UKCIP02 climate projections, and then UKCP09, the UKCP series of data have been central to the deliberations of policy and science on potential changes in climate across the UK. They have informed the development of weather generators for use in design and planning such as thermal simulations for buildings (e.g. Eames *et al.*, 2011), and modelling of prospective changes in land capability for agriculture (Brown *et al.*, 2011), as discussed in the UK MAP Discussion Paper on visions for rural areas (Miller *et al.*, 2020).

The collaboration between the Met Office and the BBC has provided easy access to data on historic, current and projected changes in climate, at levels from local to national. It combines the pre-eminent UK authority on climate modelling with the outreach of the national broadcaster. This significantly simplifies the range of outputs produced from the modelling undertaken in UKCP18 (Met Office, 2021), and their availability to public audiences.

**Further requirements for policy, practice and research**

- The ongoing production of projections of climate change, and the tailoring of messages of how it might affect people in areas in which they live, work and recreate is a core part of a strategy for raising public understanding of the magnitude and potential impacts of climate change. Ongoing support for ensuring the best scientific evidence is available should be accompanied by the further development of effective

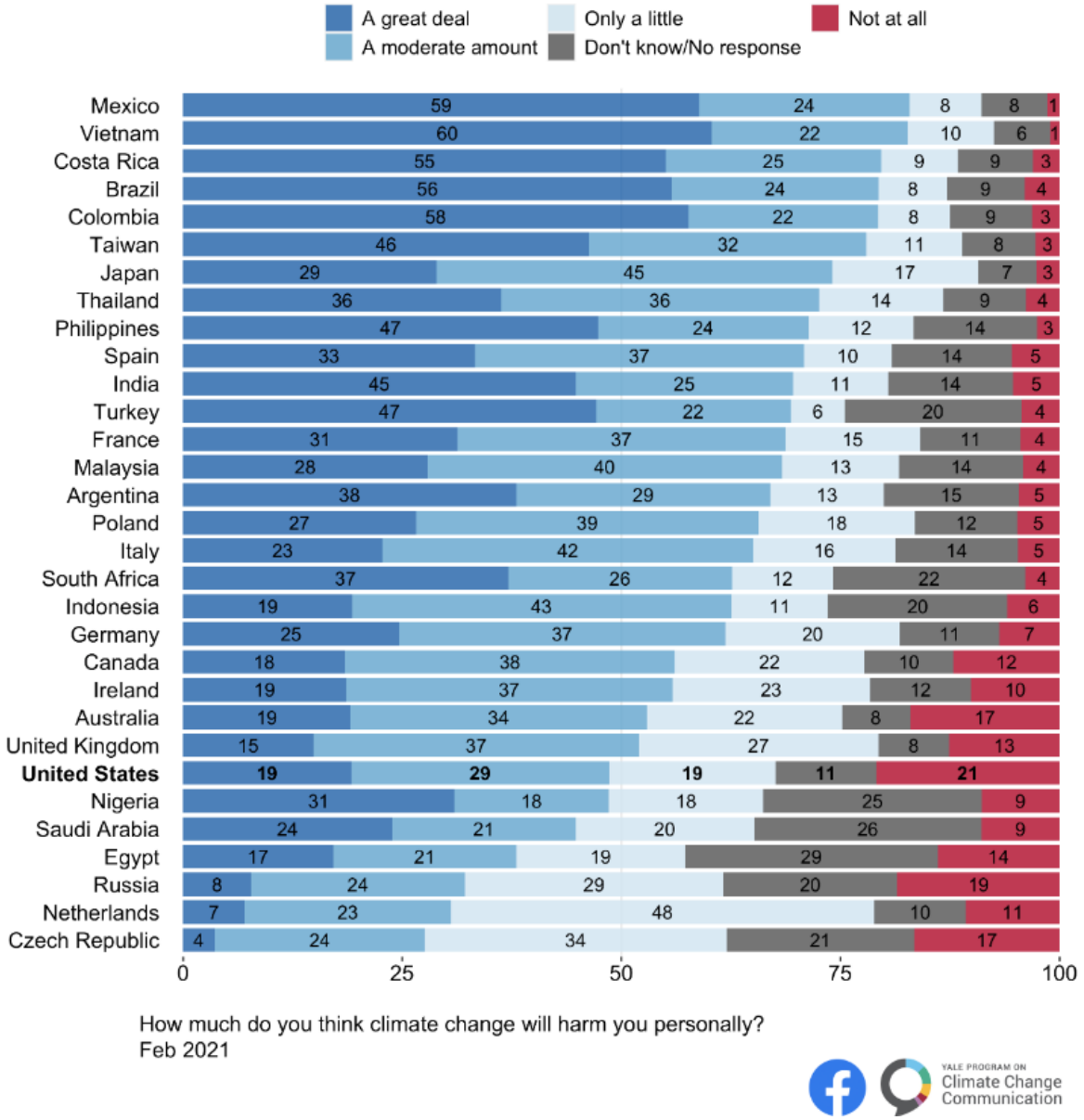


**Figure App.2.19.** Responses to the question "Do you think climate change should be a very high, high, medium or low priority for the government?" (Source: Leiserowitz *et al.*, 2021)

means of communication, learning lessons from practices such as the emergence of online dashboards, storymaps and infographics. [Also reflected in recommendations in Section 4].

- Monitoring of soil carbon and support for interventions by land managers (agriculture, peatland restoration), and quantitative data of how these influence GHG emissions. An associated need is understanding of land manager attitudes towards the benefits of monitoring, and their understanding and effective use of the data generated. [Also reflected in recommendations in Section 5.4].
- Benefits could be gained from internationalising the types of information in such a way that messages are conveyed for places with which a high proportion of the Scottish population have some familiarity (e.g. for holidays, media coverage, sports events). Although not directly equivalent, similar such information could be brigaded across Europe, and beyond, exploiting the capabilities of EU relevant institutions such as European Environment Agency, and the EU Copernicus Programme and Copernicus Climate Change Service (C3S) database.

# 3. Public Attitudes to Climate Change

## 3.1. Climate change as a problem

The Scottish Household Survey (Scottish Government, 2019) has collected data on public perceptions of climate change as a problem. The series of data are presented in Figure 3. Between 2013 and 2019, there has been a change in perception of 'climate change as an immediate and urgent problem' increasing from 46% (2013) to 68% (2019), and a decrease in those reporting 'Climate change is more of a problem for the future', dropping from 25% in 2013 to 14% in 2019. Those who did not consider climate change as 'not really a problem' or 'I'm still not convinced that climate change is happening', both dropped, to 3% and 6% respectively (Scottish Household Survey; Scottish Government, 2019). This is consistent with the reporting Ipsos MORI (Setterfield and Murray, 2020), showing an increase in perceptions that climate change is an immediate and urgent problem, from 68% to 79% (October 2020), and a reduction in the perception that climate change is a problem for the future (from 14% to 11%).

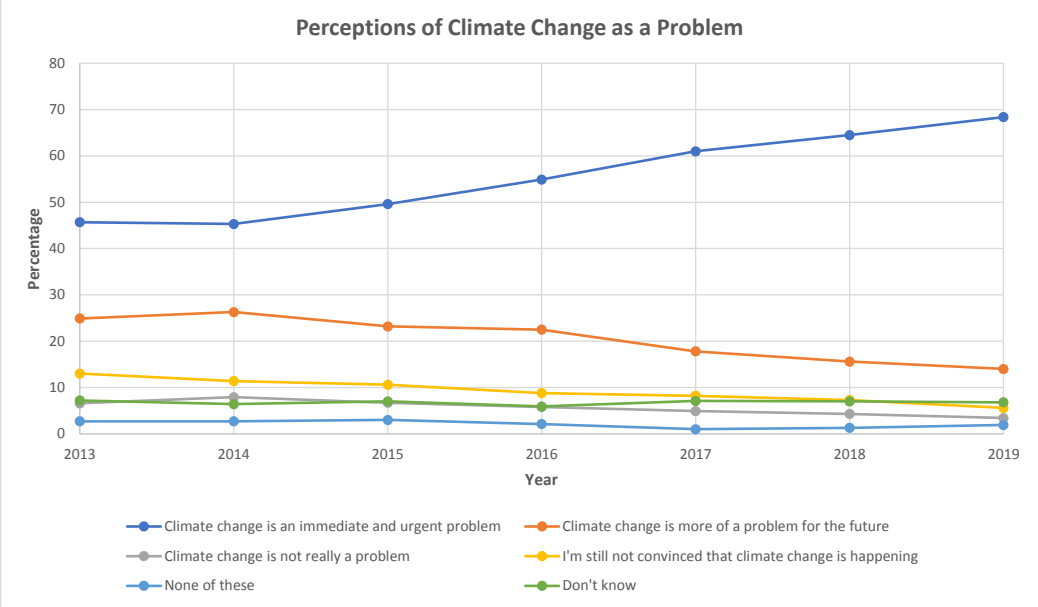


**Figure 3.** Perception of climate change as a problem, 2013 to 2019 (Source: Scottish Household Survey, accessed 1st September 2021).

When analysed with respect to levels of deprivation (Scottish Index for Multiple Deprivation; SIMD), over the period 2013 to 2019, climate change has been perceived, consistently, as more of an immediate and urgent problem more by those in least deprived areas and least in the moist deprived areas. Over that time period, the perception amongst the 20% least deprived areas (rose from 52% in 2013, to 75% in 2019), and in the 20% most deprived areas (38% in 2013, dropping to 34% in 2014, rising to 69% in 2019) (Appendix 2).

The geographic distribution of the respondents who perceived climate change as an immediate and urgent priority is presented in Figure 4 for the snapshots in time of years 2013, 2016 and 2019. The greatest change in proportion of respondents expressing this opinion was in Dumfries and Galloway (up from 35.7% to 75.9%, a difference of 40.2%), followed by Dundee City with the highest proportion of such responses of 79.7%, (up from 40.9%, a difference of 38.8%).

The lowest proportion of responses in this category is in Angus (53.0%), up from 35.4% in 2013. The lowest value reported is for the Outer Hebrides or Western Isles (Na h Eileanan Siar) (31%), down from 46.3% in 2013, and within a range of 38.9% (2014) and 63.7% (2015)[1].

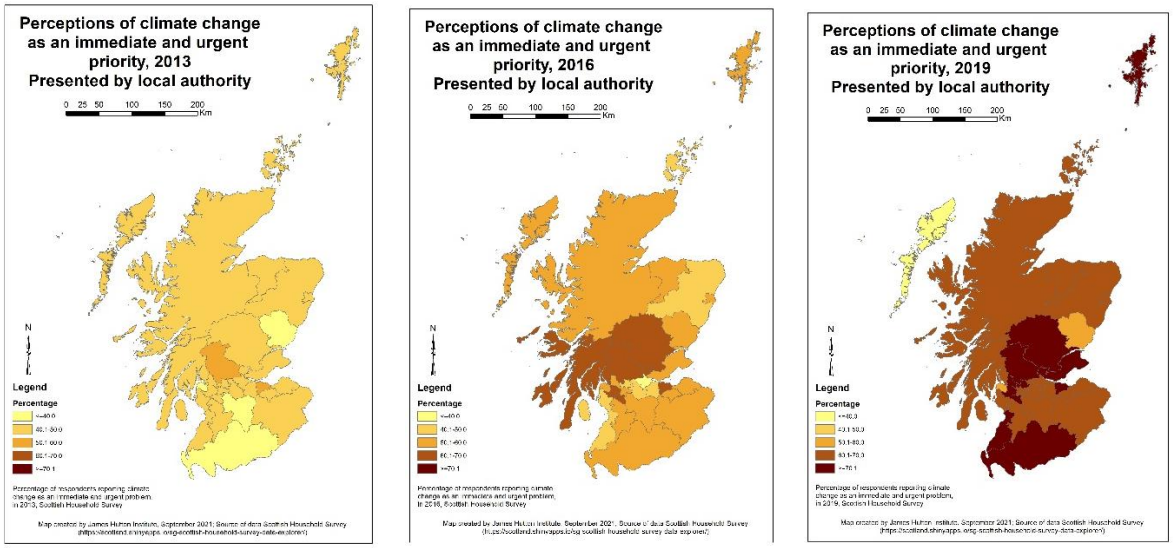


**Figure 4.** Perception about climate change as an 'immediate and urgent problem' by local authority 2013, 2016 and 2019 (Source: Scottish Household Survey, accessed 1 September 2021).

These findings are broadly consistent with those of the European Union Member States. In the Special Eurobarometer 513 survey of European citizens in March to April 2021 (European Commission, 2021a), climate change was identified as a 'very serious problem' by 78% of respondents. Figure 5 shows the issue identified as the most serious facing the world today. As of March 2021, Climate Change had become the identified as the most serious issue, closely followed by Poverty, Hunger and Drinking Water, and the Spread of Infectious Diseases, albeit down from the highest level it reached, in April 2019. However, attitudes are not consistent across all countries, with 43% of respondents in Sweden reporting it the most serious problem, compared to 5% in Bulgaria. Further details are provided in Appendix 2 of the findings of the surveys of public attitudes to climate change in Europe.

[1] Data for Na H Eileanan Siar are being checked with Scottish Government for possible explanations for the values in the data series relating to perceptions of climate change being an immediate and urgent problem.

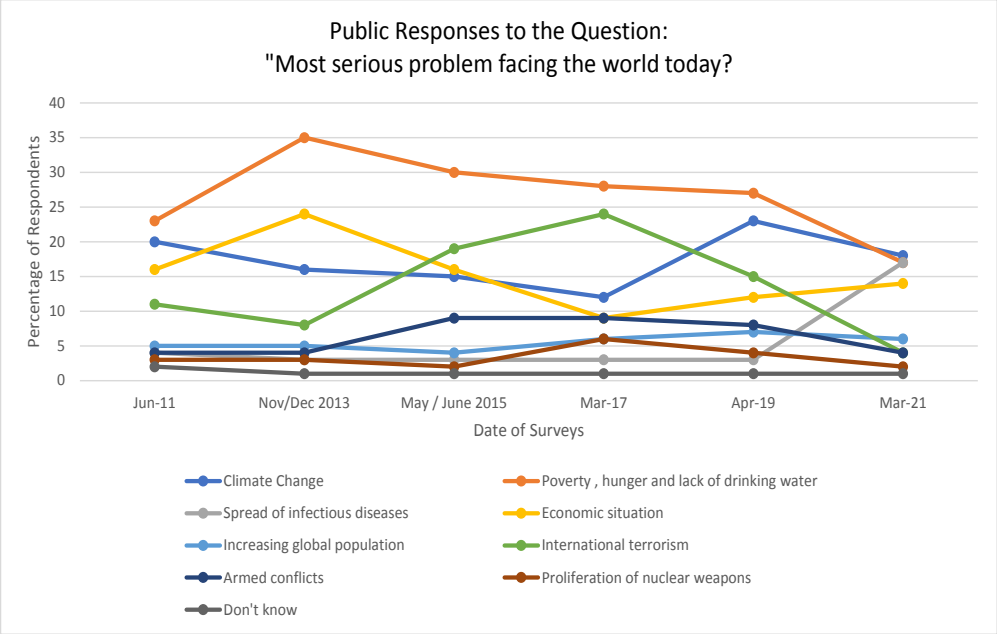


**Figure 5.** European Commission, Special Eurobarometers 490 and 513, July 2021 (*notes: options changed between 2019 and 2021 surveys; number of respondents, Eurobarometer 490: 27,655; Eurobarometer 513: 26,669).

No survey has been published of data collected post-COP26 but can be expected from the existing series or *ad hoc* surveys, in 2022. Those surveys provide insight to how public attitudes towards changing behaviours (e.g. working from home, commuting, lifestyle) have been influenced by the experiences of COVID-19, with potential implications for the development and implementation of policies for tackling climate change.

## 3.2. Interventions to tackle climate change

As noted in the SHERPA Discussion Paper (Miller *et al.*, 2021), support and implementation of policies for mitigating or adapting to climate change can be expected to be informed by the attitudes of people towards climate change. Polling of people across countries, using a range of approaches, has sought opinions on the types of topics of policies that should be adopted to tackle climate change.

One survey, for the UNDP (2021), provided 18 options. Figure 6 shows the results for the 10 most frequent responses amongst high income countries, of which conserving forest and land was supported by the highest proportion of respondents (74%). Other topics which received high levels of support included the use of renewable energy (68%), climate friendly farming techniques (63%), and building infrastructure and conserving nature to protect lives and livelihoods (63%). UNDP (2021) also report majority support for more green investment from respondents from the G20 countries in the survey, of which the UK had the highest proportion (73%).

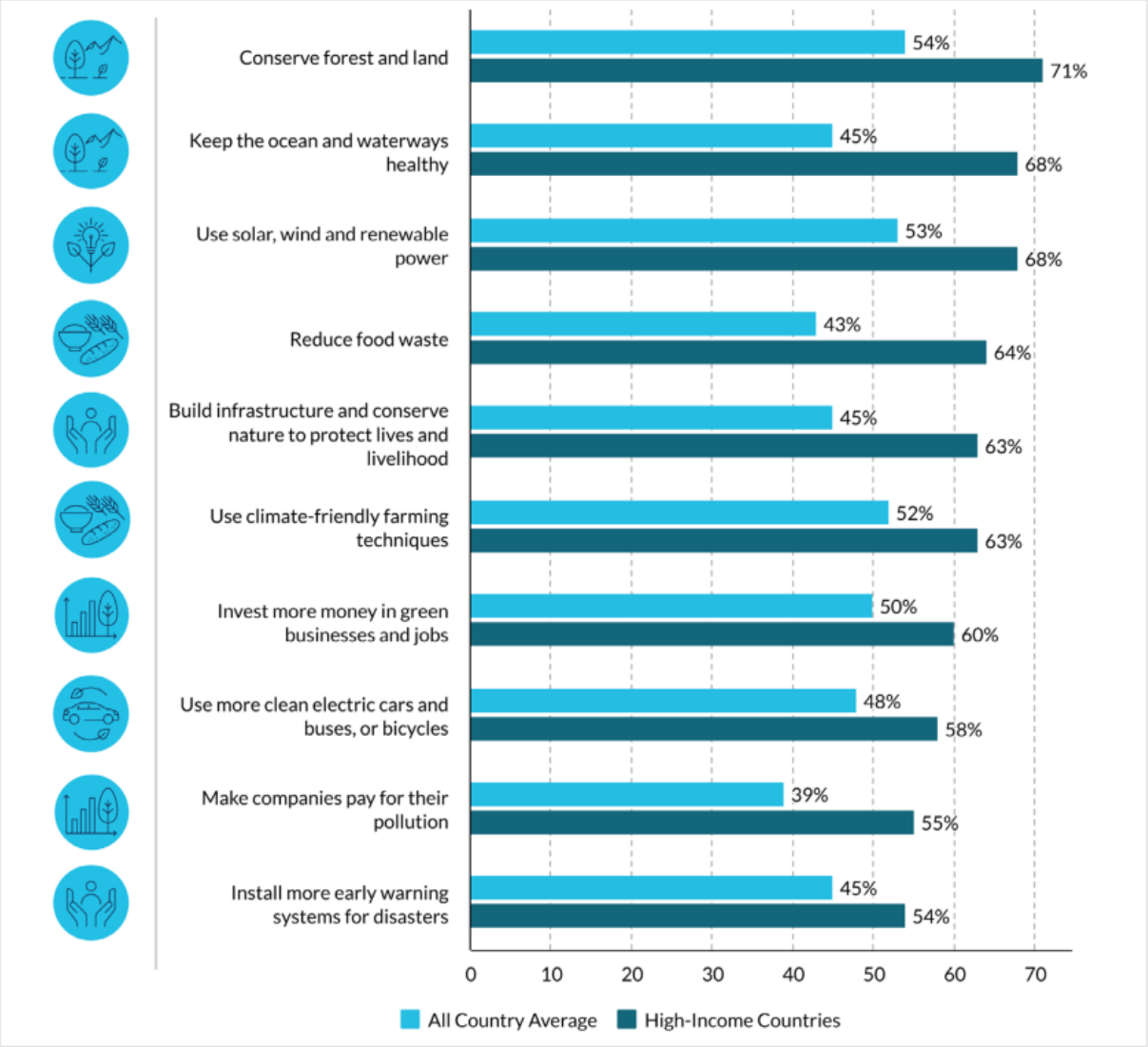


**Figure 6.** Ten most frequent responses amongst high-income countries (source: UNDP, 2021).

In 2020, the Eurobarometer (European Commission, 2020c) of public attitudes in EU Member States reported 47% of respondents 'Totally agree' to the question 'We should reduce greenhouse gas emissions to a minimum while offsetting the remaining emissions, for instance by increasing forested areas, to make the EU economy climate neutral by 2050' and 43% 'Tend to Agree.' This is 2% lower than the response to the equivalent question in 2019.

In each survey since 2011, responses have been sought from a set of 15 possible actions to fight climate change. In 2020, the most frequent response was 'try to reduce their waste and regularly separate it for recycling', by 75% of respondents, up from 66% in 2011. However, the positive responses to 10 out of 15 options were down in 2021 compared to 2019. These include consideration of the carbon footprint when planning transport (11% in 2021 compared to 12% in 2019), and when purchasing food (16% in 2021 compared to 18% in 2019).

In 2021, two questions were added. They sought opinions towards: i) eating more organic food, to which 32% responded favourably, albeit varying nationally from between 12% (Hungary) and 49% (Slovenia); ii) buying and eating less meat, with 31% responding favourably, varying nationally from between 12% (Romania) and 55% (Netherlands).

Evidence from the annual Scottish Household Surveys suggest (2016 to 2019) that a strengthening of belief that changes in personal behaviours and lifestyles can help tackle climate change (see Appendix 2).

Setterfield and Murray (2020) report that 56% of respondents strongly supported 'charges for items that are harmful to the environment that can be replaced with suitable alternatives', and a further 26% who would 'Tend to support' such charges (Figure 7). More than 50% of respondents also 'Strongly' or 'Tended to agree' with policy initiatives that would invest public money in low carbon companies (combined, 68%), replacement of gas and oil-fired boilers (61%), reducing the area of land for production of food and replacing it with habitat restoration (60%), and reducing land used for food and using it for carbon capture or storage (57%). It is not clear if the questions were accompanied by examples of what types of land uses might be changed. However, land use for carbon capture or storage can be assumed to be woodland and peatland. Further details of the findings from these surveys are provided in Appendix 2.

