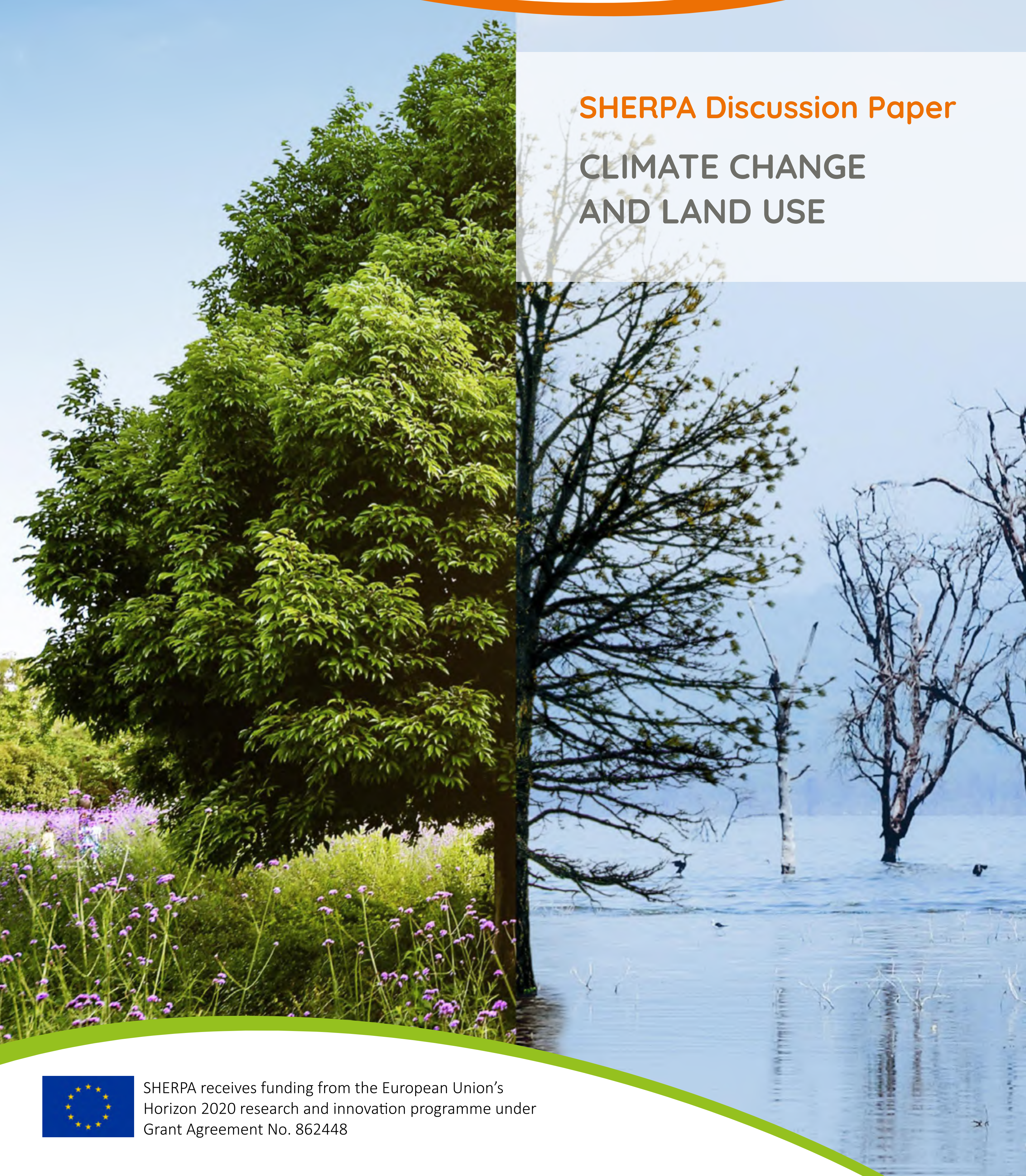
SHERPA

Rural Science-Society-Policy Interfaces

SHERPA Discussion Paper

CLIMATE CHANGE AND LAND USE



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Sustainable Hub to Engage into Rural Policies with Actors (SHERPA) is a four-year project (2019-2023) with 17 partners funded by the Horizon 2020 programme. It aims to gather knowledge thatcontributes to the formulation of recommendations for future policies relevant to EU ruralareas, by creating a science-society-policy interface which provides a hub for knowledge andpolicy. Find out more on our website:

www.rural-interfaces.eu

Table of Contents

Acronyms

BECCS	Bioenergy with Carbon Capture and Storage
CLLD	Community-Led Local Development
CBD	Convention on Biological Diversity
COP	Convention of the Parties. The 'Parties' are the governments which have signed the UN Framework Convention of Climate Change (UNFCCC)
CRD	Climate Resilient Development
DG AGRI	Directorate General Agriculture and Rural Development
EC	European Commission
EEA	European Environment Agency
EU	European Union
FAO	Food and Agriculture Organisation
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
LEADER	Liaison Entre Actions de Développement de l'Économie Rurale
LTVRA	Long Term Vision for Rural Areas
MAP	Multi-Actor Platform
NDC	Nationally Determined Contributions
RAP	Rural Action Plan
RCP	Representative Concentration Pathway
REDD	Reduced Emissions from Deforestation and Forest Degradation
RLUF	Regional Land Use Framework
RLUP	Regional Land Use Partnership
SHERPA	Sustainable Hub to Engage into Rural Policies with Actors
UNFCCC	United Nations Framework Convention on Climate Change

Summary

The SHERPA process supports the collection of scientific and practice evidence, at multiple levels, regarding climate change and land use management. It provides an overview of the key themes relating to tackling climate change, and the associated roles of land use in rural areas of Europe.

The evidence shows that significant and rapid action is required to restrict the magnitude of global warming. The target of keeping global warming to below 2°C is only possible if all conditional and unconditional pledges made before the COP26 (Glasgow, November 2021) are implemented in full and on time. Transitions in land uses, with greater investments in natural capital and associated changes in land management practices, and public attitudes and behaviours, will be essential if policy objectives of reducing the emissions of greenhouse gases (GHGs), coupled with reversing the loss of biodiversity and protecting human rights.

The SHERPA Multi-Actor Platforms (MAPs) are invited to discuss the following key questions:

- What are the needs of the area covered by the MAP in relation to climate change and land use?
- What are the policy interventions already in place, and what are examples of actions taken by local actors addressing these needs implemented in the area covered by the MAP?
- Which policy interventions (i.e. instruments, measures) are recommended by MAP members to be implemented at the local, regional, and/or national levels, and how can the EU support these interventions?
- What are the knowledge gaps, and what new research evidence is needed?

The approach of SHERPA is: i) the preparation of discussion material based on the SHERPA Discussion Paper, augmented by regionally and nationally specific research; ii) consultation with MAP members on the topic to elicit their perspectives and any additional evidence; iii) a summary of the discussions in a MAP Position Paper; and iv) a synthesis of the regional and national MAP Position Papers for discussion at European Union level.

This SHERPA Discussion Paper provides a synthesis of international and EU policy aims and findings from research as identified in recent research projects and relevant policy and discussion documents. The set of MAPs may benefit from reviewing the National Energy and Climate Plan of the relevant Member States (**European Commission, 2020a**) to enable reflection on the policy interventions planned to enable the targets in the Effort Sharing Regulation (ESR) in relation to reducing GHG emissions to be met.

See also the SHERPA Discussion Paper on **Climate Change and Environmental Sustainability** (Miller et al., 2021) for further details on the links between managing environmental services and tackling climate change.

1. Introduction

1.1. European Union strategic priorities

Building a climate-neutral, green, fair and social Europe is one of the **four strategic priorities** of the European Union for 2019- 2024. That aim includes enabling a faster transition to renewables and energy efficiency, promoting sustainable agriculture and preserve environmental systems and biodiversity. These are being undertaken in the context of implementing the European Pillar of Social Rights, and thus reflects the significance of the transitions being just.