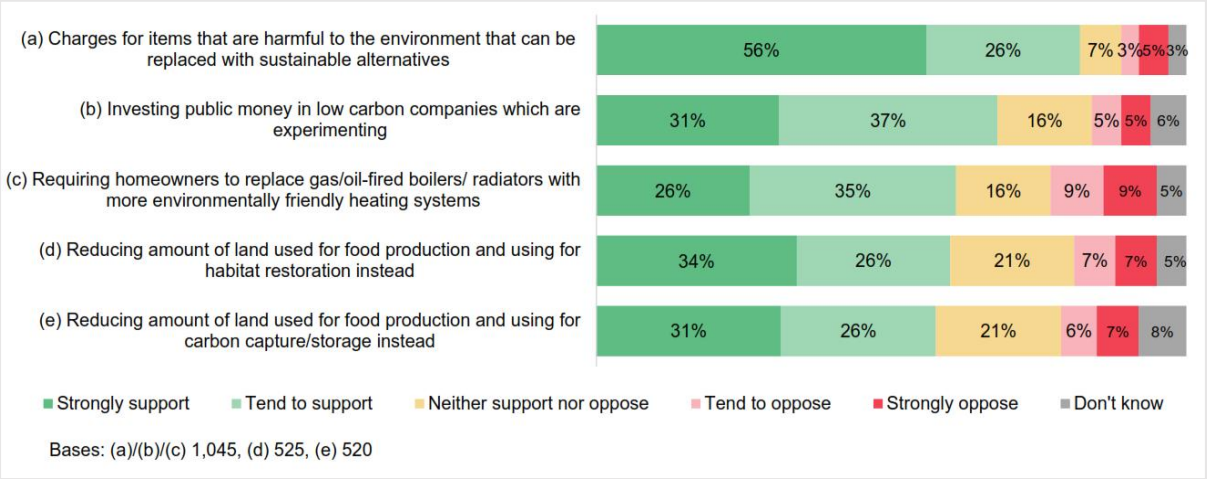


**Figure 7.** Levels of support for selected policy measures (Source: Setterfield and Murray, 2020).

Follow-up questions were asked to explore reasons for support or opposition to a policy option. For four of those measures (a, b, d and e; Figure 8) the reasons given for support identified both their contributions as being good for the environment (in general) and helping to reduce carbon emissions/ climate change.

Of the reasons for opposing measures, four are referred to more than once, 'Negative impact on farming and employment', 'Should be increasing food production, not reducing it', 'Negative financial impact on individuals', and 'Waste of Government/ taxpayers' money'.

No information is provided about the level of respondent understanding of the meaning or terminology used in any of the questions, or potential benefits that could accrue through any of the policies offered. This could be reflected in the level of response of 'Neither support not oppose' for the two questions relating to the use of land (21% for each question).

Two questions were asked about whether respondents would be willing to make a change in personal behaviour in tackling climate change, one in relation to transport and the second in the consumption of red meat (Figure 35). Seventy-four percent of responses was that people would be 'willing to reduce the amount they would travel by car' and 70% would be 'willing to eat less red meat'.

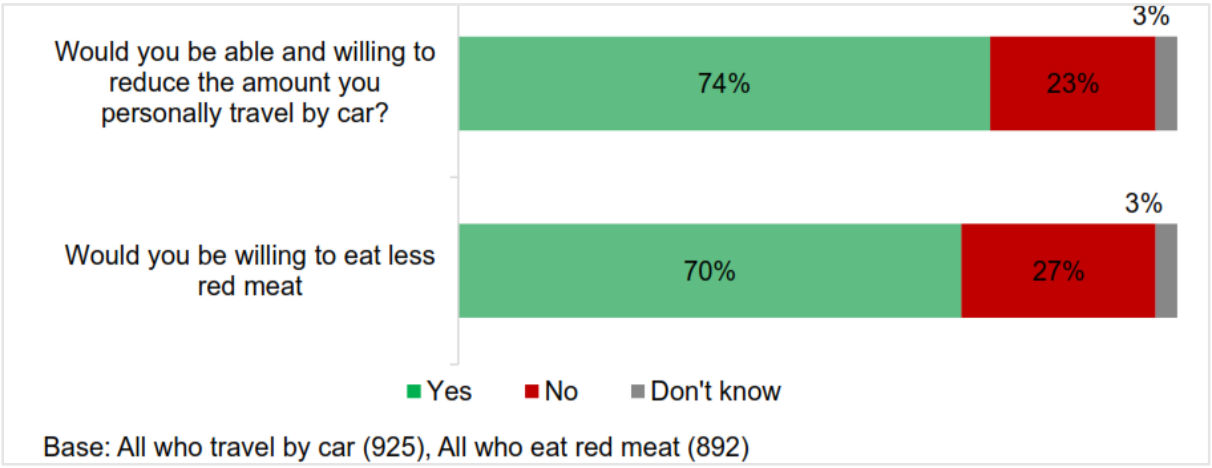


**Figure 8.** Responses to questions about willingness to change personal behaviour for tackling climate change (Source: Setterfield and Murray, 2020).

When asked about what would help with reducing travel by car, the three most frequent responses related to public transport (Figure 36). The most frequent response was for 'Better or increased public transport (28%), followed by 'More frequent public transport' (27%) and 'Cheaper public transport' (18%). 'More working from home' was identified by 4% of respondents.

However, no evidence was sourced of what public audiences understand by each type of policy intervention. For example, the relative contributions of each intervention is the magnitude, or type, of GHGs mitigated, or the relationship between those and increase in temperature associated with a changed climate.

The timing of the fieldwork (October 2020), after the first lockdown restrictions in response to COVID-19, and before the second lockdown. The survey does not include any other insights as to how people's experiences have informed the response, or may have changed since October 2020.

**Further requirements for policy, practice and research**

- The series of snapshots of public attitudes towards climate change, at international, EU, UK and Scottish levels provides some insights to changes in those attitudes over time. Maintaining the series will enable comparison to be made of change through time, and interpretations of the effectiveness of communicating information about climate change, greenhouse gas emissions, and interventions of policy and practice.
- Greater public understanding of the links between specific interventions and the GHGs mitigated, and how that relates to targets for limiting changes in climate (e.g. temperature) is needed.
- The breadth of questions in the Scottish Household Survey should be expanded, enabling comparisons of public support towards interventions for the mitigation of, or adaptation to, climate change between countries.
- The development of credible plans for transitions to net zero that involve policy interventions or changes in personal behaviour (e.g. eating less red meat, reducing use of cars) to then test public understanding and attitudes towards each step in a transition, and the potential barriers to their adoption.

# 4. Greenhouse Gas Emissions

Between 2005 and 2019, GHG emissions from Scotland were estimated to have reduced by 34.7%, from 47,532.3 kt $CO_2$ to 31,045.2 kt $CO_2$, as illustrated in Figure 9 (UK National Atmospheric Emissions Inventory for Scotland (https://naei.beis.gov.uk/laco2app/; BEIS, 2021a). Broad trends are of reductions from most sources (domestic, down 40.8%, from 14,405.9 kt $CO_2$ to 8,523.7 kt $CO_2$; commercial, down 55.6%, and the public sector, down 47.4%. Within the Industry sector, Agriculture is reported as having an increase in emissions for the period 2005 to 2019, up from 1,048.14 kt $CO_2$ 1,241.9 kt $CO_2$ (an increase of 18.5%).

The Land Use, Land Use Change and Forestry (LULUCF) sector (comprising Forest land, Cropland, Grassland, Wetlands (including peatlands), Settlements, and Harvested wood products has reduced from net emissions of 510.0 kt $CO_2$ in 2005 to 164.8 kt $CO_2$ in 2019. For 10 of the 15 years of this period, the LULUCF sector had net negative emissions, most recently in 2019 (-249.0 kt $CO_2$).

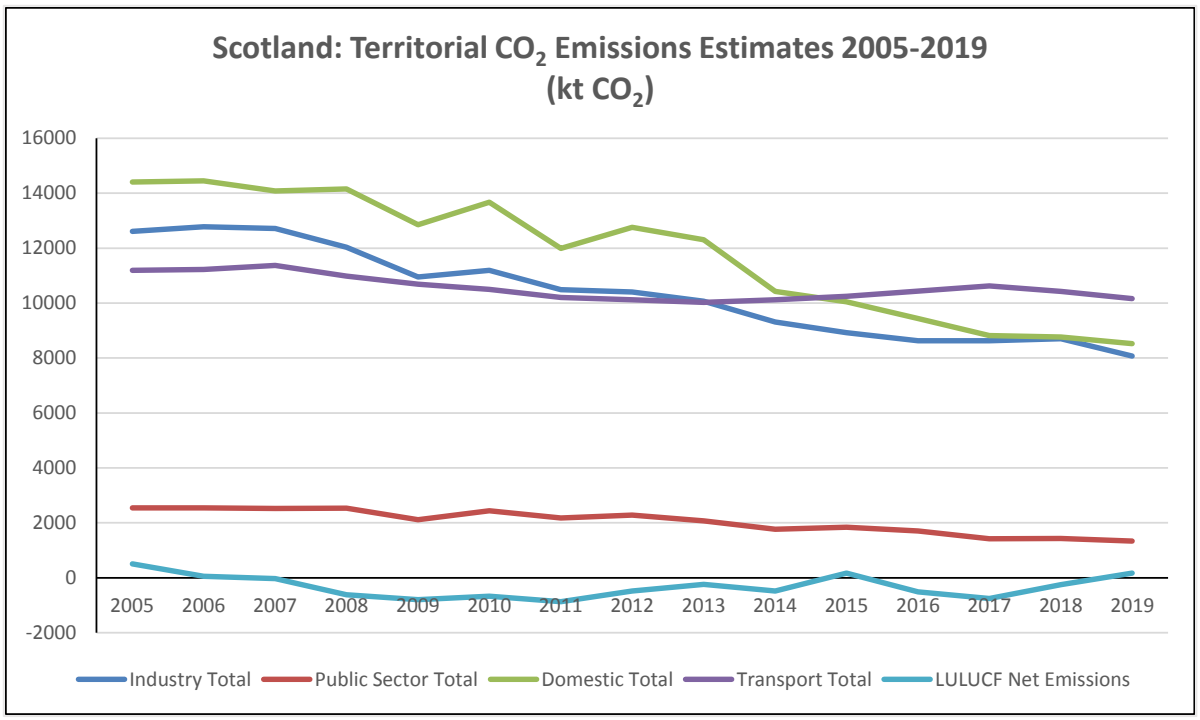


**Figure 9**. Change in net terrestrial $CO_2$ emissions from Scotland (2005 to 2019) (Source: BEIS, 2021a; updated 24 June 2021)

As noted in the SHERPA Discussion Paper (Miller *et al.*, 2021), the European Environment Agency (2020) estimated that, in 2018, land-use change and forestry (LULUCF) represented a net carbon sink of approximately 263 Mt $CO_2$e.

Within the LULUCF sector, the highest emissions are from cropland, dropping year-on-year from 6,454.3 kt $CO_2$ in 2005 to 4,907.2 kt $CO_2$ in 2019 (down 24%; Figure 10; BEIS, 2021a). Over the same period the most significant contribution to net sequestration is that of forest land, albeit reducing from -7,951.5 kt $CO_2$ to -6,894.9 kt $CO_2$ in 2019.

Note that some technical changes to the estimates of emissions particularly around those of wetlands, and that emissions from agriculture in Scotland would change from 7.5 Mt $CO_2$e to 7.7 Mt $CO_2$e for 2018 Scottish Government Climate Change Plan Monitoring Report (Scottish Government, 2021a).

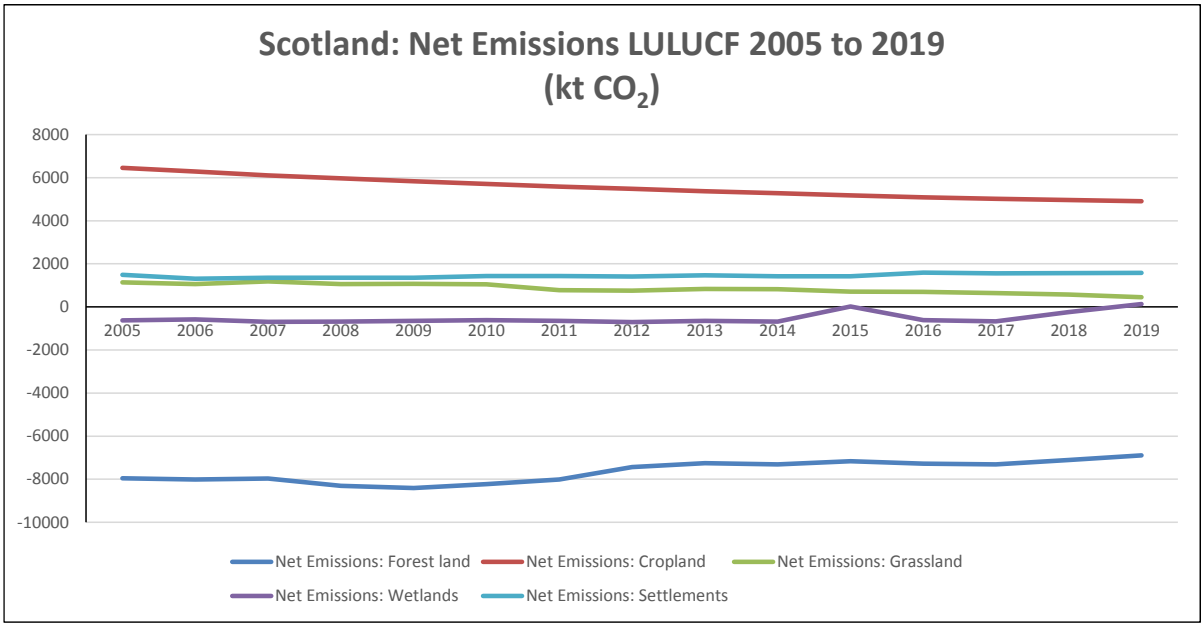


**Figure 10**. Change in net terrestrial $CO_2$ emissions from Scotland from the LULUCF sector (2005 to 2019) (Source: BEIS, 2021a; updated 24 June 2021)

Ways of working, lifestyles and management of resources make both direct or indirect contributions to the emissions or sequestration of greenhouse gases. The magnitude of emissions or sequestration is calculated through modelling, using internationally agreed approaches and standards. For example, details of the calculation of LULUCF emissions in the UK are set out in Brown *et al.* (2021).

However, improvements are required in the measurement and modelling of GHG emissions and changes therein. There is limited on site monitoring of GHG emissions in the UK. Examples are the peatland sites at Forsinard, Caithness; Auchencorth and Whim Mosses, Midlothian. New investments are being made by UK and the Scottish Government, which will expand the UK-SCAPE Flux Tower Network (Morrison *et al.*, 2019), but will take 2 to 4 years to be designed, installed and fully operational. However, they will still only provide a limited sample of combinations of types of soils and land use and management practices.

With the data available, spatial modelling of emissions is enabling the representation of the distribution and magnitude of individual pollutants (e.g. methane, $NO_2$, $CO_2$), and emissions sectors (e.g. agriculture and farming). The National Atmospheric Emissions Inventory is available online (https://naei.beis.gov.uk/emissionsapp/), at a spatial resolution of 1km x 1km, an example of which is shown for methane emissions in north-east Scotland (Figure 11a). It also enables access to information summarised at the level of local authorities. Figure 11(b) shows the level of $CO_2$ emissions from LULUCF for Scotland, northern England and Northern Ireland, with the values presented for Aberdeenshire. In summary, the map shows that for local authorities in north and western mainland Scotland, and southern Scotland, the LULUCF sector is a net sequester of $CO_2$, and for the others it is a source of net emissions.

In very broad terms, at this course level of aggregation, the map reflects the distribution of forestry and near natural peatlands in the uplands, and the predominance of the agriculturally productive areas in the lowlands. In Aberdeenshire, the lowland agriculture is offsetting the sequestration of the forestry, and in Scottish Borders the opposite is the case.

The interventions of policy and practice being planned or implemented, such as woodland expansion, peatland restoration, transitions to agro-ecological farming systems, and uptake of renewable energy can all be expected to enable all rural areas contribute to achieving aims of carbon neutrality. However, not all areas have the same natural or human resources, and therefore have different starting points on transitions, potential trajectories, and likely endpoints as at 2045. A key aspect of the just transition is that those differences in capabilities and prospects should be accounted for in types and levels of support (e.g. investing in human capital), incentives and rewards, and the diversity of perceptions of people with different cultural backgrounds, and the pathways of families (e.g. migration within and into Scotland).

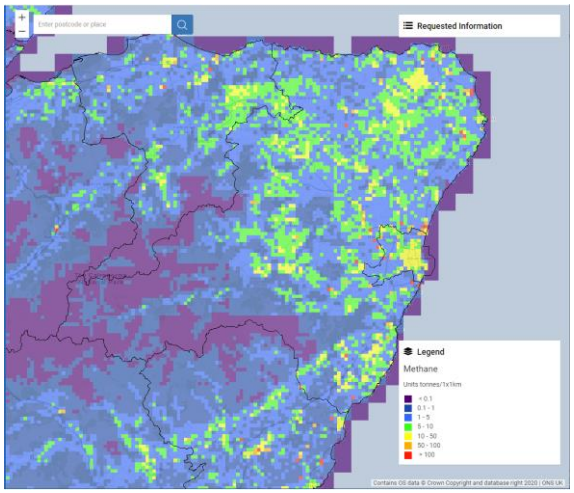


**Figure 11 (a).** Spatial distribution of methane emissions from agriculture in north-east Scotland (source: National Atmospheric Emissions Inventory https://naei.beis.gov.uk/emissionsapp/).

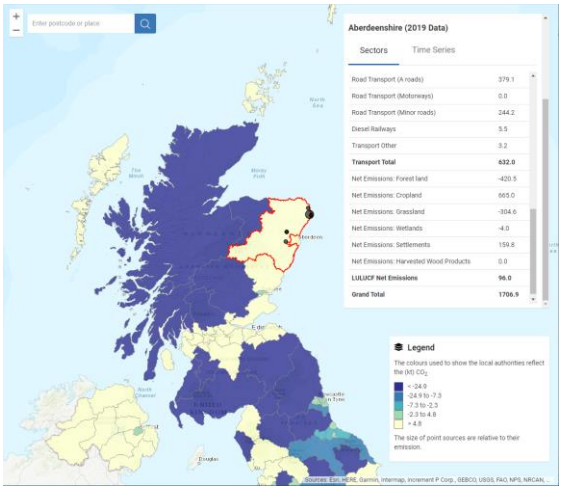


**Figure 11 (b).** Level of $CO_2$ emissions from LULUCF sector, aggregated by local authority (National Atmospheric Emissions Inventory https://naei.beis.gov.uk/laco2app/).

During the COVID pandemic the daily provision of statistics (e.g. Public Health Scotland Dashboard) may have had a long-term impact on the public appetite for numerical and graphical information that helps them track changing levels of impact (e.g. hospitalisations, deaths), and progress on actions (e.g. vaccinations). Increasingly, numerical data are being provided on GHG emissions, on a spatially relevant units (e.g. by local authority). However, the there is a need to understand the actual uses of such information, and its prospective uptake, such as by local communities or businesses to benchmark their progress against that in the local areas or other equivalent groups.

**Further requirements for policy, practice and research**

- There is a need to increase the network of sites where GHG emissions are monitored, distributed across different types of land uses, soils and land management practices, to enable improved assessments of GHG emissions, their changes through time, and evaluation of the effectiveness of different land management practices in reducing emissions combined with data on types of investments (e.g. financial capital, training). [Also reflected in recommendations in Section 5.6]
- No surveys of public attitudes directly refer to emission or sequestration of greenhouse gases by sector. No research findings have been identified that links public attitudes towards changes in behaviour or public policy to return on reducing GHG emissions. Thus, there appears to be a gap in understanding of how stakeholders and public audiences of trade-offs people may be willing to make under different strategies for reducing emissions of GHGs. [Also reflected in recommendations in Section 3].
- There is a need for a more holistic scientific assessment of greenhouse gas emissions of intimately mixed (arable/grass/livestock) Scottish farming systems. The outputs would help to inform the development of a relevant output framework by which public goods and benefits can be accurately assessed and rewarded. [Also reflected in recommendations in Section 5.5]
- The increased availability of data, presented in easily understood ways, should be exploited as part of a communications strategy with objectives of contributing to motivating actions and developing a sense of shared effort and benefits. [Also reflected in recommendations in Sections 6 and 7].

# 5. Pathways to Tackling Climate Change in Rural Areas

## 5.1. Transitions

In their 6th Carbon Budget, the Climate Change Committee (2020) identified four areas in which transitions will take place in the UK:

1. **Land and greenhouse gas removals,** with transformations in uses of land including an increase from 13% woodland in the UK to 18% by 2050, 260,000 ha of farmland producing energy crops, and the restoration and management of peatlands.
2. **Expansion of low-carbon energy supplies,** with UK electricity production zero carbon by 2035, achieved by significant increase in offshore wind energy of 100GW by 2050. Demand for electricity to double or treble by 2050 fuelling transport, heating and industry, and low-carbon hydrogen scaled-up to equivalent of electricity currently.
3. **Reducing demand for carbon-intensive activities,** through improved insultation of housing stock, reduced car travel and growth in demand for flights. Changes in diets with associated reductions in high carbon meat and dairy products.
4. **Take up of low-carbon solutions,** by people and businesses, and phase out high carbon options. By the 2030s they expect all new cars, vans and boiler replacements will be low-carbon, and primarily electric, and by 2040 all trucks will be low-carbon. Industry will be using renewable electricity or hydrogen, with a role for carbon capture and storage (e.g. the proposed Peterhead Carbon Capture Power Station).

Aligned with the recommendations of these sets of pathways, the Scottish Government Climate Change Plan (update) (Scottish Government, 2020a) sets out its approaches to achieving "new ambitious targets to end our contribution to climate change by 2045." It restates the Scottish Government targets of reducing emissions by 75% by 2030 (compared with 1990) and net zero emissions by 2045. The annual targets for percentage reductions[2] are shown in Figure 11.

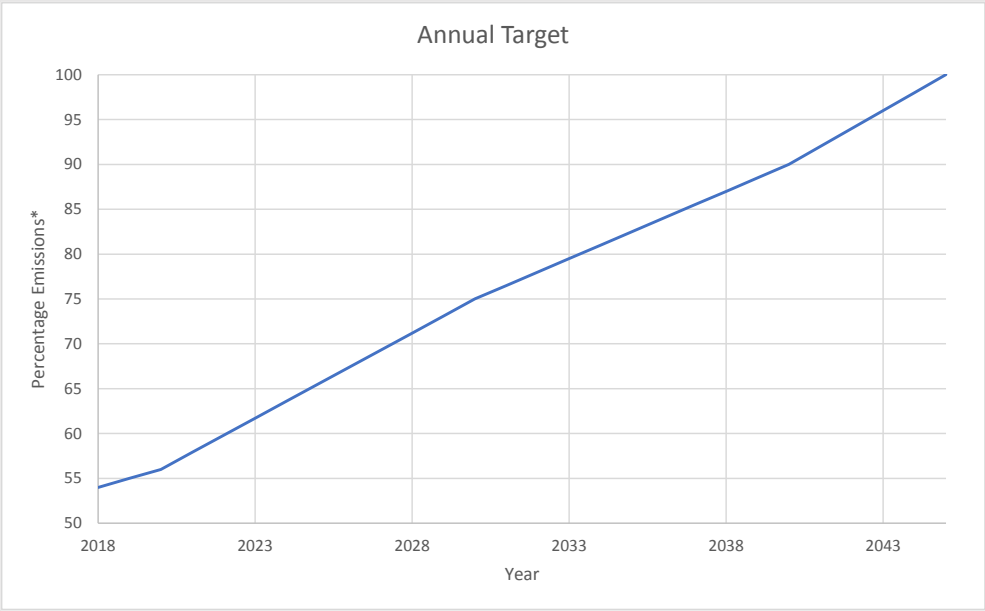


**Figure 11.** Graph of annual targets of percentage reductions in greenhouse gas emissions to reach net zero by 2045.

[2] Reductions in greenhouse gas emissions are relative to 1990 levels of carbon dioxide, methane and nitrous oxide and 1995 levels of hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride and nitrogen trifluoride.