Within the context of those priorities is the **European Green Deal** (European Union, 2019), which aims to transform "the EU into a modern, resource-efficient and competitive economy, while preserving Europe's natural environment, tackling climate change and making Europe carbon-neutral and resource-efficient by 2050."

1.2. Climate change and greenhouse gas emissions

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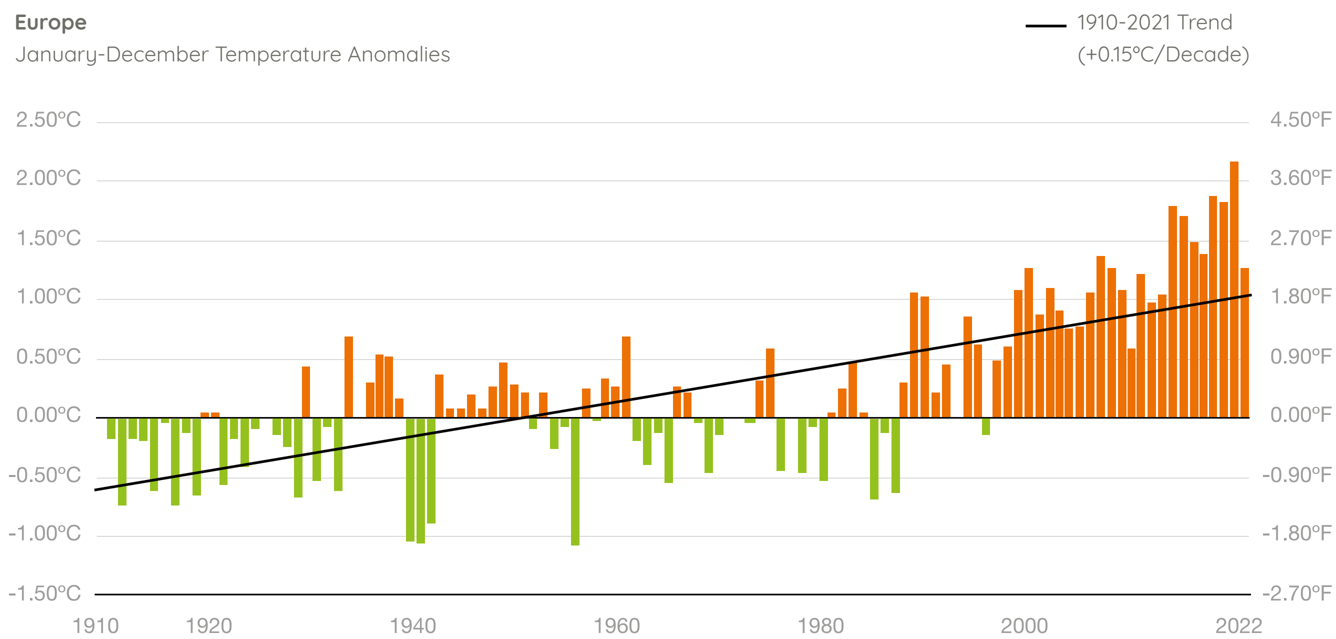

Figure 1. Annual surface temperature anomalies for Europe (annual temperatures are in comparison with the average annual temperatures for the period 1910 to 2000; Source: **NOAA**)

The **IPCC Working Group II (2022)** conclude that …

> *"Human-induced climate change, including more frequent and intense extreme events, has caused widespread adverse impacts and related losses and damages to nature and people, beyond natural climate variability.*
>
> *Some development and adaptation efforts have reduced vulnerability.*
>
> *Across sectors and regions the most vulnerable people and systems are observed to be disproportionately affected.*
>
> *The rise in weather and climate extremes has led to some irreversible impacts as natural and human systems are pushed beyond their ability to adapt."*

It also notes that, globally, 3.3 to 3.6 billion people live in contexts that are highly vulnerable to climate change.

Modelling of projected changes in climate provide an indication of alternative future climatic conditions using different assumptions about concentration pathways (**Met Office, 2018**), baselines and time periods. An example of two scenarios of changes in mean annual temperature is shown in Figure 2 (Gutiérrez et al., 2021). The high concentration pathway (Figure 2 left) shows an increase of 2.5°C or greater for all land areas of Europe by 2100, and 0.5°C or greater under a low concentration pathway (Figure 2 right).

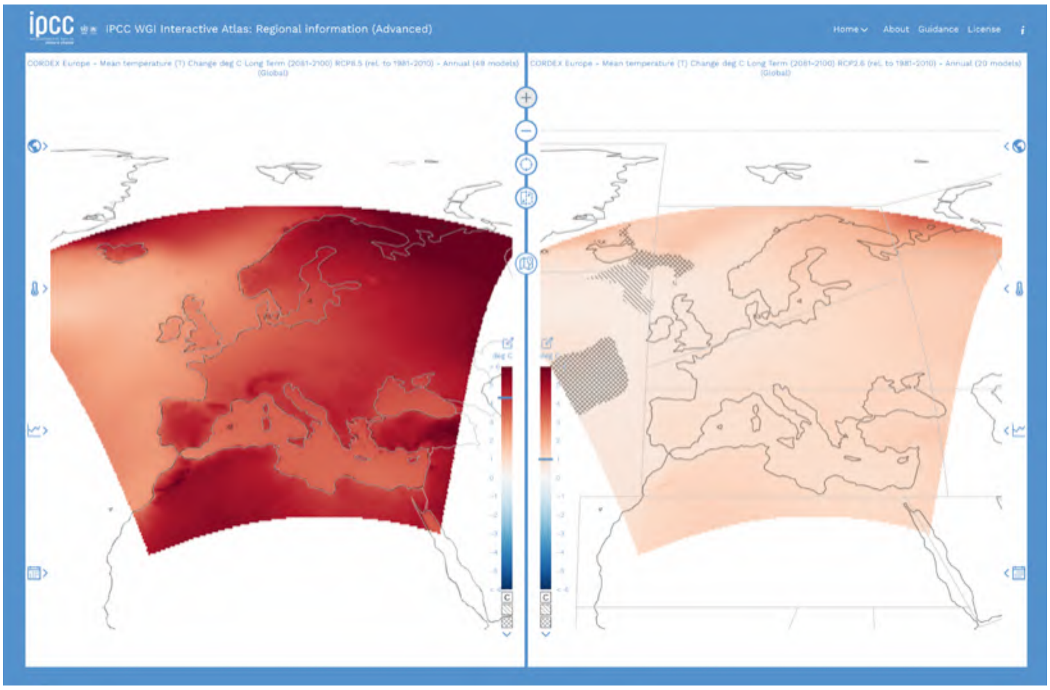

Figure 2. CORDEX Europe – Change in annual mean temperature °C for 2081-2100 relative to 1981-2010 under: Left, high concentration pathway RCP8.5 (49 models); Right: low concentration pathway RCP2.6 (20 models) (Source: Gutiérrez et al., 2021; **IPCC WGI Interactive Atlas: Regional information**).

The regional assessment for Europe (IPCC, 2021a) notes that "regardless of future levels of global warming, temperatures will rise in all European areas at a rate exceeding global mean temperature changes, similar to past observations". In its sub-regional assessments, examples of impacts of projections of climate change are:

i. Northern Europe: Observed increase in pluvial flooding attributed to human influence and projected to further increase at global warming of 1.5°C (medium confidence) and 2°C and above;

ii. Western and central Europe: Projected increases in hydrological, agricultural and ecological droughts at mid-century warming levels of 2°C or above, regardless of the greenhouse gas emissions scenario;

iii. Eastern Europe: Projected increase in fire weather at global warming of 2°C and above;

iv. Mediterranean: Projected combination of climatic impact-driver changes (warming, temperature extremes, increase in droughts and aridity, precipitation decrease, increase in fire weather, mean and extreme sea levels, snow cover decrease, and wind speed decrease) by mid-century and at global warming of at least 2°C and above.