Within its actions, its headline reference is to: "reducing greenhouse gas emissions through a Just Transition to a net zero economy and society, ensuring the journey is fair and creates a better future for everyone – regardless of where they live, what they do, and who they are." The actions cover all Scotland (both urban and rural). However, rural areas are where some actions can only happen, or predominate. Of those actions the most significant are commitments to:

- plant 18,000 hectares of new woodland each year by 2024,
- restore at least 250,000 hectares of peatland by 2030.

These actions will lead to reducing GHG emissions (e.g. from degraded peatlands) and sequester $CO_2$ or equivalent. However, both are subject to decadal timescales and are non-linear in their effects (see Sections 5.2 and 5.3).

## 5.2. Peatland restoration

Scotland has an estimated 2.4 m ha peatland, storing the equivalent of c.3 billion tonnes of carbon (Aitkenhead *et al.*, 2021). However, one of the most highly emitting IPCC peatland categories is 'eroded peat' where vegetation cover has been lost as a result of physical, hydrological and ecological factors. Much of Scotland's peatland area has been damaged with current estimates that the carbon lost from degraded peatlands in Scotland is between 8.8 and 9.7 Mt $CO_2e$ $y^{-1}$ Climate Change Committee (2019), or approximately equivalent to the entire forest carbon sink in Scotland. The distribution of estimated GHG emissions from peatland, using rates as categorised by IPCC Tier 2[3] (Aitkenhead *et al.*, 2021), is shown in Figure 12.

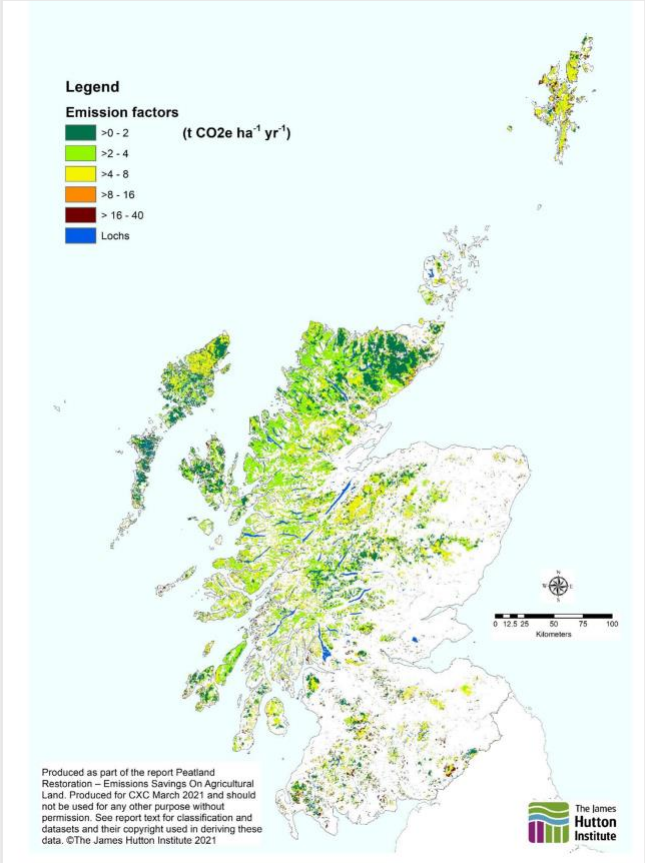


**Figure 12.** Map of emission factors for peatland under agriculture/no agriculture (Source: Aitkenhead et al., 2021).

[3] IPCC Tier 1, Tier 2, Tier 3 etc.: levels of increasing methodological complexity and sophistication for approaches adopted by the IPCC for assessment of GHG emission from landscapes.

Accompanying the emissions of GHGs is the loss of other ecosystem functions such as water storage and filtration, flood risk reduction, pollution reduction, supporting biodiversity, and cultural services such as historical archives and sense of place (see, e.g. England Peat Action Plan, Defra, 2008; IUCN Peatland Benefits, 2021). Many of the services provided by peatlands can be restored. At a UK level, the Climate Change Committee (2019) report the potential to increase the extent of restored peatland from the current area of 0.6 million hectares, to over 1.4 million hectares by 2050.

The Scottish Government has planned to restore 250,000 ha of degraded peatlands by 2030. In the Programme for Government (Scottish Government, 2021a), a budget of £22 million was allocated for the restoration of peatlands in 2021-22. However, the timescale for that policy to be translated into meaningful reductions in GHG emissions is one of several decades.

The England Peat Action Plan (Defra, 2021) describes peatland restoration as a process and not as a one-off restoration event. Artz *et al.* (2013) illustrate the likely emissions savings of different types of peatland, from damaged to near natural states, in relation to timescales. For example, restoring a damaged bog could offer significant savings in GHG emissions, with high short-term savings in carbon but requiring longer timescales (> 10 years) to approach stable Carbon savings and prospectively carbon sequestration.

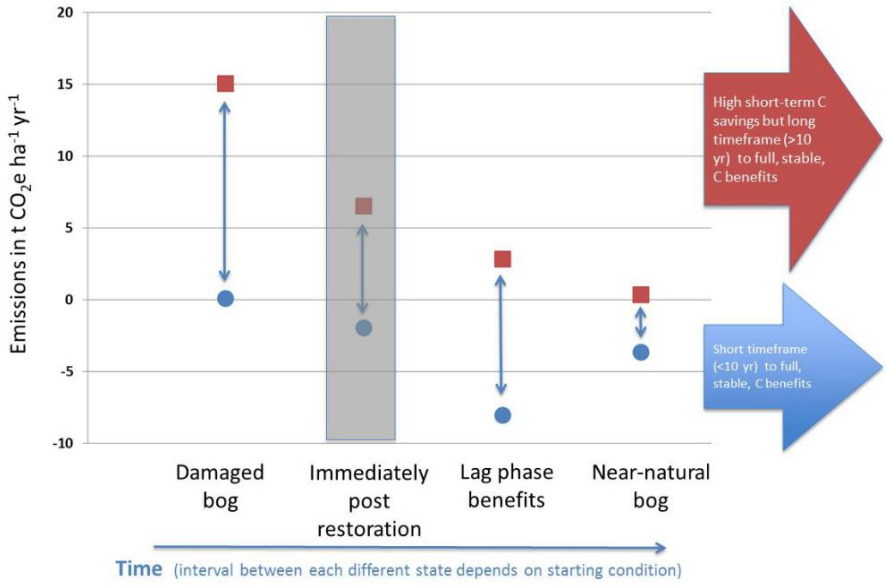


**Figure 13**. Likely carbon emission savings between worst case (red) and best case (blue) (Source: Artz *et al.*, 2013).

Figure 14 shows an indicative timeline for the restoration of peatland from start commencement of restoration works. Although only very indicative, peatland restoration starting in 2022 could enable a site to reach good hydrological and ecological functionality by 2045, at which time benefits of GHG sequestration could begin to stabilise. It should also be noted that although the process of peat formation reduces the emissions of GHGs, and transforms the land processes to sequestering $CO_2$, in a near natural state peatland also emits methane.

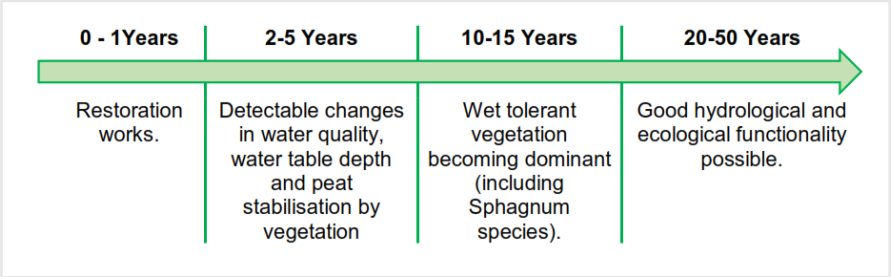


**Figure 14.** Plotting a recovery trajectory for blanket bog (Source: Defra, 2021, adapted from RSPB; page 37).

Other demands associated with peatland restoration need to be planned for and resourced effectively, such as processes for monitoring sites to inform the management of sites for the restoration processes to be effective, such as annually in years 1 to 3 after restoration, and then at 5 year intervals over the longer term. Such demands require the availability of the associated skills, but also create opportunities for development of new businesses focusing on peatland restoration (e.g. site monitoring, instrumentation capabilities, reporting).

Overall, the transitions of peatlands to healthy ecosystems, sequestering carbon, is over timescales of decades. Investment in the 2020s is required to enable benefits to be realised by the mid and latter parts of the 21st century.

The Peatland Action Project, managed by NatureScot, is the principal conduit of support for peatland restoration projects. As of September 2021, there are 691 registered peatland restoration sites in Scotland, covering a total of 25,000 ha of land in the process of restoration since 2012/13, or an average of 36 ha. Based upon on-site knowledge, the upper range of restoration areas is likely to be approximately 100ha. The organisations supported in undertaking restoration projects are across the public, private and third sectors, and communities.

Guidance is provided by Peatland Action on how information on peatland condition can be collected at a site level, for use by applicants for financial support (NatureScot, 2017). A study of peatland restoration costs in Scotland (Glenk *et al.*, 2020; Glenk *et al.*, 2021) reports a median cost per ha of £955 (in 2020) and £1,000 (in 2021), with an upper cost of £1,878 per ha (in 2021). The median value is recommended due to the influence of a number of small sites. These studies have not reported findings in terms of costs per t $CO_2e$ avoided.

Artz *et al.* (2019) report the importance of long-term monitoring of restoration sites to assess their resilience to climatic change, and the importance of tailoring interventions appropriately for the hydrology and vegetation community Noting the diversity in size of sites, a strategy for their restoration may benefit from considering the principle aims of the project (e.g. contributions to reducing GHG emissions, community or rural development).

The identification and use of novel means of measurement and communication of progress in restoration, and the contributions being made towards reducing GHG emissions, could form a component of a strategy for public engagement, exploiting open data and science, and stimulating interest in community led initiatives (e.g. see Sections 5.7, 7). It could also contribute to developing the characteristics of carbon positive landscapes, thus translating a risk into an opportunity (Section 2). Such data should provide a useful input to the deliberations of the RLUPs, albeit they are at too early a stage of development for it to be clear how such information might be deployed.

Actions to change land use such as peatland restoration and woodland expansion are subject to other uses of the land and its management. One source of such pressures is wild deer. The Deer Working Group (Pepper *et al.*, 2019) argue that improved levels of deer control are required for "improving the ecological condition of Scotland's native woodland and enabling their natural regeneration, and for safeguarding and restoring Scotland's important extent of peatlands…" (page 332). Understanding such pressures and interactions is an important aspect of the planning and implementation of interventions for climate change mitigation, and will be influence their effectiveness.

**Further requirements for policy, practice and research**

- Monitoring and reporting characteristics of the environment are key requirements for informing pathways to climate neutrality and environmental sustainability (e.g. watertable levels at peatland restoration sites). Wider adoption of technologies that support digitally enabled data measurement (e.g. using LoRaWAN) should be encouraged and facilitated. Consideration should be given to the governance and access to the data generated, with principles established for identifying what data are public or private goods, and reporting at multiple levels (local, regional, national). [Also reflected in recommendations in Section 2].
- New or updated data are required to inform discussion and decisions relating to pressures on measures for mitigating climate change (e.g. the Deer Working Group recommend that "Scottish Natural Heritage should develop its own more detailed distribution maps for wild deer in Scotland; that Scottish Natural Heritage should more accurately report the basis of national population estimates for wild deer which it publishes"; Pepper *et al.*, 2019).

- Key skills and knowledge will be required at local levels to enable the implementation of peatland restoration (e.g. monitoring the presence and types of vegetation, watertable levels). This could provide sufficient demand for centres of expertise, sharing of knowledge and development of local capabilities. Sources of training could form part of a wider programme of skilling and reskilling, and prospectively new careers and businesses. [Also reflected in recommendations in Sections 6 and 7].
- Scaling up of capabilities between sites (e.g. land managers, communities) will be required to enable placing sufficient degraded peatlands onto pathways to recovery. Lessons could be learnt from the approaches of sharing expertise and experiences, and prospective benefits and risks, between communities developing renewable energy, and peer-to-peer learning in agriculture (e.g. supported through the Rural Development Programme), including transnational learning (i.e. across countries and regions). Mechanisms should be established to ensure such sharing of knowledge rather than relying on community-led initiatives. [Also reflected in recommendations in Section 7].

## 5.3. Woodland expansion

Woodland expansion is a key element of the Scottish Government strategy for tackling climate change. It has planned to have 18,000 trees planted each year by 2024. This contributes to the actions in the COP26 Declaration on Forests and Land Use, which refers to "promoting an inclusive rural transformation", and building resilience, enhancing rural livelihoods and recognising the multiple values of forests.

In the Programme for Government (Scottish Government, 2021a) a budget of £150 million has been allocated to accelerate progress towards that target. However, the damage caused by the recent Storm Arwen in November 2021 is likely to have a significant impact on the trajectory of planting in the short and medium term. The storm is estimated to have resulted in approximately 8 million trees being blown down or damaged, which is equivalent to c. 20% of the annual timber harvest of Scotland (estimate of CONFOR, reported in the Forestry Journal, 6th December 2021).

The climate change mitigation benefits of woodlands is through the sequestration of carbon over the long term cycles of forestry, soil carbon accumulation and the substitution benefits accrued from timber products, such as building materials of concrete or brick with timber (Matthews *et al.*, 2020). However, achieving the aims of net carbon sequestration requires account to be taken of the environment in which the woodlands are planted, in particular the soil type. Friggens *et al.* (2020) show that tree planting in organic soils did not lead to an increase in net ecosystem C stock in the period up to 39 years after planting, and some conditions under which there was a net loss of carbon.

A model of outputs has been developed that combines above and below ground carbon values using scenarios of woodland expansion (Matthews *et al.*, 2020). These enable broad comparisons between forest management alternatives (e.g. native conifer, mixed purpose conifer, production Sitka Spruce) in terms of where net carbon benefits and deficits are likely to occur, how quickly they accrue, how long they persist and the dependencies with antecedent land use, soils, climate and management strategies.

Matthews *et al.* (2020) concluded that targeting "more productive land classes" delivers more net sequestration per hectare, with net benefits accrued more quickly and can deliver greater climate mitigation than anticipated by emissions reduction plans. Extensive establishment of lower yielding trees on low-quality ground, with organo-mineral soils could result in net emissions that persist for decades. The distribution of net change in carbon from afforestation under multi-purpose Sitka Spruce is illustrated in Figure 15 for 30 years after planting (left map) and for 100 years after planting (right map).

The trajectory of uptake of carbon varies by forest management alternative, underlying soil and antecedent land cover type. The spatial patterns show greatest uptake of carbon in the lower lying land, principally areas currently used for crop and dairy production. In areas of western and northern Scotland, after 30 years there remains a net loss of carbon reflecting the land preparation and disturbance of carbon rich soils, compared to the better quality land in the lowlands. Over a longer time period the areas from which carbon would be lost reduces, and more areas are contributing to the net sequestration of carbon.

The model takes no account of socio-economic factors such as land ownership or tenure, cost of establishment or management. It also does not take account of changes in context over time, such as the effects of climate change on crop growth, changes in land ownership or tenure, or any effects of the dynamics within ecosystems such as interactions between plants, animals and water. It also takes no account of damage due to storms, or the risks of pests and diseases identified in Section 2.

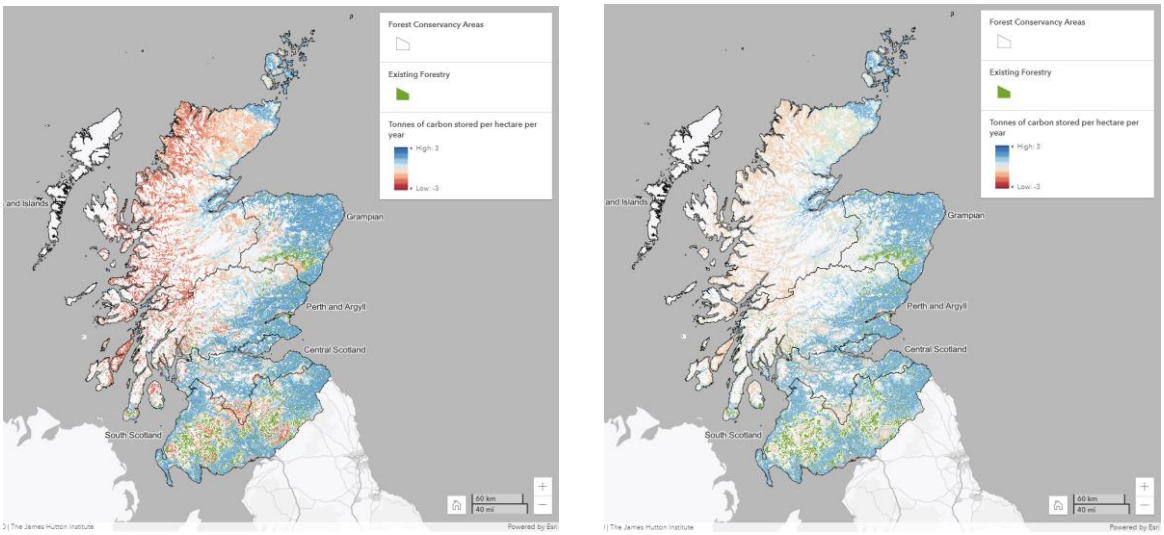


**Figure 15.** Map of net change in carbon from afforestation of multi-purpose Sitka Spruce, Scotland-wide (Tonnes Carbon per hectare per year). (Left) net change in carbon 30 years after planting; (Right) net change in carbon 100 years after planting (Source: Matthews *et al.*, 2020; online web mapping platform: https://woodlandexpansion.hutton.ac.uk/). [Contains OS data © Crown Copyright and database right 2020 | The James Hutton Institute]

Broadly, the policy of woodland expansion is consistent with the public attitudes reported in Section 3 towards the conservation of forests and land, and those of the Scottish Household Survey (Setterfield and Murray, 2020) of "reducing the amount of land used for food production and using it for habitat restoration instead." However, there is a gap in recent evidence of public attitudes towards woodland expansion in given localities, understanding of benefits, or timescales to realise those benefits (e.g. short-term restrictions on access, disturbance of features in the landscape), and the trade-offs which would require to be made (e.g. lock-ins to changes in land uses over the medium to long term). It is also essential to plan and exploit the role of woodland to store Carbon alongside the need to tackle the biodiversity crises. Whilst planting quick growing softwoods may help with the former, they may be counterproductive in tackling the twin crises together.

It is also important to recognise evidence of growing discontent in some communities about the apparent land grab for carbon credits associated with new forestry (e.g. in south-west Scotland), where organisations and communities feel that the push for carbon credits is leading to a significant decrease in biodiversity, whereas both should be considered in an equal and balanced way. So, in some parts of Scotland, local opinions may not consider forestry or woodland expansion to be "habitat restoration", and instead consider describe it as "habitat desecration".

The types of scenario modelling illustrated, combined with other assessments of values and trade-offs (e.g. between antecedent and new land uses; new land uses and changes in carbon emissions or sequestration) could usefully inform debates over future land uses and the planned Regional Spatial Strategies, as well as dialogue within the RLUPs, and society in general. Initiatives emerging from these strategies could form part of a sustainable bioeconomy which includes carbon farming, non-forest wood products, and cultural services.

**Further requirements for policy, practice and research**

- To inform place-based planning, there is a need to understand the types and magnitude of trade-offs required at relevant geographic levels or units, such as in the vicinity of a village or town, within a landscape unit (i.e. landscape character area), a water catchment or an ownership unit, and from the perspectives of people at each geographic level (e.g. local, regional, national, international).
- Understanding trade-offs associated with woodland expansion needs to include the dimensions against which they are being measured (e.g. carbon, biodiversity).
- Multiple benefits should be sought from opportunities offered by woodland expansion, for tackling both the climate and biodiversity crises.
- The purchase of woodlands has formed part of, or is a focus of, community buy-out schemes (e.g. Lochcarron Community Development Company purchasing and replanting a woodland for use as arts activities, runs a community café, and training in crafts and rural skills. There is a need for

understanding how further benefits could be realised of such assets through their contribution to natural capital (e.g. including a financial value for the carbon sequestered, or emissions avoided). [Also reflected in recommendations in Section 5.6].

- For the policy to develop and maintain momentum there is likely to be a need for ensuring public and land manager support over the period of time during which the area of woodland is expanding. The changing biophysical, social and economics contexts, and evidence of benefits, can be expected to change, perhaps leading to a need to accelerate or decelerate the rate of change. There is a need to capture public opinions on the types of changes taking place, perhaps expanding surveys of forest use as well as the questions in the Scottish Household Survey (Section 3).

## 5.4. Renewable energy

As noted in the SHERPA Discussion Paper (Miller *et al.*, 2021), to achieve the targets of climate neutrality will require increasing the rate of development of renewable energy. Along with economic and environmental considerations, increased generation of energy from renewable sources will need public acceptance, relying on the attitudes of new generations of citizens towards energy generation and use, and any associated implications for land uses and landscapes (Miller *et al.*, 2018).

The Scottish Government had a target of 100% of electricity to be generated by renewable sources by 2020, and to cover 50% of Scotland's total energy consumption by renewable energies in 2030. Latest figures suggest that in 2020 62% of energy generated in Scotland was from renewable sources (Figure 16), and 98.6% of gross electricity consumption being from renewable sources in 2020 (Scottish Government, 2021c).

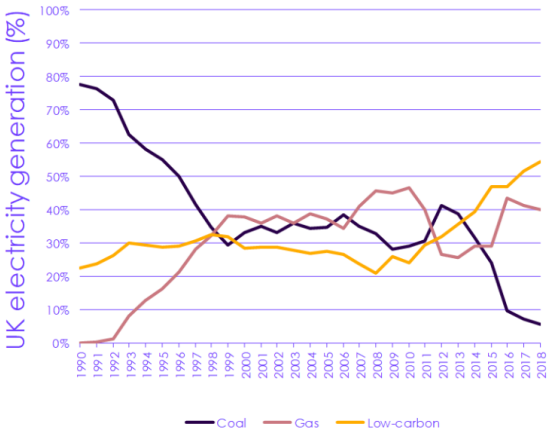


**Figure 16 (a).** Share of electricity generation by Source (1990-2018) (Sources: Climate Change Committee, 2020; derived from BEIS (2020) Energy Trends Table 5.1 and Energy Trends Table 6.1).

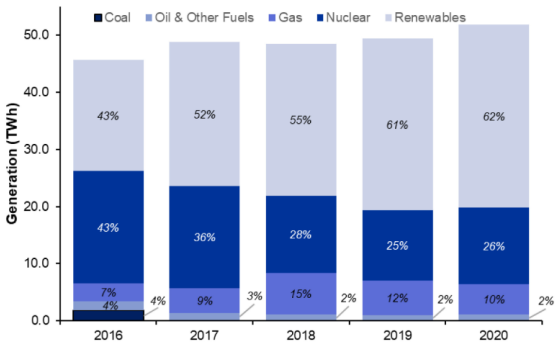


**Figure 16 (b).** Energy generation by fuel, for Scotland (Source: BEIS, 2021b).

The provision of renewable energy by onshore wind systems has developed rapidly, in particular, since the 1990s. By the end of 2020, Scotland had 12.2 GW of installed renewable energy capacity by September 2021, of which 60.2% was from onshore wind and 10/7% from offshore wind (Scottish Government, 2021c; Figure 17), updated from UK MAP SHERPA Paper on EU Long Term Vision for Rural Areas; Miller *et al.*, 2020).The total of heat generated from renewable sources was 6.3% by 2020, compared to the target of 11%.

The lack of a national spatial strategy for the development of onshore renewable energy at early stages of its development led to an opportunistic approach to development, particularly of onshore wind energy. However, some rural areas show patterns of development that have within region similarities (e.g. on-farm wind energy in Aberdeenshire). This may reflect effective demonstrators or leadership by high profile landowners, sharing of local knowledge (e.g. through machinery rings), regionally dominant developers, and consistent approaches to the planning of wind energy within planning authorities, although not necessarily between local authorities.

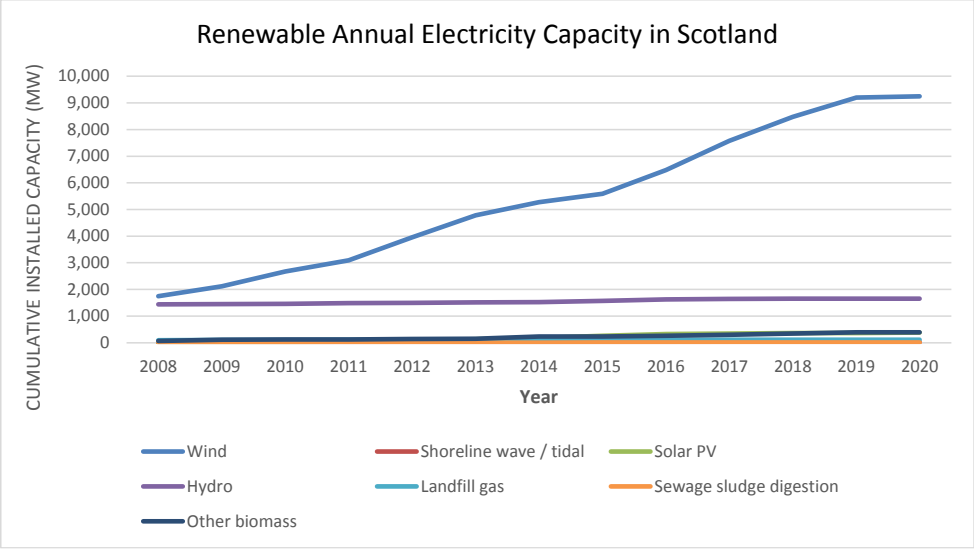


**Figure 17.** Installed capacity of renewable energy production in Scotland, 2008 to 2020 (Source BEIS, 2021b).

Future development of renewable energy in Scotland, such as returbining, will be in the context of updated targets for renewable energy and heat, and costs of energy. The composition of sources of energy generated in Scotland will include an accelerated transition away from domestic nuclear power due to the decommissioning of the power stations at Hunterston (January 2022), and Torness (2028). Significant contributions towards future demands for electricity are likely to be from the projected large-scale development of marine renewables, in particular tidal energy (e.g. Pentland Firth) and offshore windfarms (e.g. Moray Firth). The principal support bases for such developments are in areas identified as remote rural (e.g. Orkney, Caithness) and Accessible rural (e.g. Moray, vicinity of Inverness) (Scottish Government, 2021e). However, the manufacturing of structures is outwith Scotland limiting the value gained from the value added of the entire supply chain.

Scottish Government set a target for Scotland to generate 2GW of locally owned energy by 2030 (Scottish Government, 2017). The significant increases in international gas prices in 2021, with consequential impacts on the prices of gas and electricity, are expected to result in increases in domestic prices in 2022. Such changes could influence public perspectives on the generation of energy locally (see descriptions by Local Energy Scotland), or in which they have a direct stake (e.g. through local development trusts). No estimate is available of the proportion of type of renewable energy in schemes considered to be local. However, the highest proportion can be expected to be onshore wind. A challenge for policy could be how to encourage the ongoing development of new projects of local renewable energy generation. The type of renewable energy with the most rapid increase in uptake is that of solar/photovoltaics. Although still relatively small in absolute terms (379 MW installed capacity, in 2019, compared to 9,248 MW for wind), it has increased from zero capacity in 2009. Prospectively, this provides an alternative source of energy, suitable for contributing to multiple uses of land, or land of limited alternative use, and triggering less opposition to environmental impacts than exhibited with wind energy.

The next generation of renewable energy in rural areas should include hydrogen, such as for energy storage and the manufacturing of anhydrous ammonia fertiliser. However, its uptake needs to be commercially viable, an essential step towards which is the scaling up of generation and use of hydrogen in land-based industries.

Early incentives for the uptake of some forms of renewable energy (e.g. guaranteed rates of Feed in Tariffs) were more easily taken up by those with knowledge at a relevant time and financial capital available to invest. Those agreements provide beneficial lock-ins, typically for 25 years. The nature of agreements reached between developers and landowners has provided some certainty of income. Sutherland and Holstead (2014), explain how investment in renewable energy production, for example, can be undertaken to 'future proof' the farm for future generations. However, agreements with developers can also include forms of lock-in which may inhibit future cycles of development of renewables.

**Further requirements for policy, practice and research**

- Supporting the strategic planning of future phases of renewable energy generation, including the returbining of the existing developments in Scotland, in the context of the National Spatial Strategy, and emergence of the Regional Land Use Partnerships.
- Increasing the proportions of renewable energy across a diversity of sources, and increasing the components of the value chains that deliver benefits to rural areas (e.g. to micro- and small business, residents).
- Supporting development of human and social capital associated with successful development of local energy systems, and broadening the areas within which such developments take place (e.g. with respect to SIMD).

## 5.5. Agricultural systems

As noted in Section 4, GHG emissions from agriculture in Scotland increased between 2005 and 2019 by 18.5%. It is the third highest emitting sector after transport and industry, overtaking energy. Achieving a net zero agricultural system will need agreement on what is produced, where and how. In turn this will shape our rural communities, landscapes, and natural heritage.

Public policies towards agriculture of the European Union (e.g. Green Deal), and UK and Scottish Governments all propose mechanisms for achieving net zero GHG emissions by 2045 or 2050. The Scottish Government consultation on agricultural transitions noted that "reforming our approach to land use and management will be core to delivering all the requirements set by Parliament for Scotland's efforts to reach Net Zero" (Scottish Government, 2021f). The implementation, uptake and effectiveness of the approaches proposed will become apparent over the next few years.

The uptake of suitable agricultural practices can make a significant contribution to climate change mitigation by reducing GHGs and increasing carbon capture in ecosystems (The Royal Society and Royal Academy of Engineering, 2018). Yeluripati *et al*. (2019) list the principal land management practices that contribute to sequestering soil organic carbon in agricultural soils. They provide an assessment of the feasibility of such practices under Scottish conditions, and provide estimated rates of sequestration. Examples of such practices are of reduced or no tillage, increased residue returns, fertilising and liming, crop rotation and organic manures, catch crops and changes in grazing intensity.

One of the greatest risks is the loss of carbon form soils, realised by farming practices. Managing agricultural soils to increase soil carbon and/or reduce GHGs has the benefit of helping to build resilience to climate change for agriculture and the surrounding environment. For example, soil carbon, as part of organic matter, helps to buffer against the adverse effects of high rainfall or drought conditions. Farmers and other land managers are taking a greater interest in soil carbon management to help them work towards Net Zero and for the potential investment opportunities from carbon and natural capital markets. Realising these opportunities requires reliable information about the levels of carbon in the soils at depth, typically to 30 cm. The ability for farmers and others to generate this valuable information is being made more accessible and cost-effective through technical innovations, for example by Agricarbon (https://agricarbon.co.uk/). Further, a UK Farm Soil Carbon Code is under development, which contains reviews of the agricultural land management practices which could contribute to soil carbon sequestration, and a draft code to support farmers in monitoring, reporting and verifying soil carbon.

Research shows how land management practices of no tillage and direct drilling can reduce the risk of nutrient losses by run-off, and can reduce GHG emissions while maintain or increasing crop yield in certain conditions (Huang *et al.*, 2018). Modelled estimates of trade-offs between conventional and direct drilling shows promising findings but require more systematic evidence to be gathered (e.g. Albanito *et al.*, 2020). To facilitate the uptake of land management practices which are consistent with a pathway to climate neutrality, a set of factsheets have been co-produced by NFUS and researchers in SEFARI. These summarise headline issues associated with 6 themes relating to GHG emissions, and an indication of guidance on approaches to minimise losses, from which the following are extracted or based:

a. Grasslands – The potential of managed grasslands in Scotland to sequester carbon and what farmers can do to maintain grassland carbon stocks;

b. Uplands – Climate impacts of agriculture on Scottish uplands, including how grazing can be optimised to help mitigate climate change, and the impacts of muirburn on greenhouse gas emissions and soil carbon in the Scottish uplands;
c. Forestry - The impacts on climate of forestry on shallow peat soils, and the net greenhouse gas balance of forestry on shallow peat soils in Scotland;
d. Methane – How Scottish beef producers can reduce methane emissions from their cattle, and the role that technology can have in reducing methane;
e. Options for mitigating agricultural nitrous oxide emissions
Nitrous oxide (N2O) - Options for mitigating agricultural nitrous oxide emissions, and how farmers can reduce $NO_2$ emissions;
f. Arable - The impacts of arable production in Scotland on climate change, and the challenges and opportunities from climate change.

Farmers and foresters who are innovators should benefit from their investments in learning, testing and implementing new approaches to land management. The same is true of communities, some of which are themselves engaging in land management as one aim of community buy-outs. Means of rewarding technical, product and social innovations should be financial, and more broadly. Those wider benefits are likely to accrue from improvements in business or community resources (e.g. quality of soil, landscape, renewable energy), and in societal well-being. Recognition could also be given through awards schemes, learning from those of the annual Nature of Scotland Awards (which includes one on Nature and Climate), to celebrate success stories and publicise initiatives that can motivate followers or stimulate new actions.

Food and drink preferences in Scotland can be expected to be influenced by climate change. As noted in Section 3.2, there is evidence of public willingness to change diets with a reduction in the amount of red meat. Scientific evidence is presented in the SHERPA Discussion Paper (Miller *et al.*, 2021) of alternatives to red meat in human diets, and how consumer views on food attributes and labels influence purchases. For example, Akaichi *et al.* (2020) report preferences and willingness of consumers in the UK and Spain to pay for nutrition labels, and effects of labels such as organic, local and low greenhouse gas emissions. Results showed a willingness to pay premiums for certain combinations of food attributes and labels, and in the UK demand for beef mince with low fat content can be increased if also labelled as organic or low GHG.

The uptake of knowledge and practical guidance on types of land management practices that can contribute towards reductions in GHG emissions and transitions towards net zero and form part of a sustainable bioeconomy. Findings of the EU UNISECO project on the transition to agro-ecological farming systems, from a case study in Tayside and Grampian, show that measures which had the highest levels of effectiveness were those which provided targeted support for actions (e.g. Agri-environment Climate Scheme, AECS) and access to knowledge and advice (e.g. Scottish Farm Advisory Service; Galioto *et al.*, 2021).

An assessment of the effectiveness of the AECS (Pakeman *et al.*, 2021) showed that, overall, the scheme has benefits for biodiversity. They note that uptake of AECS options led to improvements such as in pollinator habitat, including Maintenance and Restoration of Hedgerows (Arable only), Wild Bird Seed for Farmland Birds, Water Margins in Arable Fields and Species Rich Grassland Management. Hedgerow creation also benefitted plant biodiversity. However, they also note that some options had "no detectable impact on the groups monitored including Wader Grazed Grassland and Moorland Management". They also note that methodologically, assessments need to cover a wider area than only farms in or out of the scheme. Otherwise there is insufficient account taken of context when assessing farmland bird and corn bunting options as they require resources from the wider landscape such as cover for nesting (farmland birds) and spring cereals (corn bunting).

Also of note is the increasing number of "rewilding" projects being undertaken across Scotland. Examples of 29 projects are available from the Northwoods Rewilding Network. Although many such rewilding projects are based around woodland restoration, a growing number, such as are more agriculture based (e.g. Berwick Wood Produce, Aberdeenshire). Such enterprises are beginning to demonstrate that they can be as profitable as "conventional farming", and deliver across a range of public goods.

There is a need for a strategic view of the geography and connectivity of each step in the production chain, such as siting processing nearer to production sources. This could reduce food miles, and associated benefits of reducing stresses on animal welfare linked to transportation and GHG emissions. It would also be consistent with the concept of 'local', as envisaged in the Scottish Government consultation on a Local Food Strategy, and steps to increase the level of self-sufficiency within Scotland of food and energy.

There is also scope for increasing the use of digitalisation in agriculture to monitor and report on performance, and create feedback loops from the value added stages and producers. Such digitalisation could link up information along supply chains using Internet of Things, from production conditions, to processing, to value added at abattoir and retail sales, linking information on the quality of land and grasslands on which cattle graze, GHG emissions linked to grazing and animal condition, animal weight at abattoir, and how weight grades match market requirements, and provide the feedback to the producer.

The mechanisms for supporting transitions should also place significant importance on the people responsible for implementing the changes on the ground, principally in farming and crofting, otherwise there are dangers that some sectors of farming or farmers could be disadvantaged, such as smallscale farmers, or new entrants.

**Further requirements for policy, practice and research**

- Regulatory positions need to remain contemporary to reflect new and emerging technologies (e.g. gene editing and CRISPR [clustered regularly interspaced short palindromic repeats], vertical farming).
- There is a need for better understanding of the GHG emissions of mixed farming systems (arable/grass/livestock) designed around sustainable intensification, under different biophysical conditions and scenarios for how such mixes could change through time, and the trade-off decisions that would be expected between environmental, economic and social factors. [Also reflected in recommendations in Section 4]
- There is a need to support implementation phases of transitions, where evidence suggests there is considerably less advice available to land managers once they start to implement the innovation and embed it in their businesses. Yet, these are the points at which farmers need to make modifications to suit their businesses, and are at greatest risk of 'dropping' the innovation if it appears to complicated.
- There is a need to understand what lock-ins may be experienced by land managers and communities which may prevent or inhibit the realisation of new opportunities (e.g. regulatory restrictions on land use change towards new forms of food production; land management contracts that do not take advantage of latest knowledge; commitments to a customer which restricts the uptake of agro-ecological farming systems).
- The feasibility of digital solutions is aided by their low cost, flexibility and ease of deployment. However, further development may be required to ensure that they are durable under the practicalities of field conditions in different biophysical environments.
- Further advances are required in developing the circular economy in agriculture. Progress has been made in the development and use of new technologies (e.g. drones, precision agriculture, reprocessing systems, green chemistries and crop wastes), alongside changes in attitudes of land managers towards the re-use of products, but more work is required on valorising agri-food waste, closing nutrient loops, and the use of big data analysis in agricultural production.

## 5.6. Natural capital in pathways to net zero

The Report of the Advisory Group on Economic Recovery (Scottish Government, 2020b) recommended investment in Scotland's natural capital, providing means of supporting the design and implementation of carbon positive businesses and multi-functional land use. They propose that natural capital approaches could be important to the future of land-based industries, rural and nature-based economies, and can form part of 'brand Scotland', and the need for financial solutions to fund nature-based solutions, forestry and agriculture.

The concept of natural capital, a means of framing the stocks and flows of services that nature provides to society (Barbier, 2020), is embedded in plans for the Regional Land Use Partnerships (RLUPs), and expected to be in the Regional Land Use Framework (RLUFs), as set out in the Land Use Strategy. An aim of the RLUPs is to work across national and local government, communities, land owners and stakeholders to optimise land use in a fair and inclusive way, and meet local and national objectives and supporting a just transition to net zero greenhouse gas emissions are expected to facilitate a "natural capital led collaboration on regional land use changes to help Scotland's just transition to net-zero."

The South of Scotland RLUP is planning to create Innovation Hubs as part of a strategy being developed around the role of natural capital as part of the development of the regional economy of South of Scotland.

The plans are for "a dedicated Natural Capital Innovation proposal that seeks investment of up to £5 million in South of Scotland pilot projects on farming, forestry, marine management, data management and private finance." (Convention of the South of Scotland, 2021). The development of such innovation hubs could focus on locally significant investments in natural capital such as multi-functional peatland restoration, woodland expansion, and nature-based solutions more broadly. The monitoring requirements of such investments (e.g. biodiversity, GHG emissions) could be linked to national and international equivalents, consistent with Open Science and Data, and offering the potential for such innovation hubs becoming flagship activities.

The NatureScot Natural Capital Pilot Programme (NCAPP) is exploring how to work with natural capital at different levels. In its pilot project 'Facilitating Local Natural Capital Investment' (Hume *et al.*, 2021) note that Scotland has a "strong community of Scottish natural capital pioneers and practitioners", with "varied experience and capacity to engage with novel funding approaches." They make several recommendations relating to the need for public sector support "to catalyse the growth of natural capital investment markets", and in particular a Scotland Carbon Fund. Their study of peatland restoration provides an example of how "carbon-based finance could be used to fund long term habitat maintenance and compensate for the loss of existing revenues on the land. In this way, private finance may be more attractive to landowners and enable larger-scale restoration compared to short term grants." The scenario they reported is of a fund of £50m, used in the first 5 years of a 30-year cycle, enabling the restoration of 35,000ha of degraded peatland, abating 5.4 million t $CO_2$e over 50 years. They also note that public funding through Peatland Action has been intermittent, and has not incentivised private investment.

Tests of the application of the Natural Capital Protocol are extending across different types of environments and land management systems. Ovando (2021) applied the natural capital protocol at its Glensaugh Climate Positive Initiative, Aberdeenshire. Findings suggested it provides a tool for businesses to understand their impacts and dependence on natural capital, and "to identify risks and opportunities that could be integrated into business models to respond to global environmental challenges."

The Crown Estate assessed of its Glenlivet Estate (Columbus Consultants, 2018), reporting improved data for internal reporting for the estate, identification of indicators to track natural capital, and the importance of working with partners and stakeholders, and identification of priorities for capital investment. They estimate that an investment of £120,000 in peatland restoration in 2014 yielded a present value of £537,000 (in 2018) through reducing carbon emissions over a 50-year timescale.

Blackstock *et al.* (2020) analysed five pilot studies on uses of natural capital based approaches to support sustainable land management in Scotland, concluding that these can be used to build consideration of the natural environment in discussions about business decisions. The process of implementing a natural capital approach encouraged collaboration and knowledge sharing between stakeholders. However, there is limited evidence it has directly affected land management to date.

It should also be noted that the Scottish Government is committed to a wellbeing economy, built around the 4 capitals: natural, financial, human and social. The Cabinet Secretary for Finance and the Economy has a Wellbeing economy as one of their remits. The concept of a wellbeing economy is also built into the draft National Planning Framework 4. How this concept is taken forward in terms of transitions to net zero is unclear and may await publication of the forthcoming 10 year National Strategy for Economic Transformation.

**Further requirements for policy, practice and research**

- Realistic assessments are needed of the state-of-the-environment and the role of land management in enhancing or degrading Scotland's natural assets.
- The natural capital concept provides considerable opportunities for making progress towards net zero targets. However, it should be recognised that there is debate over the concept, approaches to accurately quantifying and valuing natural capital, and weak understanding of what it offers.
- There are needs for evidence of the magnitude and timescales for contributing to achieving targets of net zero GHG emissions and wider environmental sustainability.
- Challenges requiring to be addressed include understanding assessments of natural capital at the level of individual land-based business, and their links of assessments at sub-national levels (e.g. catchment, landscape, regional, and national). Addressing this challenge will be of particular significance to the impacts of the application of natural capital approaches by the RLUPs.

- Further support is required for the provision of environmental data (e.g. soils, land cover, water quality) to support the implementation of natural capital approaches, the effectiveness of which are contingent on the availability of data of relevance, and sufficient accuracy.

## 5.7. Changing opportunities for communities

As with most countries, the geography of the economic development of Scotland has been heavily influenced by proximity, or access, to natural resources notably coal, hydroelectricity, and oil and gas. Areas of rural Scotland became area of industrial development and associated characteristics of new housing, retail and services. Historical examples are the evolution of the coal industry in rural areas of Ayrshire, Lanarkshire, Fife, and the Lothians. The most recent open cast mines to open were in 2004 (Ayrshire) and 2012 (West Lothian), both now closed. No coal extraction sites are operational in Scotland since 2020, with the final open cast mine, at Cumnock, Ayrshire (in areas classified as Remote rural and Accessible rural), closing in 2020.

More recent examples are of public industrial strategy supported development of aluminium smelting alongside hydroelectric energy resources (e.g. for British Aluminium at Fort William, Kinlochleven, Invergordon), of which the site at Fort William remains (under ownership of a consortium of finance groups). Similarly, with the development of North Sea oil, investments in rural areas included fabrication yards at Ardesier (Moray), Arnish (Lewis), Ardyne Point (Argyll and Bute), and Nigg Bay (Highland).

In most cases, each example was accompanied by forms of public support to site and develop, but weak strategies for support on closure. As development closed, so change was relatively abrupt, and transitions haphazard (e.g. Ardyne Point to a marina, with limited local economic footprint). All these examples are in areas classified as Remote rural or Accessible rural in the Scottish Government Urban Rural Classification 2016 (Scottish Government, 2018).

To address challenges such as climate change, reversing the loss of biodiversity, and the provision of rural services, Slee and Mosdale (2020) propose a greater emphasis on the third sector, and the important role of citizen-led or socially motivated activities (e.g. care services and support). One such model is that of social innovation (Nijnik *et al.*, 2019). The process of social innovation can contribute to shaping and accelerating development trajectories in social and socio-ecological transitions (Haxeltine *et al.,* 2017). They can contribute to building new practices, networks and governance arrangements (Ravazzoli *et al.*, 2021), some formal (e.g. Development Trusts, e.g. Fintry Development Trust), others informal (e.g. volunteer groups), and several linked in networks (e.g. Scottish Communities Climate Action Network). Numerous such initiatives have been taken in Scotland, some in response to support and funding from Scottish Government, notably the Climate Challenge Fund, National Lottery, and European Union supported mechanisms through the Scottish Rural Development Programme.

Slee (2020) describes the role that social innovation has had for rural development through place-based or issue-based groups in community energy, such as communities with the technical and human capacity to deliver renewable energy projects (e.g. Udny Community Wind Turbine). He provides evidence of impacts of building social capital and developing community resilience, and of 'greater engagement with GHG reducing behaviour'. That finding is supported by the evidence from Irvine *et al.* (2020) in relation to the Climate Challenge Fund, noting 'by building community capacity to embed a legacy of continued bottom-up change that can also support larger-scale policy intervention'.

Since its launch in 2008, to mid-2020, the Climate Challenge Fund had supported 1,150 projects, worth in excess of £111 million, on activities across all of Scotland's local authorities. Between 2017 and March 2021, it reports funding 298 projects, with £36m, involving almost 320,000 people and 6,700 new growers, and an estimated 117 kt $CO_2$e saved (Keep Scotland Beautiful, 2021).

The Regional Land Use Partnerships could provide a further stimulus for civil society led initiatives, and the broadening of the community base for actions towards climate neutrality. They should have a role in linking national land use objectives with the characteristics of each area, and with local communities. The Scottish Land Use Strategy (Scottish Government, 2021c) notes that the pilot Partnerships will enable the testing of "governance options and partnership working on a regional scale to understand how best to work collaboratively", and adoption of structures that meet regional and local requirements, and that facilitate and signpost funding opportunities for land owners, managers and community groups. Reflections on governance should include consideration of principles of fairness in distribution of benefits and responsibilities arising from initial investments in resources and facilities (e.g. charging for car parking, provision of electric charging points, maintenance of equipment and site, accessibility to funds by the relevant local community).