An illustration of the projected changes in seasonal and mean temperature and precipitation with respect to 3 scenarios of global warming (1.5 °C, 2°C and 4°C) is shown in Appendix 1.

The framework for the international response to climate change is the **Paris Agreement** (United Nations, 2015) which set the goal to limit global warming to well below 2°C or 1.5°C above pre-industrial levels. At the **Climate Change Conference, COP26** in November 2021 (Glasgow, UK) negotiations between national delegations concluded with agreements that 'keeps alive the Paris Agreement target of limiting global warming to 1.5°C.' The implication of the agreements is a path to between 1.8°C and 2.4°C of warming, above the target of the Paris Agreement, but marking progress in several areas affecting rural areas (**IPCC, 2021b**; Figure 3). Meinshausen et al. (2022) calculate that the target of keeping global warming to below 2°C is only possible if all conditional and unconditional pledges made before the COP26 are implemented in full and on time.

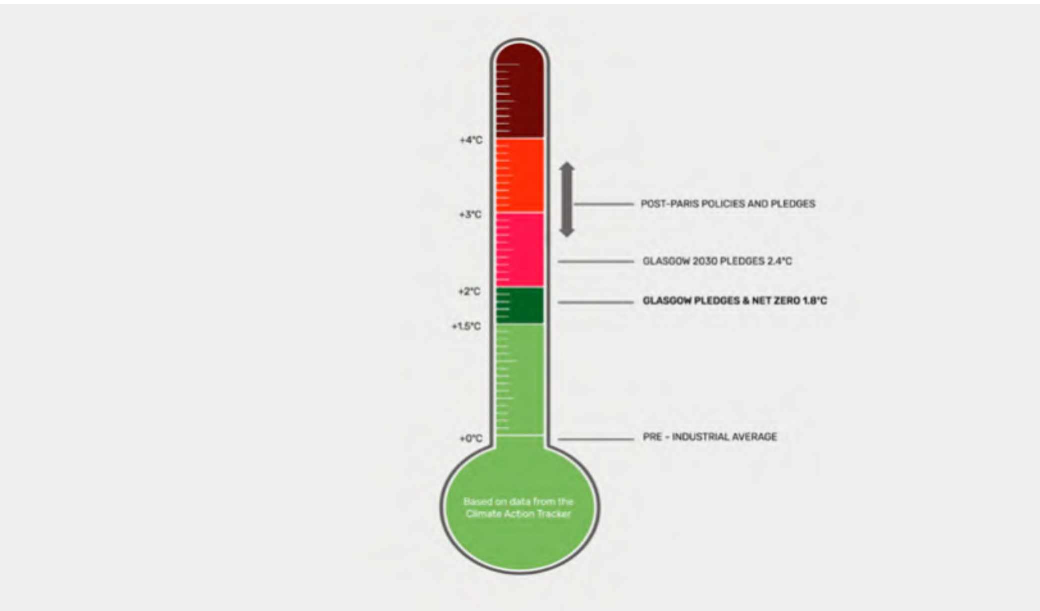

Figure 3. Overview of implications of national pledges for reducing greenhouse gas emissions (GHGs) in relation to modelled warming of global climate (Source: **IPCC, 2021b**).

Since COP26, the **IPCC Working Group II (2022)** analysed the Nationally Determined Contributions (NDCs), calculating a reduction in GHGs by approximately 4.5 $GtCO_2eq$ compared to the estimates of 2015/16. Updates on NDCs will be produced at more frequent intervals to enable tracking of changes in emissions, progressively being made more accessible for wider public access, consistent with principles of open data.