Direct contributions by citizens does not necessitate social innovation or civil society led initiatives. For example, Participatory Budgeting (Scottish Government 2021b) provides citizens with a direct role in deciding how budgets are spent. Its National Participatory Budgeting Strategic Group (NPBSG) identified four areas of focus of education, health and wellbeing, and housing, and an emerging area relating to tackling climate change. In its response to the NPBSG, the Scottish Government proposes priorities for the use of participatory budgeting, one of which is the cross-cutting issue of climate justice, with a focus on a Just Transition in tackling climate change (Priority 7). However, adopting such approaches has to be with the recognition that outcomes could be counter to pathways to net zero.

Bentz (2020) explains how art can be a mechanism for learning and motivating actions, and play a part of transitions under climate change. This may be achieved through demonstrating approaches to talking climate change the school curriculum, alongside concepts relating to climate science, and how climate change and transformations can be taught through arts and humanities. The establishment of Creative Carbon Scotland, the predominant funding of which is from Creative Scotland, is an example of institutional investment in enabling engagement in climate debates and actions that compliment those of science communication. Its mechanisms include providing arts organisations with training in carbon measurement, reporting and reduction, and climate engagement with and through art Bentz (2020) by engaging communities in creative-participatory processes. Those include support for artists living in rural and remote locations, an example of which is the Climate Beacons for COP26. The 7 Climate Beacons are a focus of activities which provide "physical and virtual space for the public, artists and cultural sector professionals, environmental NGOs, scientists and policymakers to discuss and debate COP26 themes and climate action specific to each local area."

The Climate Beacons for COP26 initiative runs to July 2022. As a result, it is an example of funding to support debate and actions post-COP26 and in the lead up to COP27. That reiterates a key message that the COP events are waymarkers on a long-term process, to which policy, science and society have a diversity of ways of contributing.

**Further requirements for policy, practice and research**

- There are opportunities, and needs, to learn from experiences of withdrawl from related areas of industrial activities in rural areas, with environmental, economic and social consequences. Examples could be mapped onto a conceptual framework of transitions and interpreted in terms of their characteristics of a just transition.
- There is a need to understand the skills requirements for delivering each stage of change in land use, and equitable access to such skills locally. [Also reflected in recommendations in Section 7].
- Clarification is required on the governance of plans for achieving net zero GHG emissions, and ensuring consistency between overlapping geographic areas of responsibility, and across sectors (e.g. complicated by the remits of the RLUPs).
- Identification of opportunities for communities to take leads in initiatives, and support for scaling out successes and aim to broaden uptake.

# 6. Just Transitions to Climate Neutrality by 2045

The target of achieving net zero by 2045 is motivated by understanding of the need to stabilise climate change through reducing greenhouse gas emissions and consequences of changes in climate to date, and those yet to materialise. As noted in Section 2, there is increasing public understanding of the level of importance of climate change, and that it needs to be addressed with urgency.

Means of achieving the target provide both opportunities (e.g. for innovation, business and economic and social change), and risks (e.g. of creating or exacerbating inequalities). Planning approaches to achieve the target needs to recognise the interconnectedness of the climate crisis and the biodiversity crisis, and the close links between climate justice and social justice.

Changes in ways of working or lifestyles without consideration of the consequences risks complying with one obligation, but compromising others. Planning and implementing those changes needs to be in a just and fair way, i.e. a 'just transition'. It also needs to be honest and open, ensuring the sharing of knowledge of the challenge being faced, and the difficult choices associated with its resolution.

The Scottish Government definition of a Just Transition is used as a basis for considering the requirements for just transitions in rural areas: "how we get to a net zero and climate resilient economy, in a way that delivers fairness and tackles inequality and injustice" (Scottish Government, 2021d).

Key characteristics of a just transition are:

i) achieving a net zero and climate resilient economy in a way that delivers fairness and tackles inequality and injustice
ii) a process undertaken in partnership with those impacted by the transition
iii) achieve desired outcomes of sustainability along with decent work, social inclusion and poverty eradication.
iv) facilitating and enabling changes in practices and behaviours (e.g. new skills and areas of employment to replace those phased out)
v) ensuring equality of opportunity
vi) acting to ensure no-one is left behind in reaching net zero.

A key requirement in planning a just transition is to address 'how' to get to net zero (i.e. how to achieve climate neutrality, and thus the process). Lessons should be learnt from other transitions, not all of which may be considered to have been 'just' (e.g. deindustrialisation, changes in rural land use), with consequences of leaving people behind, which includes adverse impacts on human mental health and wellbeing. In extremis those impacts include loss of life (i.e. suicide). Other forms of impacts can be gender related. For example, when an industry with a male dominated workforce has declined, such as coal mining, there is evidence of substitution effects, such as an increase in male employment in manufacturing in the vicinity of closed businesses (Aragon *et al.*, 2015).

To achieve an outcome of a fairer, greener future for all, and the process that must be undertaken in partnership with those impacted by the transition to net zero. This requires identification of the type of contributions to transitions, including whether these are involving conscious actions, or passive, with high or low levels of awareness of the changes taking place. The impacts of transitions may be direct (e.g. change in employment, business service, investment in energy sources, change in behaviours), or indirect (changes in land use where living or recreating). The types of contributions may also reflect understanding of public attitudes towards to tackling climate change and the types of policy interventions of individual actions that citizens (Section 3, Appendix 2).

Recognition is required of the differences in potential for places to adapt to climate neutrality. They are not all starting from the same place, with the same biophysical, economic or social scope for options and capabilities for adapting at the same rate or achieving the same targets. Similarly, different types of transitions are taking place simultaneously, at different rates, interacting with each other in different ways.

Arguably, aims and types of changes are being followed by plans for such changes. However, the form, pace and unintended consequences of such transitions are less clear. As transitions progress, various drivers and barriers will take effect, not all known at the beforehand, with some emerging from new understanding, technologies, capabilities or attitudes (societal, policy or business). There is no evidence to suggest there will be any reduction in needs for mechanisms to support business and society in periods of change, and those organisations which provide such support. The types of support will span the public, private and voluntary sectors, and individuals. For example, public authorities may be the principal focal points for support (e.g. members of task forces responding to industrial closures), but it may be the voluntary sector, faith groups and individual citizens who provide emergency aid through local formal or informal networks (e.g. local wildfire groups).

In some areas of rural Scotland there has been clear benefits to infrastructure which have accrued directly from the oil and gas industry. Most obviously those are the communities in Shetland and Orkney, with local 'oil funds', such as the Shetland Charitable Trust which has distributed £320m on charitable activities its formation in 1976 to 2021, to a local charities, organisations and individuals, and enabling investment in transport (i.e. road quality), services (e.g. leisure facilities), and support for local communities. Prospectively, over the long term, the nature of support in such areas would change, but potentially replaced by income from investments in renewable energy.

Responsibilities for taking actions to tackle climate change encompass the stewardship and investment in natural resources for which there is direct responsibility. However, there is also a global dimension to the transitions to net zero of Scotland. There is a need to recognise the potential for 'offshoring' emissions. The nature of such offshoring needs to be understood, and measures taken to avoid such offshoring.

The approach taken should treat all places and people with respect and dignity for their initiatives and contributions to an objective shared globally, cultural contexts, and provide protection and support from consequences of changes in work, and ways of life.

**Further requirements for policy, practice and research**

- Progress is being made on adopting principles for just transitions. However, there is a lack of specific plans of an appropriate level of granularity in how transitions take place, recognising sequences, timing, overlaps in actions, and the nature of closure or cessation of activities.
- To stimulate and motivate transitions, there is a need to understand types of pathways that would be required or available to people at different stages of careers, and the differences in contexts that may be due to gender, age, ethnicity and geography.
- There is a need to identify steps that may be required if actions are not having the impacts on reducing GHG emissions required to keep changes in temperature below 2°C, and at what times those would have to be taken to have effect in the timescales required.
- To communicate the steps towards net zero, there is a need for research into what people understand net zero to mean to people for the environment, society and economy.

# 7. Knowledge, Open Science and Skills

Knowledge exchange, skills development and innovation are vital parts of an effective just transition. They are crucial to the future of the rural economy and communities in Scotland, and overcoming barriers to uptake of practices that can lead to net zero (e.g. H2020 UNISECO, Miller *et al.*, 2021).

This is being reflected in public policies at EU, UK and Scottish levels. The UN Paris Agreement recognises 'the imperatives of a just transition of the workforce and the creation of decent work and quality jobs'. The European Commission (2021b), in its recommendation for ensuring a fair transition towards climate neutrality, it reports the creation of 1 million jobs by 2030 and 2 million by 2005 as a consequence, or part of, the transition. It also reports the socio-economic risks in the absence of 'well-designed accompanying employment and social policies'. In response it proposes the support of mechanisms for quality employment and job-to-job transitions, equal access to quality training and education (for young people, and life-long), and affordable access to services.

The Scottish Government also recognise the need for the provision of training, education and life-long learning for relevant authorities and practitioners. Potentially, the new Green Jobs Workforce Academy, worth £45m (Scottish Government, 2021d), to be distributed through local partnerships, could be a source of funds for supporting such some of those needs. A further recently formed mechanism is the Skills Action Plan for Rural Scotland Implementation Group which should enable structured insights to prospective future needs of rural businesses, with other such insights coming from intelligence gathered from the providers of training and education. The processes of skilling and reskilling should be linked to the transitions by place and sector, as well as in the building of capacities. The timing and availability of knowledge and information need to align with that when scoping and planning of changes are being made (Sutherland *et al.*, 2012; the 'Triggering Change Model').

A strategic perspective is needed to ensure the design, planning and implementation of an appropriate pipeline of skills required for rural areas. It requires joined up engagement between the teams responsible for developing public policy, the businesses or organisations responsible for implementing policy (e.g. NGOs, civil society groups), and the providers of training and education (e.g. further education colleges, universities and the school Curriculum for Excellence), and continuing professional development (e.g. of land managers, officers in public agencies). The evidence from COP26 has shown how effectively young people can contribute to providing visions for the future, and the moral obligation to include them in creating those visions and the actions required.

Pathways to net zero that implement the types of options for mitigation which rural areas can offer, such as woodland expansion, peatland restoration, and agro-ecological farming systems, will require the availability of relevant skills and knowledge. Some such skills may require the re-establishment of previous capabilities amongst institutions with renewed purpose and technologies, for example in agriculture and forestry.

As noted in Section 5.2 with reference to peatland restoration, the types of skills and knowledge required for new business opportunities are still emerging. However, to realise those opportunities, will require the

availability of skills and infrastructure. Actions in situ, with communities of place, offers the prospect of demonstrating proof of concept, providing leadership through innovation, and the development of experiences which can be shared with other like-minded communities. Approaches to designing mechanisms of sharing those experiences should learn from those of peer-to-peer approaches in agriculture, such as Monitor Farms, supported by the Scottish Rural Development Programme, and the social innovations of communities in renewable energy (e.g. previous Fintry Renewable Energy weekend). Such peer-to-peer learning is not constrained to lessons within Scotland, but should recognise opportunities created by digital technologies of transnational and inter-regional learning, including on the ground.

However, there is a need for recognition of the risks of losses of the types of local knowledge that could be significant in the achievement of aims of transitions. Such risks are recognised in the Glasgow Sharm el-Sheikh work programme on the global goal on adaptation, which requires actions to be participatory, fully transparent, based on and guided by the best available science and, as appropriate, local knowledge systems with a view to integrating adaptation into relevant socio-economic and environmental policies and actions (UNFCCC, 2021).

Tai and Robinson (2018) argue that the adoption of open science can accelerate the mitigation of impacts of climate change, especially in areas where research capacity is limited (e.g. vulnerable areas). Citizens and civil society can play a central role in collecting and using environmental data, and thus support transitions towards sustainable development and reducing negative environmental impacts of human activities. Citizen science, in collaboration with actors in science, practice, business and policy, offers the prospect of benefits of data collection by civil society and citizens, the co-interpretation of changes in environmental factors measured, and co-learning of, and adopting changes in behaviours that reduce environmental footprints and negative impacts. As such, citizen science is developing the principles of the Aarhus Convention (UNECE, 1998) and European Pillars of Social Rights through the empowerment of citizens.

International responses to global emergencies such as climate change or COVID-19 benefit from Open Science through the free flow of research data and ideas so accelerating research to combat the disease and in recovering from its impacts. As explained by OECD (2020) in its report on Why open science is critical to combatting COVID-19, Open Science requires sustainable infrastructures, human and institutional capabilities, and mechanisms sharing data across borders and between the public and private sectors, civil society, and researchers.

Encouraging uptake of different forms of citizen science would contribute to operationalising an Open Science approach that enhances transparency (e.g. access new environmental data), collaboration (within communities of place; between citizens, civil society, businesses, policy and research), co-creation[1] and foster innovation and transformative visions (both social and technical innovation)[2]. It would also contribute directly to the European Data Strategy with its aim of digital technology transforming "work for people and businesses, while helping to achieve its target of a climate-neutral Europe by 2050".

In the development of their capabilities, and those of their stakeholders (e.g. communities), the role of the RLUPs should be of providing insight to the requirements for training and skills, and what and where those could be most effective. In developing that insight, regional opportunities should be identified, particularly in relation to creating a critical mass of expertise, which augments or has synergies with existing infrastructure and networks such as regional centres of universities or research groups (e.g. the Scottish Universities, SEFARIs, public agencies).

**Further requirements for policy, practice and research**

- Funding mechanisms are required to enable the upskilling of all sectors of the workforce in the types of skills that will be necessary to achieve a sustainable future, and enable uptake and utilisation of materials made available through open science. Ensuring such lifelong access to the development of new skills is also in line with the Scottish Government 'Adult Learning in Scotland – Statement of Ambition' (Scottish Government, 2014).
- The introduction of new concepts, technologies, and their interpretation need to be trusted, with authoritative and accurate evidence and information. The emergence of new suppliers may also necessitate users (land managers, communities, policy teams) with means of checking advice from suppliers, to differentiate between sales and marketing of materials and their viability for innovation (e.g. land management practice; digital dataset; model). Enabling access, validation and quality control align with the expectations of a Rural Observatory, envisaged in the EU Rural Action Plan, and by Scottish Government in support of the RLUPs.

# 8. Conclusions

There is a need for strong leadership to implement the types of changes required for mitigating climate change in the timescales required. Such leadership needs to motivate innovation and changes in behaviours, and have the capabilities to navigate through the types of resistance that may be encountered, such as in relation to changes in land use change (e.g. significant expansion of woodland), energy and agriculture systems, transport and public attitudes. It also has to ensure a shared approach, connecting thinking across policy, practice and civil society, and sectors, noting that attitudes, behaviours, pressures and stresses affect everyone, irrespective of role, but with unequal impacts.

Rural areas are, and will continue to be, at the forefront of measures required to reduce GHG emissions and mitigate climate change. They are also where businesses and communities have had to develop and implement approaches to climate adaptation, and policy is seeking to prepare governance and structures to support plans and actions. Those approaches will require investment in natural, social and economic capital.

To achieve the target of net zero GHG emissions there should be encouragement and support for technical, product and social innovation in developing new ways of working and living which:

a. stimulate innovative approaches to valuing natural assets, funding their restoration, and realising the multiple benefits delivered;

b. incentivise carbon neutral or positive land management systems, and associated actions by land managers and along the supply chain;

c. support micro and small businesses to establish and develop new capacities, and the creation of new markets for products and services.

The environmental, economic and social changes necessary to achieve the target of net zero GHG emissions from Scotland by 2045 will require transitions that operate over different timescales and are implemented in different ways. Those transitions should:

a. align with pathways to net zero that are characterised by their effectiveness and their equitability;

b. be undertaken in ways that ensure no one or place is disadvantaged, and recognise the differences in current stages of transition of different sectors and places, and timelines to make effective contributions to the overall aim of achieving net zero;

c. respect the differences in cultural heritage and traditions in different industries, communities and areas of the country.

Research is being undertaken into the environmental, economic and social dimensions of climate change, including drivers, emissions, mitigation and adaptation, and increasingly the types of impacts that can be expected in particular places. However, there is a need to address gaps in relation to the understanding (of citizens, business and policy teams) of the steps and timelines for changes in infrastructure and systems, and thus public appreciation of the types of changes for which they need to prepare, such as:

a. the number of years of the transition period from combustion engine technology to alternatives of electricity and hydrogen;

b. credible dates for ceasing the sale of diesel and petrol;

c. future roles for commonly used facilities (e.g. service stations) and what might replace their wider functions in rural areas.

Currently, there are relatively good datasets for material aspects of Scotland's land, but lack measures of how satisfied communities are with their local land uses, landscapes, or how they would like to see their local area evolve under transitions to net zero by 2045. Securing citizen support for any changes needed will be essential in making the transition to net zero. There is a need to greater citizen and stakeholder capabilities and participation in collecting, interpreting and acting on data and information to inform how actions can reduce their climate and environmental impacts, through:

a. motivating citizens to be agents of change, whilst recognising that human capital and roles of individuals within a community differ, the diversity of members of Scottish society, and the importance of the involvement, and opportunities for leadership, of younger people;

b. facilitating step changes in empowering and enhancing the capabilities of citizens and communities in rural areas to be able to take full advantage of new and emerging digital technologies and concepts. This requires education, training, and support mechanisms that are informed and responsive to the needs of rural areas;

c. understanding the links people make between investments in mitigation actions and their return, and articulation of outcomes of actions in terms of public and private goods, and geography of where actions are taken and benefits gained.

To achieve the target of net zero GHG emissions by 2045, and to maintain progress into the longer term, there is a need to strategically plan the pathways for just transitions, comprising:

a. consistent long-term policy based on a strong evidence base derived from meaningful consultation and industry input;

b. alignment of national planning and local development planning to evolve rural infrastructure for a carbon neutral future;

c. consistent approaches to procurement that help to create and stimulate markets for low carbon products and services;

d. expansion of woodland, on the right land type, with a mix of fast growing species for carbon sequestration, storage and substitution (i.e. by timber of energy intensive construction materials);

e. developing approaches for sharing financial benefits from investments in climate mitigation that are more widely accessible. An example would be to create a national Climate Fund from which communities that are not in the ownership or vicinity of a development can benefit from the next phases of expansion of renewable energy, or realisation of financial returns from peatland restoration or other forms of natural capital.

A coordinated approach should be taken to using high impact events relevant to achieving net zero GHG emissions, to raise understanding amongst audiences across Scotland, and motivate actions on the ground.

As noted in the Introduction, at COP26 commitments were made that form contributions towards pathway(s) towards net zero. Those pathways are transitions to ways of working and life that are consistent with the aim of net zero, in a timeframe to be achieved by 2045. The COP26 provided a unique opportunity to communicate issues relating to the topic of net zero GHG emissions amongst public, civil society, policy and research audiences. Similarly, in 2022, Scotland is the venue for the 22nd World Congress for Soil Science is Glasgow (July 2022), typically attracting over 4,000 leading experts in soil science, policy and practice from around the world. Dedicated sessions include the topic of soil carbon, regenerative agriculture, agroecology, and sustainable land use, and on the roles of soils in achieving public policy, with a broad range of field visits to various sites around Scotland.

A lesson from the activities relating to COP26 was of the potential to create significant interest in the lead up and during the event, but of needs to link that to the lives of citizens, and of maintaining progress towards the next COP and translating agreements into impacts. The Climate Beacons (Section 5.7) are examples of initiatives, which are planned to deliver over a period that is significantly beyond that of the COP26, and could form part of maintaining public awareness in the lead up to COP27.

A concluding observation from a member of the UK MAP on the challenge being faced is that …

> *"We have done very well out of cheap energy, food and resources without paying the real costs. It will not always be the government or taxpayer who foots the bill. Everyone has to help pay the bill, and not pass it on to future generations."*

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# Appendix 1: Climate Change Risk Assessment

Risk analysis of climate change and interdependencies.

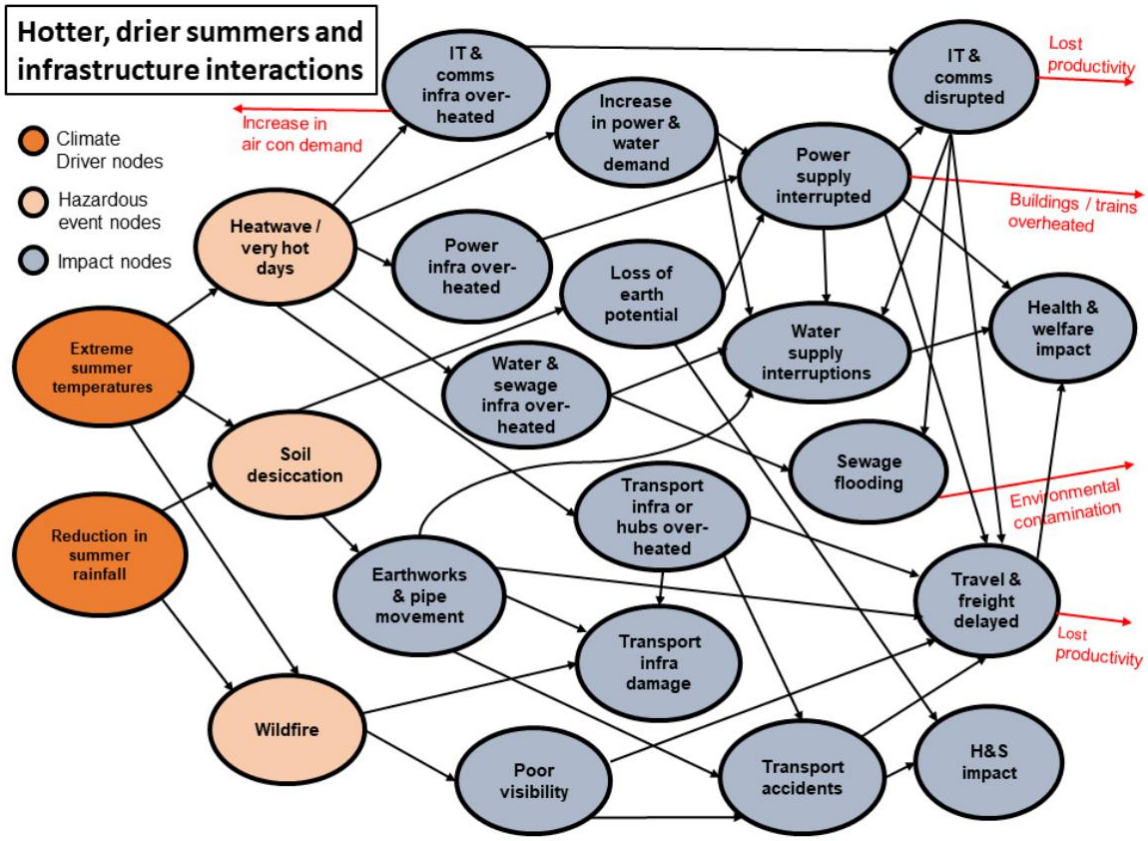


**Figure App.1.1.** Interacting risk analysis for extreme temperatures and reduced summer rainfall on infrastructure, considering heatwaves, wildfire and soil desiccation (from Jaroszweski *et al.*, 2021, modified from WSP, 2020).

# Appendix 2: Public Attitudes to Climate Change

**Scotland**

As noted in Section 3, the Scottish Household Survey (Scottish Government, 2019) has collected data on public perceptions of climate change as a problem. The series of data are presented in Figure App.2.1. They show a change in perception of 'climate change as an immediate and urgent problem' increasing from 46% in 2013 to 68% in 2019. There is a corresponding decrease in respondents who consider 'Climate change is more of a problem for the future', dropping from 25% in 2013 to 14% in 2019. The proportions of respondents who consider climate change as 'not really a problem' which dropped from 7% in 2013 to 3% in 2019, and 'I'm still not convinced that climate change is happening' dropping from 13% in 2013 to 6% in 2019.

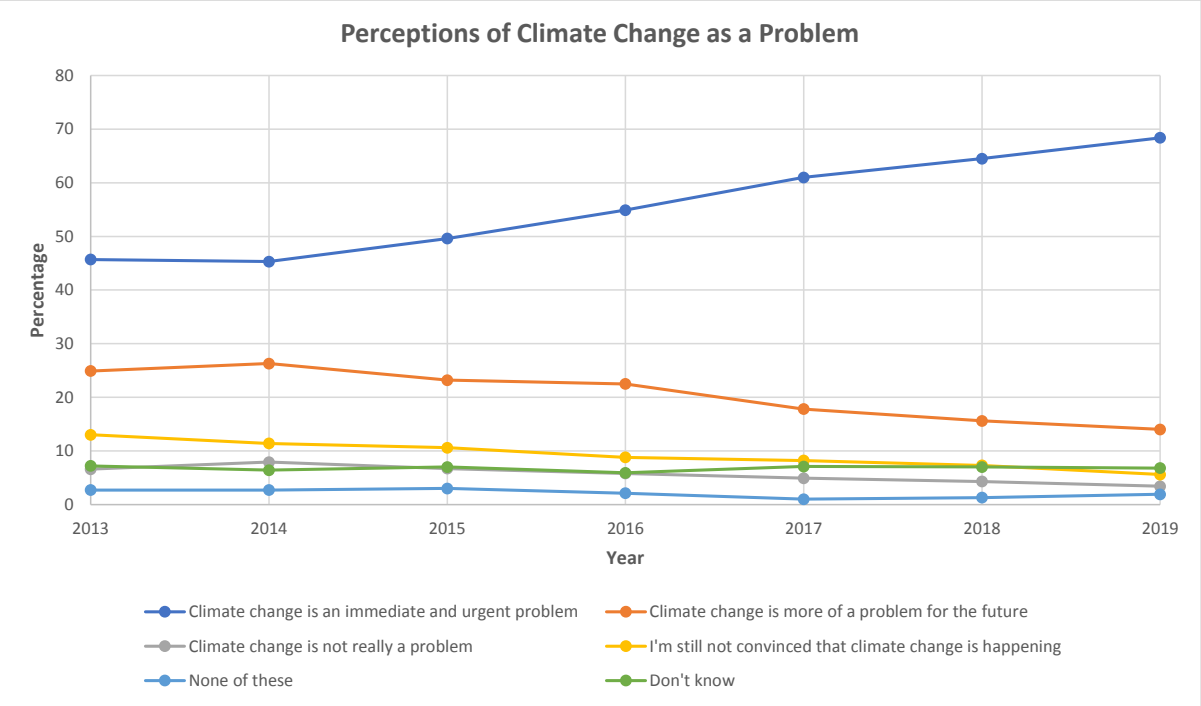


**Figure App.2.1.** Perception of climate change as a problem, 2013 to 2019 (Source: Scottish Household Survey, accessed 1st September 2021).

The perceptions of climate change as an immediate and urgent problem has increased across all age ranges between 2013 and 2019. The age range for which this perception is consistently highest is that of 35 to 44 (dipping to a minimum of 51% in 2014 and increasing to 72% in 2019), and the lowest is aged over 75 (dipping to a minimum of 31% in 2014 and increasing to 56% in 2019) (Figure App.2.2).

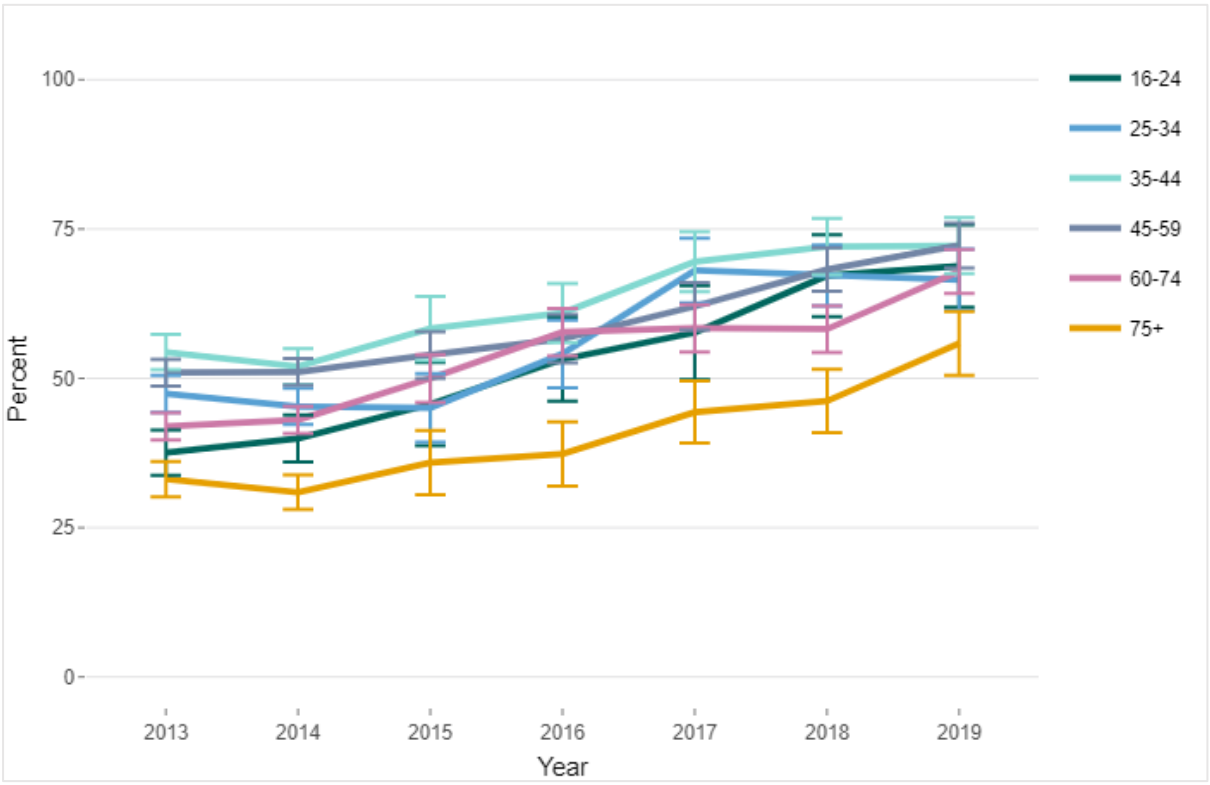


**Figure App 2.2.** Perception about climate change as an 'immediate and urgent problem' by age (Scotland) (Source: Scottish Household Survey, Table 10.2. Data Explorer, accessed 30th April 2021).

The same question was asked in 2020, in the study public attitudes towards climate change policy and a green recovery, carried out by Ipsos MORI for Scottish Government (Setterfield and Murray, 2020). Their findings suggest an increase in the perception that climate change is an immediate and urgent problem, from 68% to 79% as of October 2020, and associated reduction in the perception that climate change is a problem for the future (down from 14% to 11%) (Figure App.2.3).

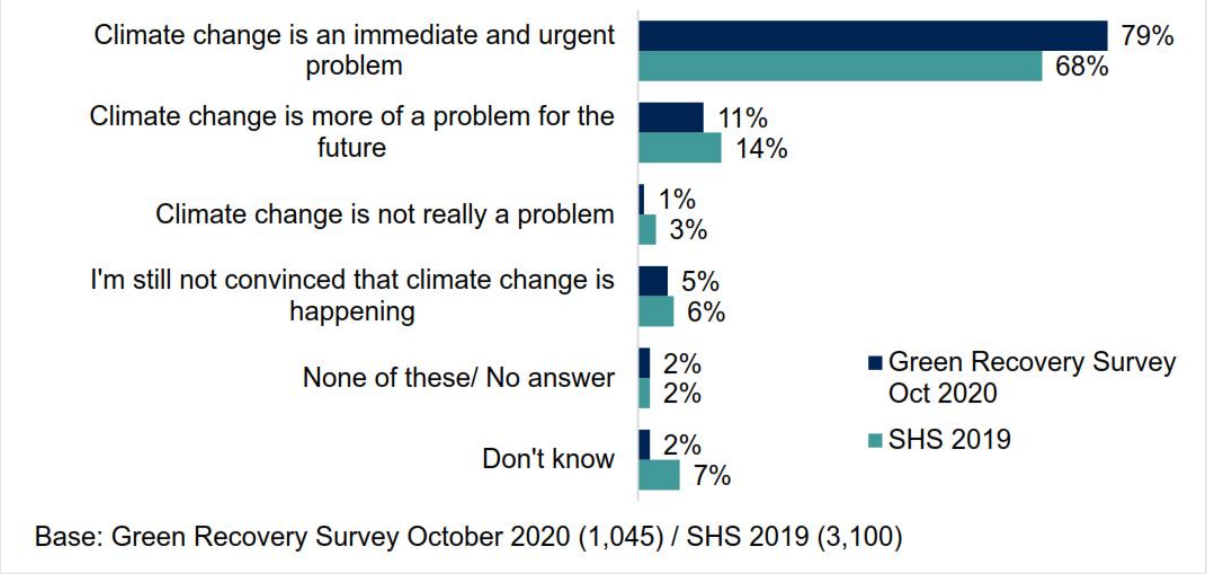


**Figure App.2.3.** Perception about climate change as an 'immediate and urgent problem', as of October 2020 (Source: Setterfield and Murray, 2020).

These findings are consistent with the conclusions from a series of Climate Change Public Conversations run by ClimateXChange in 2016. They concluded that there is a low level of public scepticism in Scotland about climate change, and a willingness and interest of people to engage in discussions about societal responses to climate change irrespective of the level of technical expertise.

Relative to the level of deprivation (as classified by the Scottish Index for Multiple Deprivation) the mean value for each of the 20% quintiles of deprivation for each year show the same order of ranking of climate change as an immediate and urgent problem (although noting the overlapping confidence limits). Over the time period 2013 to 2019, climate change has been perceived as an immediate and urgent problem most by those in the 20% least deprived areas (75% in 2019), and least by those in the 20% most deprived areas (69% in 2019) (Figure App.2.4).

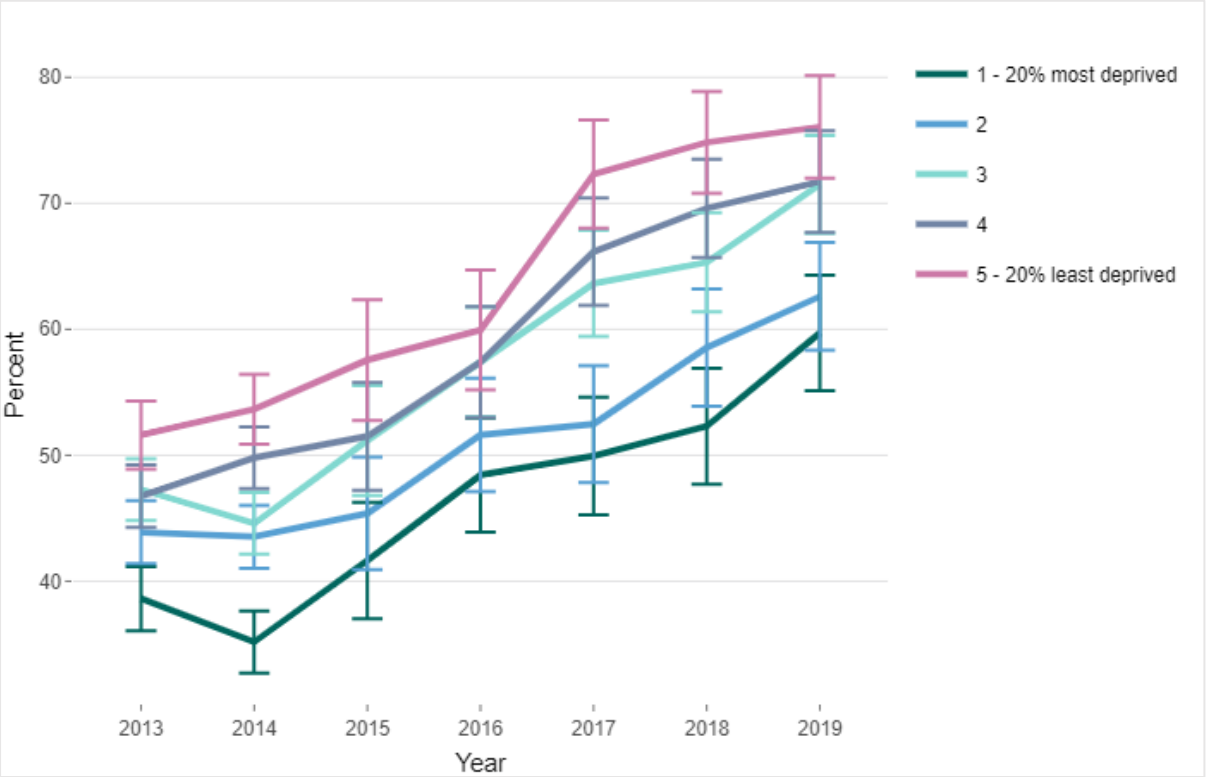


**Figure App.2.4.** Perception about climate change as an 'immediate and urgent problem' by deprivation of the area of respondent, 2013 to 2019 (Source: Scottish Household Survey, Table 10.4. Data Explorer, accessed 30th April 2021, rechecked 1 September 2021).

Broadly, there is the same pattern of an increasing perception of climate change as an 'immediate and urgent problem', between 2013 and 2019, across all levels of educational attainment. For most of that time period that perception is highest amongst those with degree or professional qualifications (up from 60% in 2013 to 80% in 2019), followed by HNC/HND or equivalent (up from 51% to 71%), and Higher, A level or equivalent (up from 45% to 73%). Responses from those reporting no qualifications were up from 33% to 49% over the same time period (Figure App.2.5).

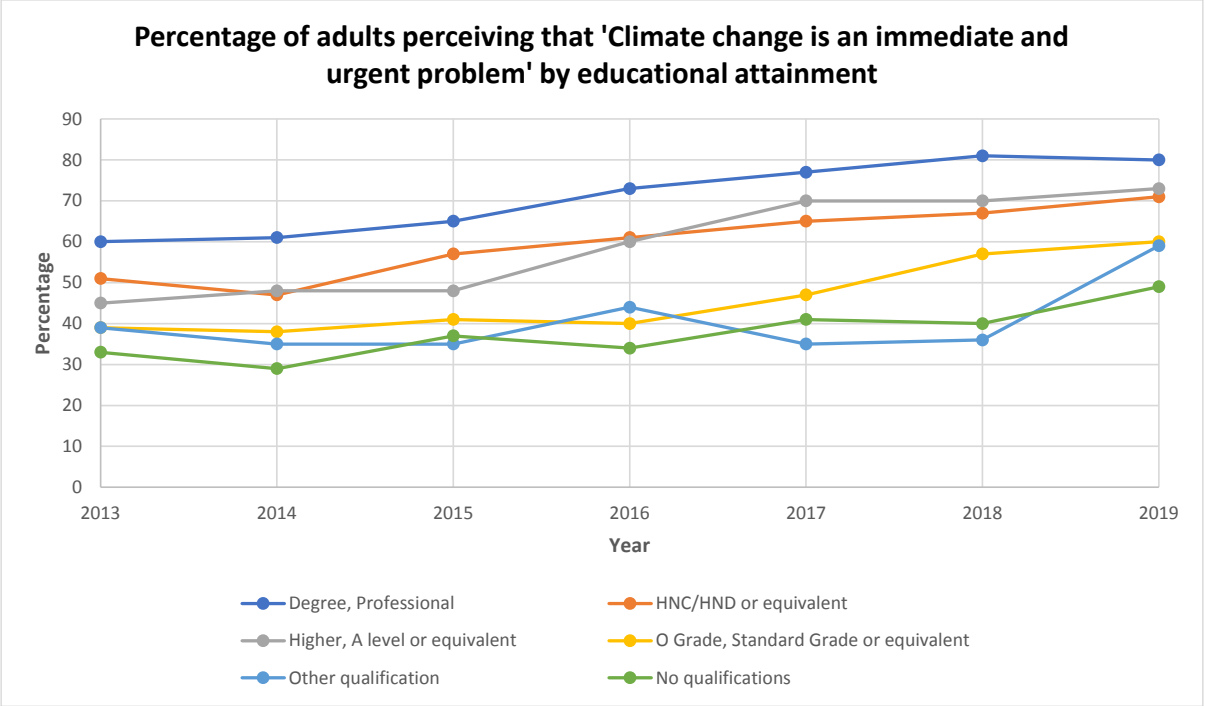


**Figure App.2.5.** Perception about climate change as an 'immediate and urgent problem' by educational attainment (Source: Scottish Household Survey, Table 10.4. Data Explorer, accessed 30 April 2021, rechecked 1 September 2021).

Public perceptions of the effectiveness of the actions they could take having an impact on climate change have been tested in the Scottish Household Survey between 2015 and 2019, in the four questions below, the results of which are presented in Figure App.2.6:

a) 'It's not worth me doing things to help the environment if others don't do the same' (Figure App.2.6a);

b) 'I don't believe my behaviour and everyday lifestyle contribute to climate change' (Figure App.2.6b);

c) 'Climate change will only have an impact on other countries, there is no need for me to worry' (Figure App.2.6c);

d) 'I understand what actions people like myself should take to help tackle climate change' (Figure App.2.6d).

The responses to each of the 4 questions suggest that respondents believe that they can take actions which can make a contribution to benefiting the environment in general, or responding to climate change. The results show a slight strengthening in the view that it is worth doing things to help the environment, even if other people do not (Figure App.2.6a), that people believe their behaviour and lifestyle can contribute to climate change (Figure App.2.6b), that climate change will not only have an impact on other people (Figure App.2.6c), and that people understand what actions they should take to help tackle climate change. However, no questions have been posed of specific actions that people could take, or are willing to take to tackle climate change, or what government or other organisations could take.

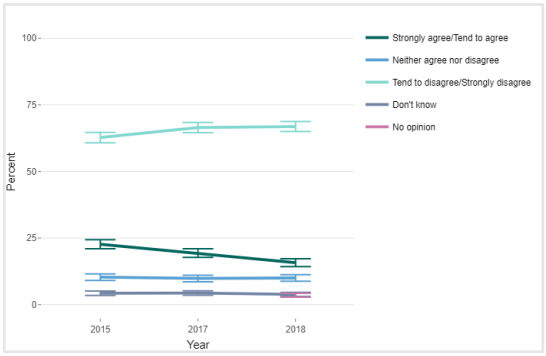


**Figure App.2.6 (a).** Responses to the question 'It's not worth me doing things to help the environment if others don't do the same', 2016 to 2019.

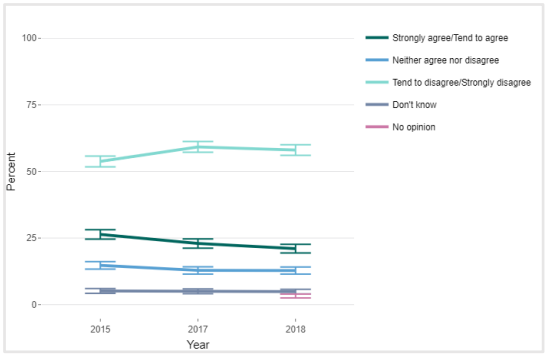


**Figure App.2.6 (b).** Responses to the question 'I don't believe my behaviour and everyday lifestyle contribute to climate change', 2016 to 2019.

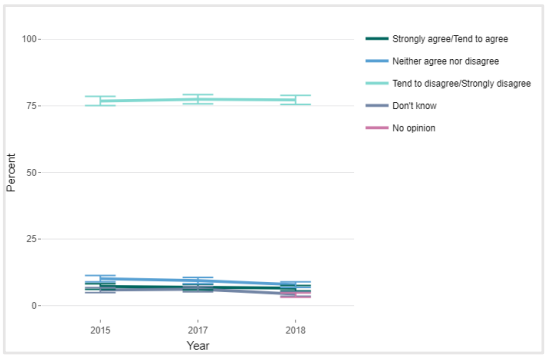


**Figure App.2.6 (c).** Responses to the question 'Climate change will only have an impact on other countries, there is no need for me to worry', 2016 to 2019.

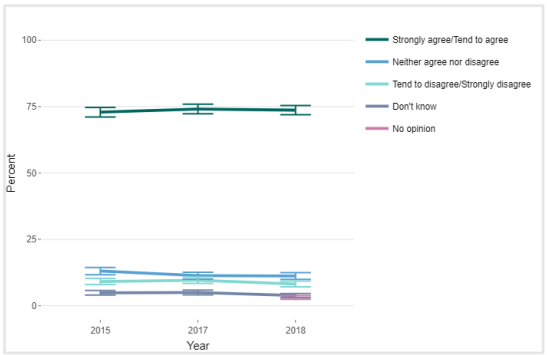


**Figure App.2.6 (d).** Responses to the question 'I understand what actions people like myself should take to help tackle climate change', 2016 to 2019.

Levels of support for selected policy measures were tested in the study reported by Setterfield and Murray (2020). Figure App.2.7 illustrates the responses for 5 policies. These show Strong(ly) support of 56% of respondents of 'charges for items that are harmful to the environment that can be replaced with suitable alternatives', and a further 26% who would 'Tend to support' such charges.

Lowest support, as measured by combining responses of Strongly support and Tend to support, were in response to the two questions about reducing the use of land for food production, replacing it with habitat restoration (60%), or for carbon capture or storage instead (57%).

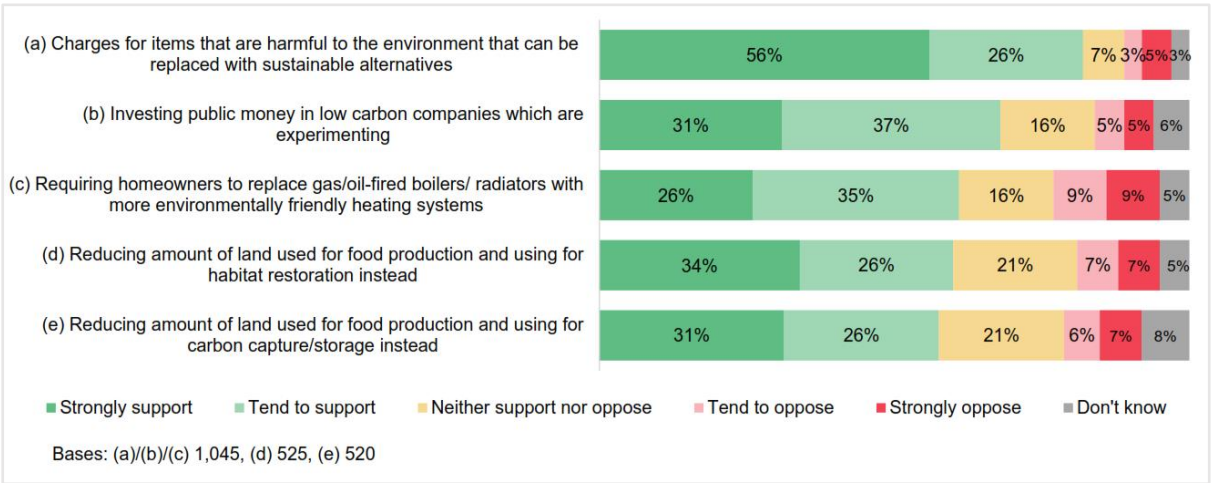


**Figure App.2.7.** Levels of support for selected policy measures (Source: Setterfield and Murray, 2020).

One category of response that was explicitly linked to the COVID-19 pandemic, and thus not directly linked to tackling climate change in the long-term, was that more COVID-secure public transport would help reduce car travel (Figure App.2.8).

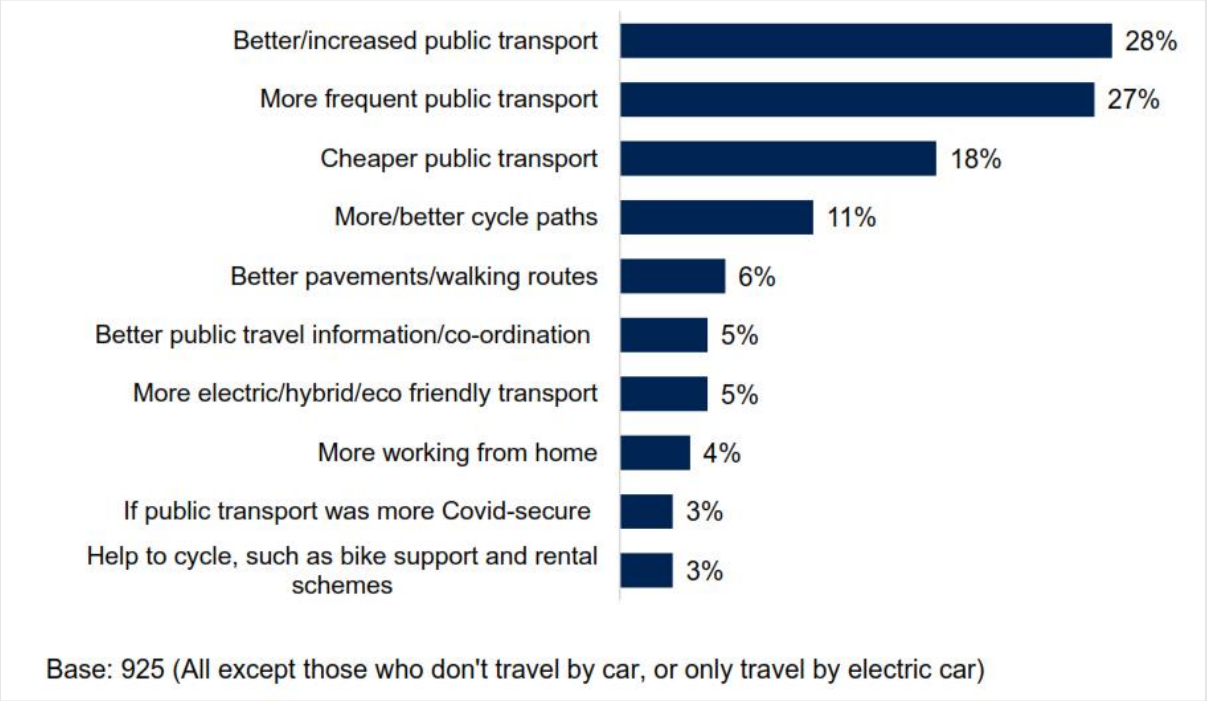


**Figure App.2.8.** Responses to questions about what would help reduce travel by car (Source: Setterfield and Murray, 2020).

The annual Scottish Social Attitudes Survey, up to 2017, does not contain a question specifically on climate change (Scottish Government, 2017). The question of closest relevance is that on "*What should be the Scottish Government's highest priority*?", with responses covering 8 topics, one of which includes 'Improve the environment'. That response could include perspectives of respondents in relation to climate change. In 2004 the percentage of respondents who considered this should be the highest priority was 4%, rising to 6% in 2006, and dropping to 2% by 2017. However, no reference is made to public attitudes towards climate change in any of the reports.

**European Union**

*The 'Eurobarometer'* is a collection of cross-country public opinion surveys conducted regularly on behalf of European Union Institutions since 1974. The Eurobarometer Survey on "Attitudes of European citizens towards the Environment" (European Commission, 2020b)[4] reports 94% of European population 'say that protecting the environment is important to them personally', with climate change ranked the most significant problem (76% of respondents).

In response to the question '*How serious a problem do you think climate change is at this moment'*, 76% of respondents in the EU-27 answered that it was 'A very serious problem' (the same percentage for the EU-28), ranging from 46% in Estonia to 90% in Spain. Ninety six percent of respondents claimed to have taken at least one action to reduce their negative impacts on the environment, with 21% claiming 'many actions (7 to 14)'. The findings suggest a willingness to take action by a considerable majority of people. However, there is no insight as to whether an action is repeated or maintained over a long-term, or the trigger or motivation for such actions. In a follow-up survey of European citizens in March to April 2021 (Special Eurobarometer 513; European Commission, 2021), continued to be identified as a 'Very serious problem' by 78% of respondents.

The Eurobarometer Survey 490 on Climate Change (European Commission, 2019) reported 23% of people in the EU-28 considered climate change to be the most serious problem facing the world as a whole, in 2019. Between countries, this opinion ranged from 10% in Bulgaria to 50% in Sweden (Figure App.2.9).

When asked to rank a set of options of the '*most serious problems faced the world today*' the highest was that of 'Poverty, hunger and a lack of drinking water', ranging between 26% (in 2019) and 35% (in 2013). Climate change ranked 2nd in 2011, with a score of 20%, dropping to 12% in 2017, and back up to 23%, in 2019. In each of the 5 surveys between 2011 and 2019, the issue of 'Spread of infectious diseases' ranked 5th or 6th and scored no higher than 5%.

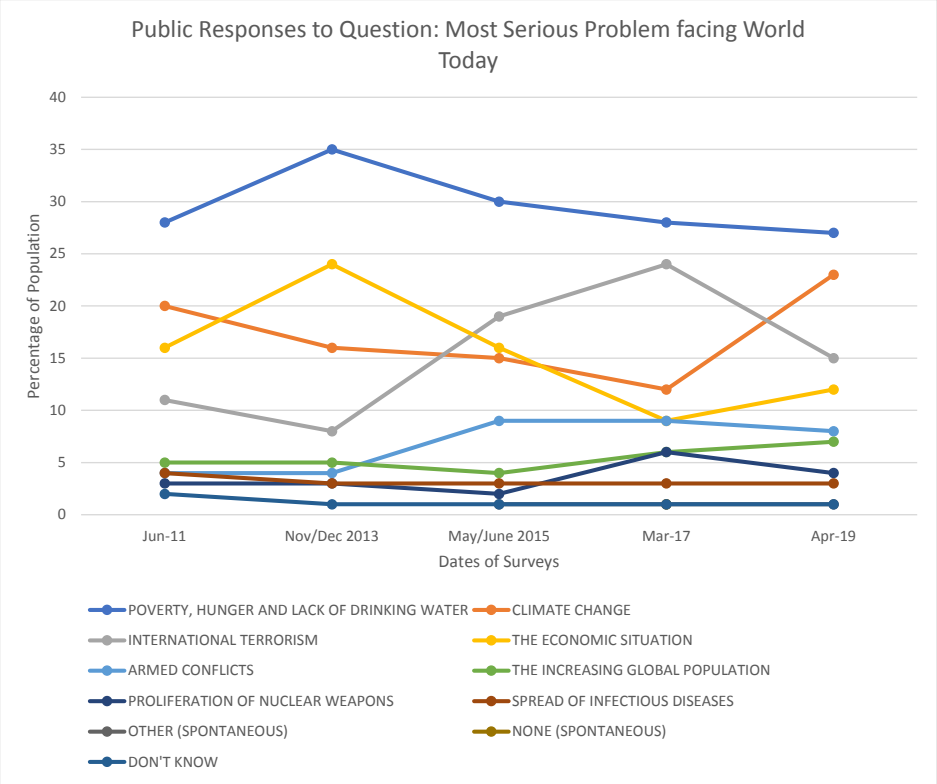


**Figure App.2.9.** Public identification of the most serious problem facing the world as a whole, in 5 surveys from 2011 to 2019 (Source: European Commission, 2019; number of respondents, Eurobarometer 490: 27,655)

In the Special Eurobarometer 513 (European Commission, 2021; number of respondents, 26,669) climate change dropped in the ranking as the most significant issue to be faced to 18% of respondents. This has been omitted from Figure App.2.10 because of the impact of COVID-19 on the response to certain questions. In absolute terms, the ranking of climate change as the most important issue was replaced in the ranking by 'Spread of infectious disease', reflecting the timing of the COVID pandemic increasing in 26 EU Member States, e.g. in Italy, by 39% to 70%; in Spain by 31% to 44%.

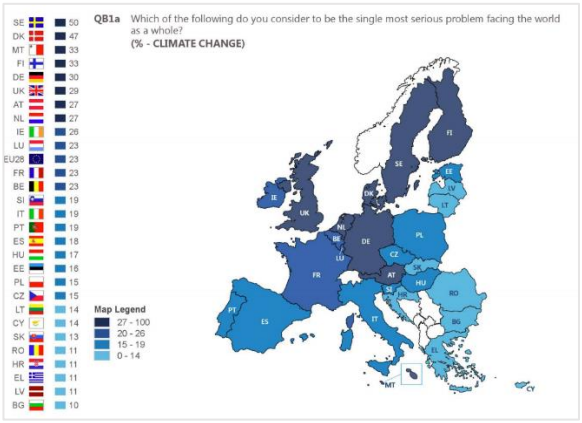


**Figure App.2.10 (a).** Percentage of people, by country, who think that climate change is the most serious problem facing the world as a whole in 2019 (Source: European Commission, 2019).

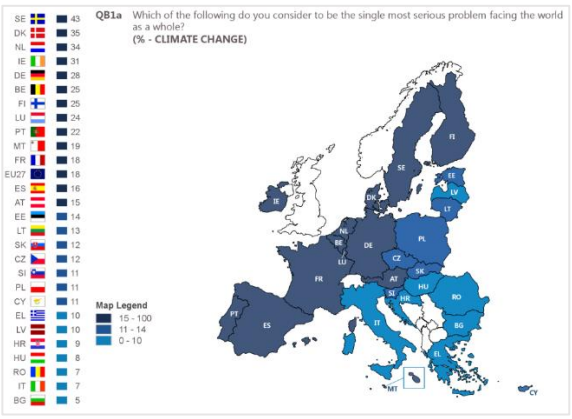


**Figure App.2.10 (b).** Percentage of people, by country, who think that climate change is the most serious problem facing the world as a whole in 2020 (Source: European Commission, 2021).

Of respondents who ranked climate change as the most important issue, the proportions were similar for men (18%) and women (17%). By age, it was ranked highest by 22% of those aged 15 to 24, and 16% of those aged 55 and over. Across social grades, the topic was ranked highest by 28% of those who associate with being 'working class' or 'lower middle class', and 72% of those who associate with 'middle, upper middle, or upper class'.

The Eurobarometer (European Commission, 2020c) reported 69% of respondents agreeing with the statement 'EU farmers need to change the way they work in order to fight climate change even if that means that EU agriculture will be less competitive'. From a review of 40 practices, Smith *et al.* (2019; H2020 CIRCASA) explain what land management practices can co- deliver food security, climate change mitigation and adaptation, and combat land degradation and desertification, and where competition may arise.

Overall, there is significant support for EU aims of a climate neutral continent by 2050, with 47% responding 'Totally agree' to the question "We should reduce greenhouse gas emissions to a minimum while offsetting the remaining emissions, for instance by increasing forested areas, to make the EU economy climate neutral by 2050' and 43% 'Tend to Agree.' This is 2% lower than the survey in 2019.

In response to choose from a list of 15 possible actions to fight climate change, at least one action is identified by 96% of respondents, an increase of 3% since 2019 (European Commission, 2021). The most frequent response was "try to reduce their waste and regularly separate it for recycling", by 75% of respondents, up from 66% in 2011.

The response to several other options has increased over the 10 years of the question being posed (e.g. reducing consumption of disposable items, up from 46% in 2011 to 59% in 2021; lower energy consumption is important when purchasing electrical goods, up from 30% to 42%).

However, the headline proportions for 10 out of 15 options were down in 2021 compared to 2019. These include consideration of the carbon footprint when planning transport (11% in 2021 compared to 12% in 2019), and when purchasing food (16% in 2021 compared to 18% in 2019).

Two new questions were introduced in the 2021 survey of eating more organic food (32%), with responses varying nationally from between 12% (Hungary) and 49% (Slovenia); and, buying and eating less meat (31%), with responses varying nationally from between 12% (Romania) and 55% (Netherlands).

The majority of respondents consider it very important that the EU (53%) or national governments (51%) set ambitious targets to increase the amount of renewable energy used by 2030, ranging from 32% (Latvia) to 74% (Portugal). There is also significant support for the belief that the costs of damage due to climate change are greater than the level of investments needed for a green transition (74%). To aid the process of transition to clean energy, 81% Totally Agreed, or Tended to Agree there should be more public financial support.

The majority of respondents also expressed positive responses to questions about adaptation to climate change. For example, when asked about attitudes towards adapting to climate change, 62% of respondents either Totally Agree (23%) or Tend to Agree (39%) that "adapting to the adverse impacts of climate change can have positive outcomes for citizens in the EU". Similarly, the majority of respondents (78%) either Totally Agree or Tend to Agree that taking action on climate change will lead to innovation that will make EU companies more competitive.

**Global Polling of Public Opinion**

A 'People's Climate Poll' was conducted by the United Nations Development Programme (UNDP) and the University of Oxford (UNDP, 2021), between 7th October and 4th December 2020. The UNDP notes that 'a key factor for countries raising levels of climate ambition is popular support for policies that address climate change.' (UNDP, 2021).

The approach was to access people through popular mobile games (e.g. Words with Friends, Angry Birds, Dragon City, Subway Surfers), replacing in-game adverts with 8 questions on topics relating to climate change (Appendix 2). It was designed to enable responses across gender, ages and education attainment, with a mix of size and high- and middle-income countries. In total it was distributed across 50 countries from Africa, Arab States, Asia and the Pacific, Eastern Europe and Central Asia, Latin America and the Caribbean, and Western Europe and North America, in 17 languages. Responses were received from 1.22 million people. The margin of error reported for the results is +/- 2%.

In response to the question "Do you think climate change is a global emergency?", 64% of respondents replied 'Yes'. Of those, the highest proportion (74%) is in the small island developing states, closely followed by high income countries (72%), with the lowest proportion reported in the least developed countries (58%) (Figure App.2.11). At a national level, affirmative responses were highest in the United Kingdom and Italy (81%), and lowest in Moldova (50%). Responses for selected other countries for which more detailed surveys are reported in later sections are: Canada, 75%; Australia, 72%; and the United States, 65%.

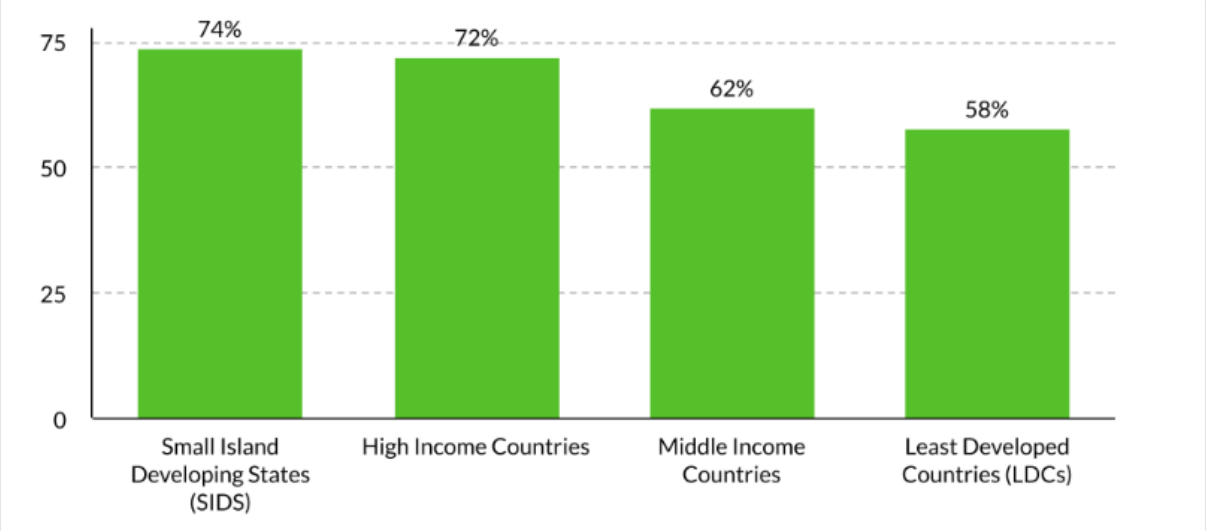


**Figure App.2.11.** Public belief in a Climate Emergency, by country group (source, UNDP, 2021).

Amongst respondents who believe there is a climate emergency, 59% believe 'Do everything necessary, urgently', compared to 20% who selected 'Act slowly while we learn more about what to do', and 10% stating that 'The world is already doing enough'. Figure App.2.12 illustrates the distribution of responses across the different country groups.

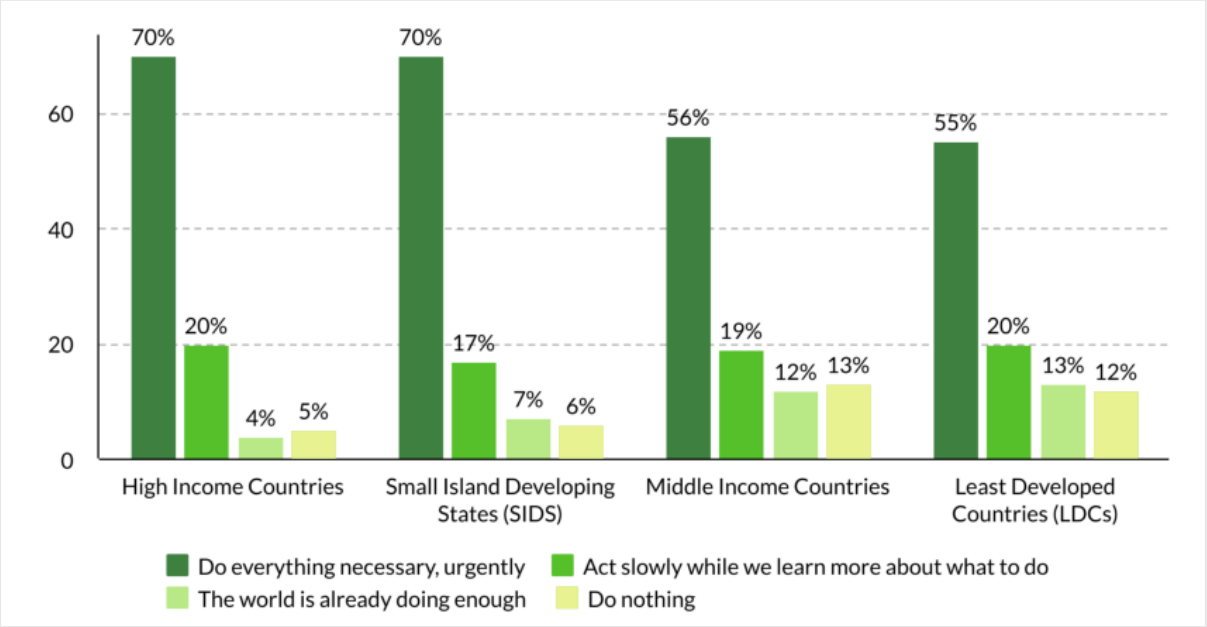


**Figure App.2.12.** Reported urgency of response required amongst respondents who believe in the Climate Emergency, by country group (source, UNDP, 2021).

Overall, slightly more men and boys perceived there to be a climate emergency than women and girls, but only by 4% (52% male, 48% female). However, there are significant differences between countries. This range shows the largest proportion of females more than males reporting belief in a climate emergency was in Canada (12% higher amongst females), compared to Nigeria (12% higher amongst males than females) (Figure App.2.13). Responses for selected other countries for which more detailed surveys are reported in later sections are the United States, 11% more females than males; Australia, 10% more females than males; and the United Kingdom, 6% more females than males.

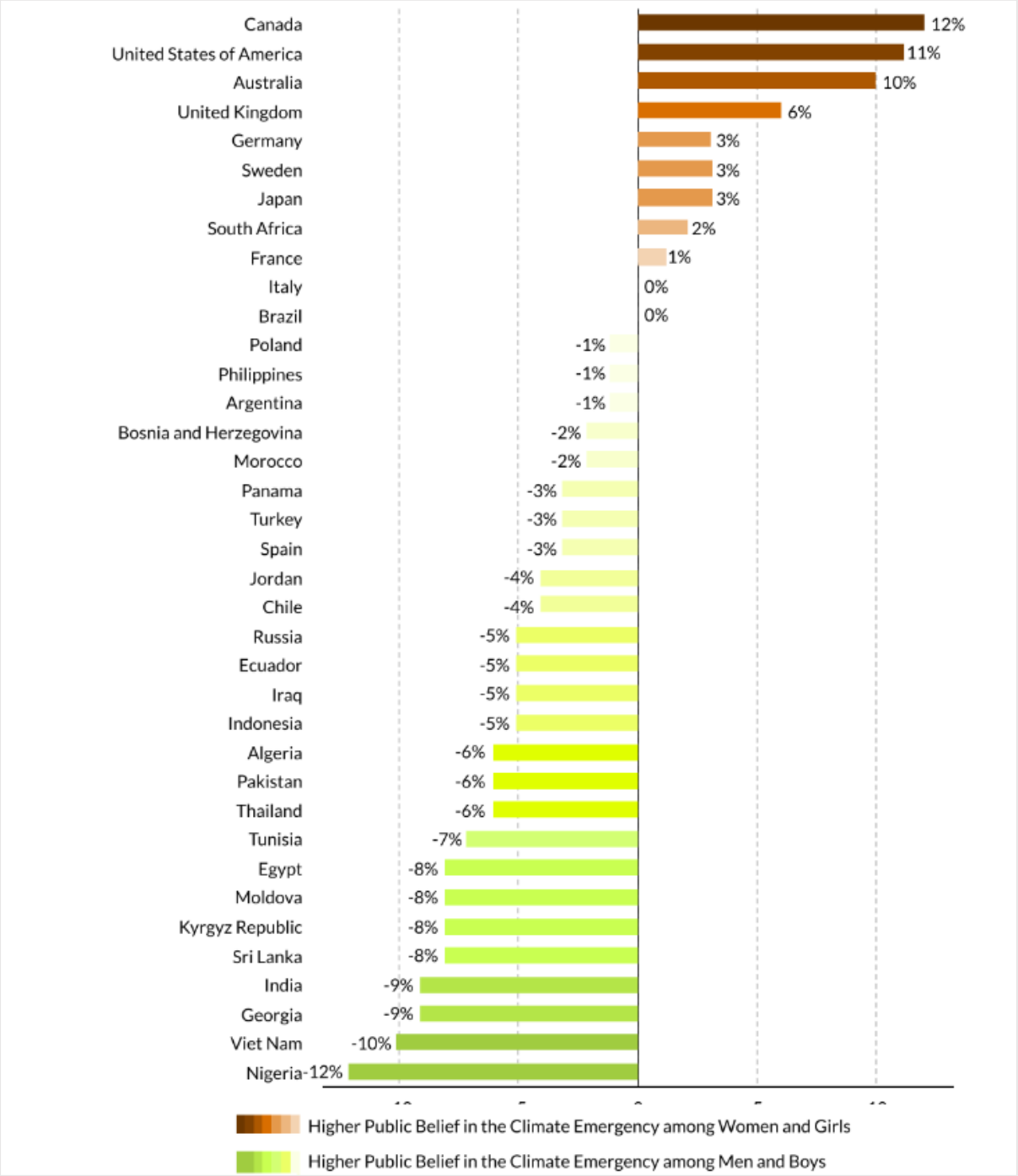


**Figure App.2.13.** The influence of gender on belief in the Climate Emergency, by country (source: UNDP, 2021).

Greatest support for policies to tackle climate change come from respondents with post-secondary education (58%), across all age groups and genders, compared to 42% across all respondents. At a national level, public belief in the climate emergency amongst respondents with post-secondary education is greatest in Italy (90%) and France (87%). Responses for selected other countries for which more detailed surveys are reported in later sections are: United Kingdom, 85%; Canada, 79%; Australia, 78%; and the United States, 66%.

Public belief in the Climate Emergency is greatest amongst the younger age group (69%, for aged under 18), and lowest amongst the oldest group (58%, for aged 60 and over) (Figure App.2.14).

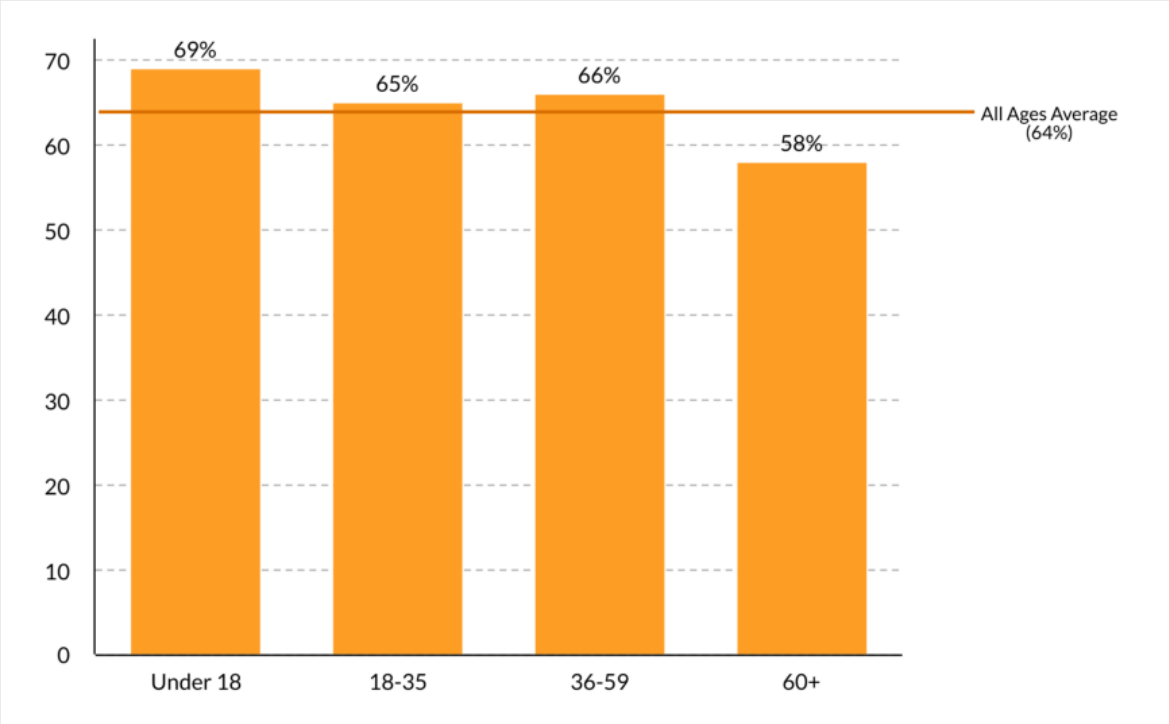


**Figure App.2.14.** Public belief in a Climate Emergency, by age group (source, UNDP, 2021).

Amongst those agreed under 18, belief in the climate emergency was highest in the United Kingdom and Italy (86%). Responses for selected other countries for which more detailed surveys are reported in later sections are: Canada, 83%; Australia, 82%; and the United States, 75%.

The polling provided opportunities for responses on policies relating to tackling climate change: energy, economy, transportation, farms and food, protecting people, and nature. The total responses to all of the questions about policies was 421,170, or 35% of the total number of responses.

Participants were asked questions about 18 policies, in questions typically of the form "To address the climate crisis, what should your country do about [energy/economy/transportation/farms and food/protecting people/ nature]"? From these questions, the highest responses were to conserve forests and land (54%) and use solar, wind and renewable power (53%), climate friendly farming techniques (52%), and investing more money in green businesses and jobs (50%). The lowest response was for promoting plant-based diets (30%). The distribution of responses is illustrated in Figure App.2.15.

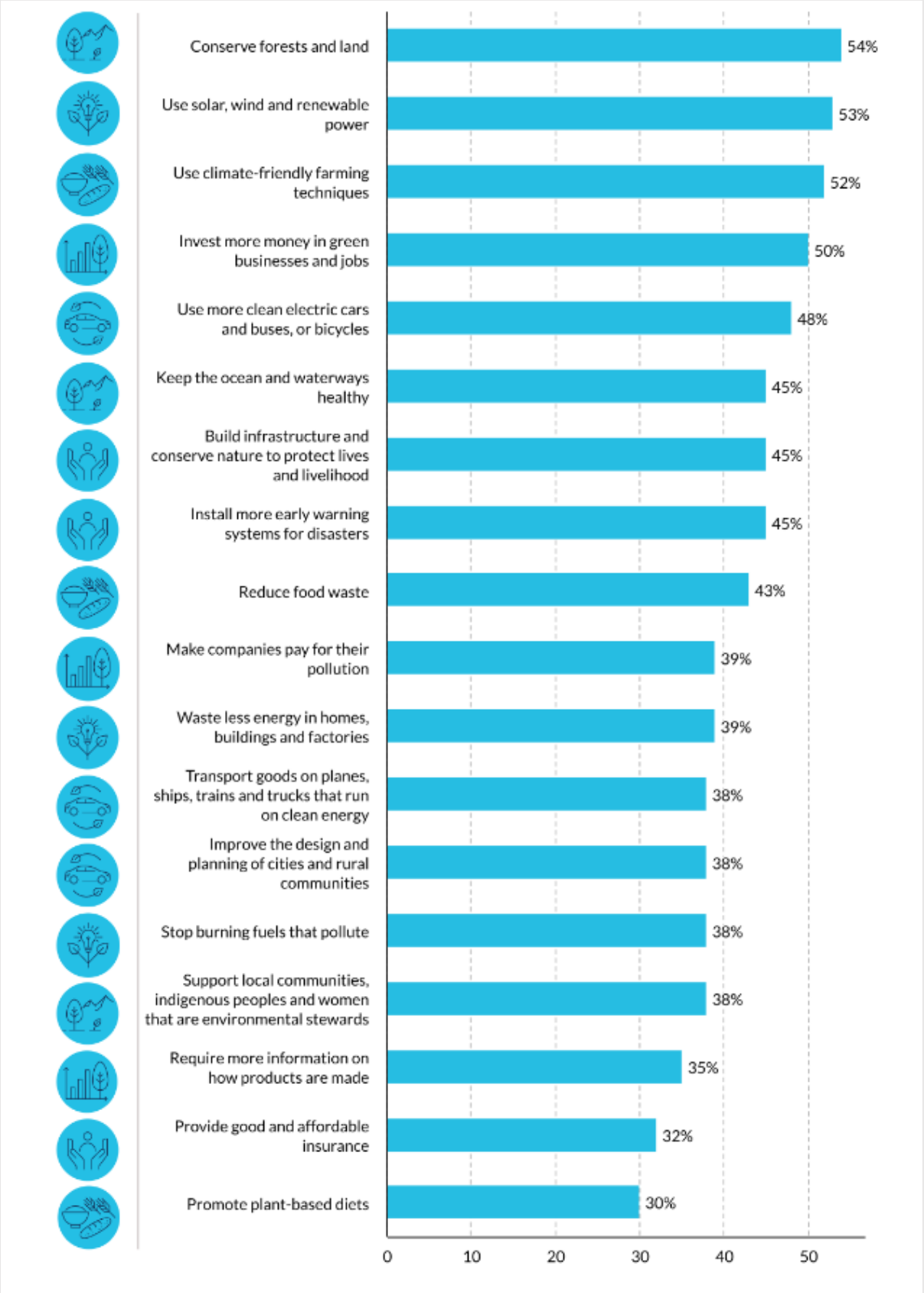


**Figure App.2.15.** Frequency of responses to policy options offered to respondents (source: UNDP, 2021).

The 10 most frequent responses amongst high-income countries are shown in Figure App.2.16. It shows that the most frequent response is for Conserving forest and land (71%), which was considerably higher than for responses from all countries (54%).

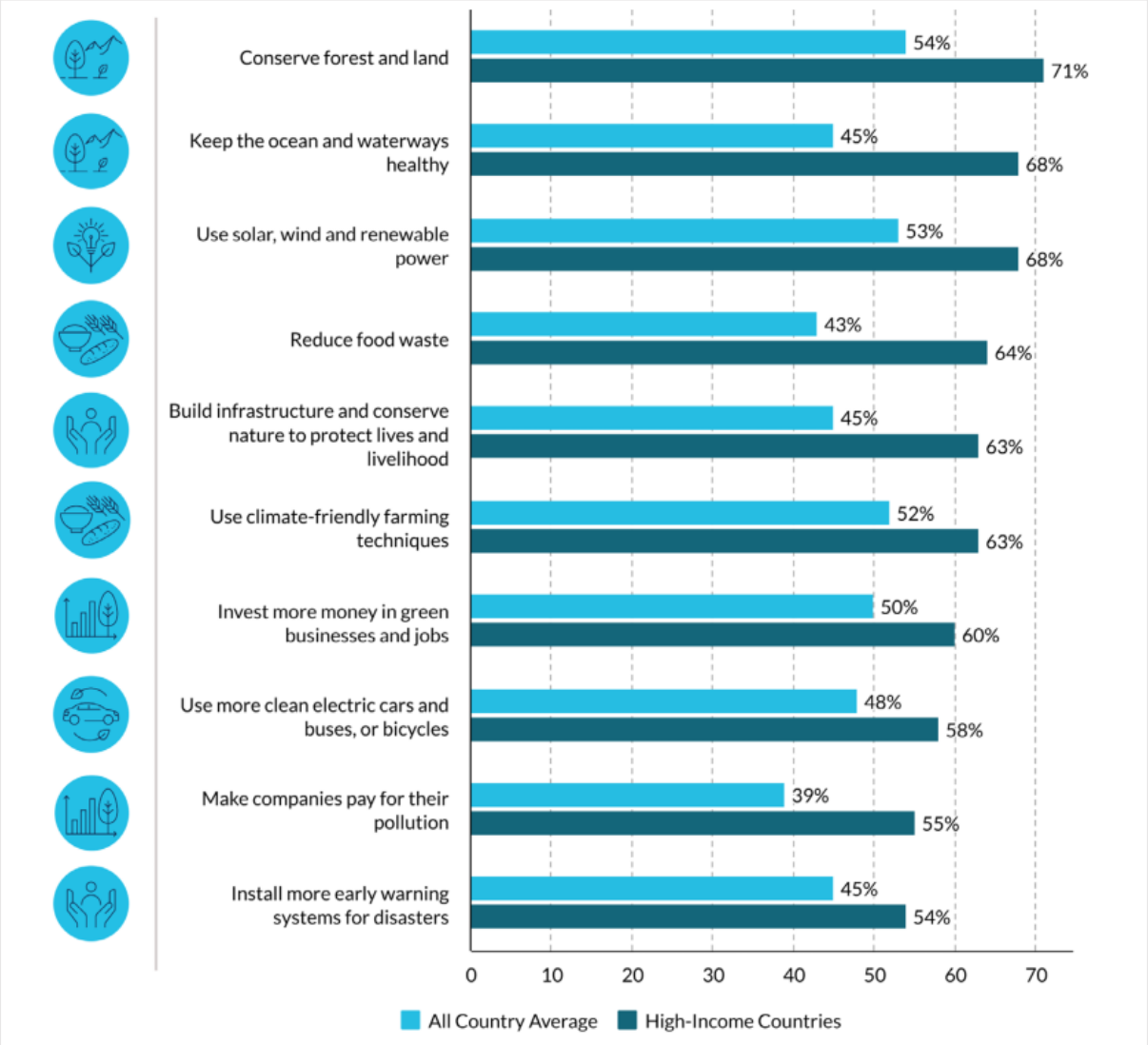


**Figure App.2.16.** Ten most frequent responses amongst high-income countries (source: UNDP, 2021).

Considering the G20 countries in the survey, there is majority support for more green investment, of which the United Kingdom has the highest proportion (73%). Responses for selected other countries for which more detailed surveys are reported in later sections are: Canada, 68%; Australia, 68%; and the United States, 57%.

In the 10 most urbanized countries in the survey, clean transport (e.g. electric vehicles) has a response ranging from 46% to 73%, with only Jordan having a response of less than 50% (Figure App.2.17). Lower proportions of respondents identify the need for climate friendly planning policies, the four highest being Australia (68%), Canada (65%), United Kingdom (62%), and the United States (54%).

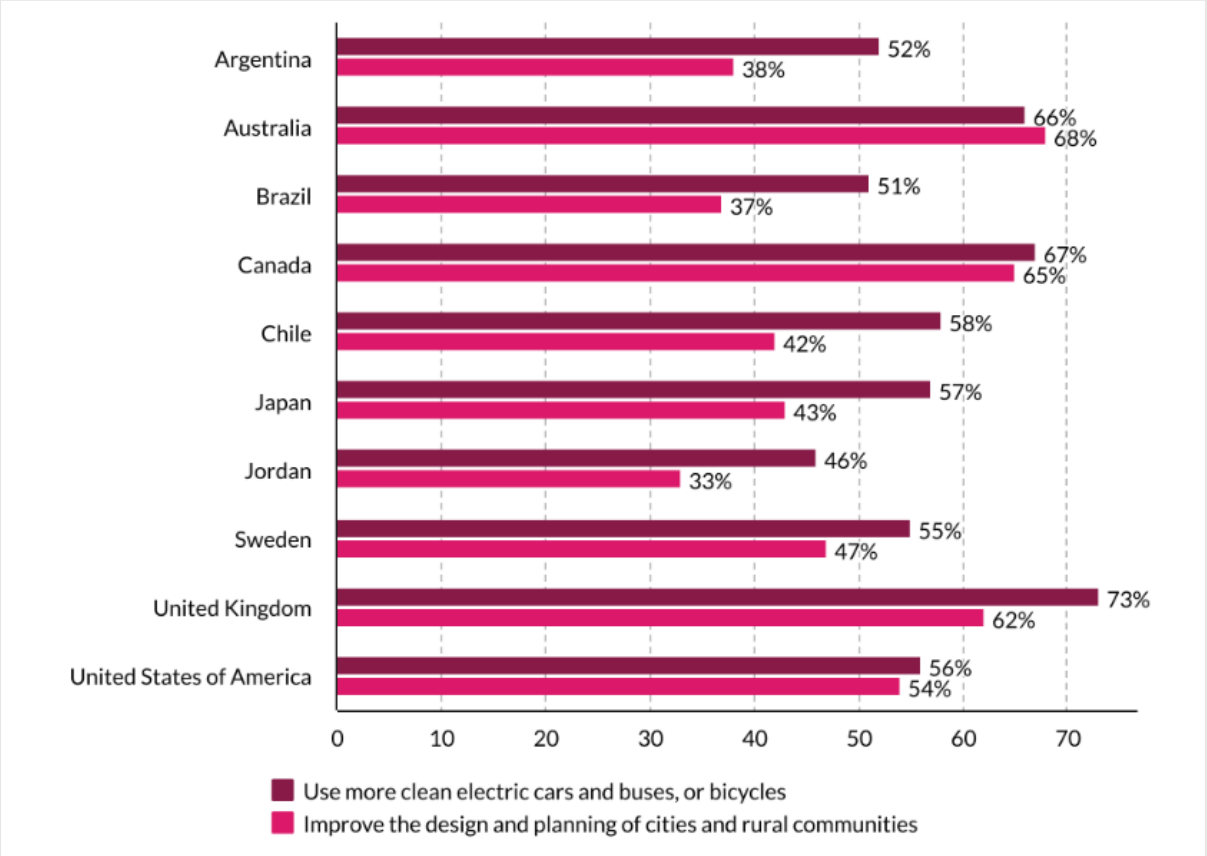


**Figure App.2.17.** Most frequent responses regarding clean transportation and climate-friendly planning policies in the most urbanized countries (source: UNDP, 2021).

Three further findings from the UNDP (2021) are that:

- "In countries with high emissions from deforestation and land-use change, there was strong backing for conserving forests and land. Four out of five countries in the survey with the highest emissions from land-use change saw majority support for conserving forests and land, including Brazil (60%), Indonesia (57%) and Argentina (57%)."
- renewable energy was supported in eight of the ten countries with the highest emissions from the electricity/ heating sectors: the United States (65%), Australia (76%), Canada (73%), Germany (71%), South Africa (69%), Japan (68%), Poland (57%), and Russia (51%).
- Support for climate-friendly farming, but with results that are mixed in those countries with the largest agricultural sectors.

The UNDP reports that later in 2021, it plans to sample options in countries not included in its initial survey.

A second recent international survey provides complementary information about public opinions on climate change to that of the UNDP. The International Public Opinion on Climate Change (Leiserowitz *et al.*, 2021). The data were collected between 17th February 2021 and 3rd March 2021. The respondents were 76,328 Facebook monthly active users, in more than 30 countries and territories.

In response to the question of How worried are you about climate change", the highest proportion of respondents who were 'Very worried' was Costa Rica (68%), followed by Mexico and Columbia (both 65%) (Figure App.2.18). The European country with the highest proportion for 'Very worried' was France (48%). The lowest proportion was reported in the Netherlands (15%). Responses for selected other countries for which more detailed surveys are reported in later sections are: United Kingdom, 27%; Canada, 34%; Australia, 32%; and the United States, 32%.

The highest proportion of respondents who reported either 'Very worried' or 'Somewhat worried', was Mexico (95%), with Spain the highest placed European country (89%). The equivalent proportion from respondents from the United Kingdom was 76%.

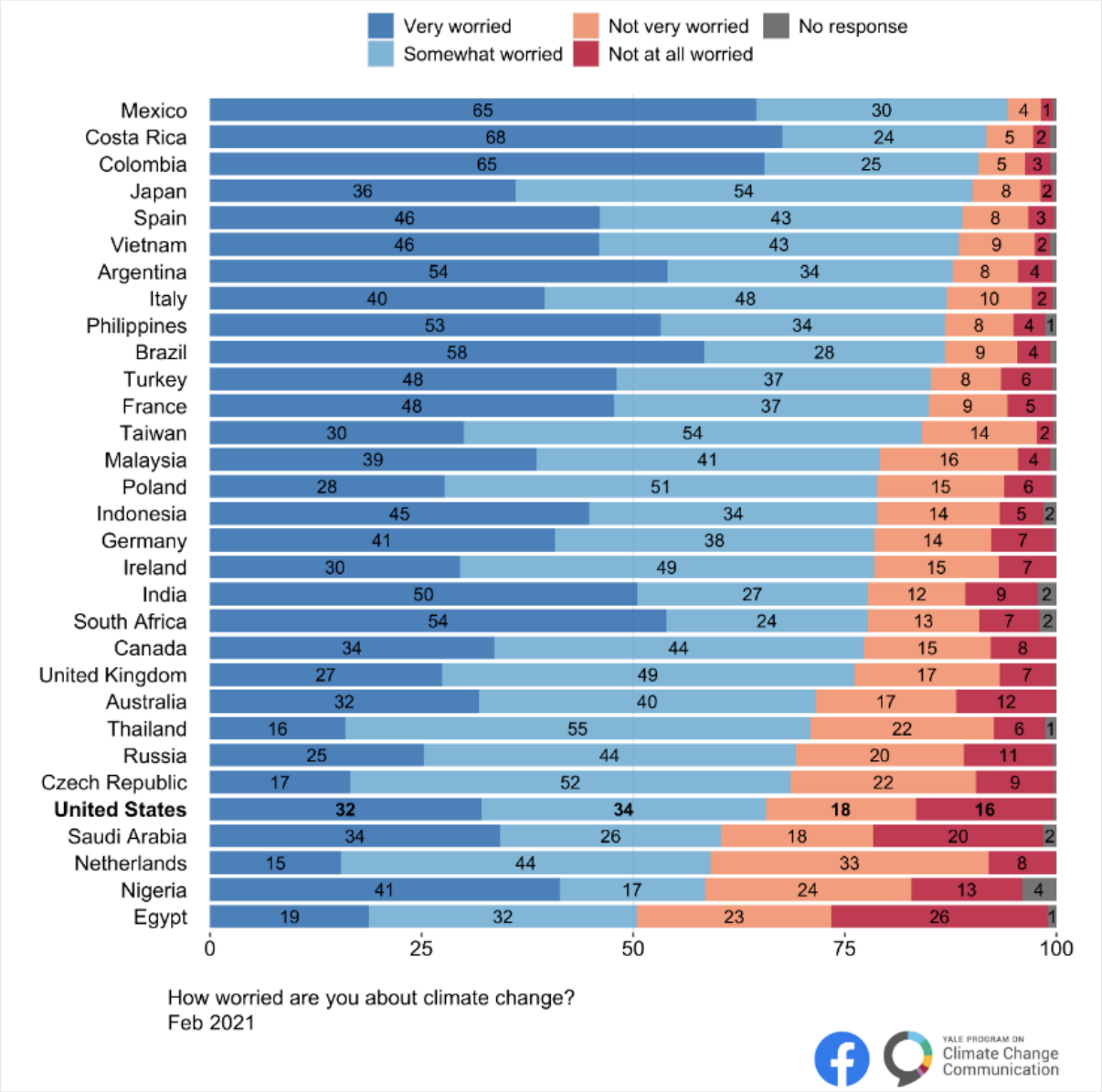


**Figure App.2.18.** Responses to the question "How worried are you about climate change?" (Source: Leiserowitz *et al.*, 2021).

The country in which the highest proportion of respondents was 'A great deal' was Vietnam (60%), followed by Mexico (59%). The European country with the highest proportion for 'A great deal' was Spain (33%). The lowest proportion was reported in the Czech Republic (4%). Responses for selected other countries for which more detailed surveys are reported in later sections are: United Kingdom, 15%; Canada, 18%; Australia, 19%; and the United States, 19%.

The highest proportion of respondents who reported either 'A great deal' or 'A moderate amount', was Mexico (83%), with Spain the highest placed European country (70%). The equivalent proportion from respondents from the United Kingdom was 52% (Figure App.2.19).

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