The **European Environment Agency (2021a)** report that greenhouse gas emissions (GHGs) in the EU decreased by 31% between 1990 and 2020, exceeding its target by 11% points. This reflects effects of fossil fuel prices and policy measures, and the Covid-19 pandemic. It notes that Member States have not realigned their ambitions to the new target of the EU of a net 55% reduction by 2030. The profile of GHG emissions required to reach that target, and net zero by 2050, is shown in Figure 4, with projections for both existing measures and additional measures, including the contributions of sequestration by LULUCF, indicating that it will be challenging for the target for 2030 to be met.

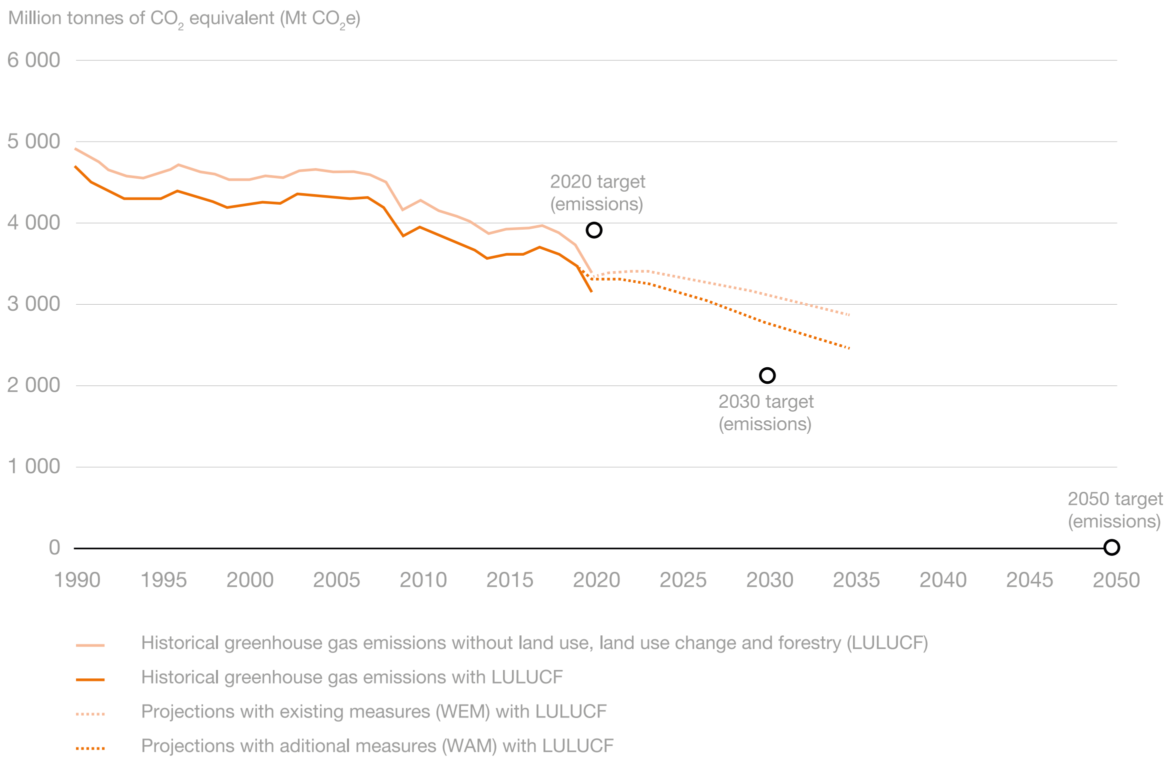

Figure 4. Historical trends and future projections of greenhouse gas emissions (Source: **European Environment Agency, 2021a**).

The latest breakdown of sectors within the **EU GHG inventory** is compiled by totalling the national inventories compiled by the EU Member States (EU-28 in 2019), illustrated in Figure 5. This shows significant reductions in absolute amount and proportionately in GHGs due to energy supply (-32%) and industry (-35%). Increases have come from international aviation and shipping, residential/commercial, and CO_2 biomass. Emissions from agriculture reduced by 19%. LULUCF is approximately the same level of net sequestration in 1990, reducing from a maximum sequestration of 321,802 kt CO_2e to 258,074 kt CO_2e in 2018.

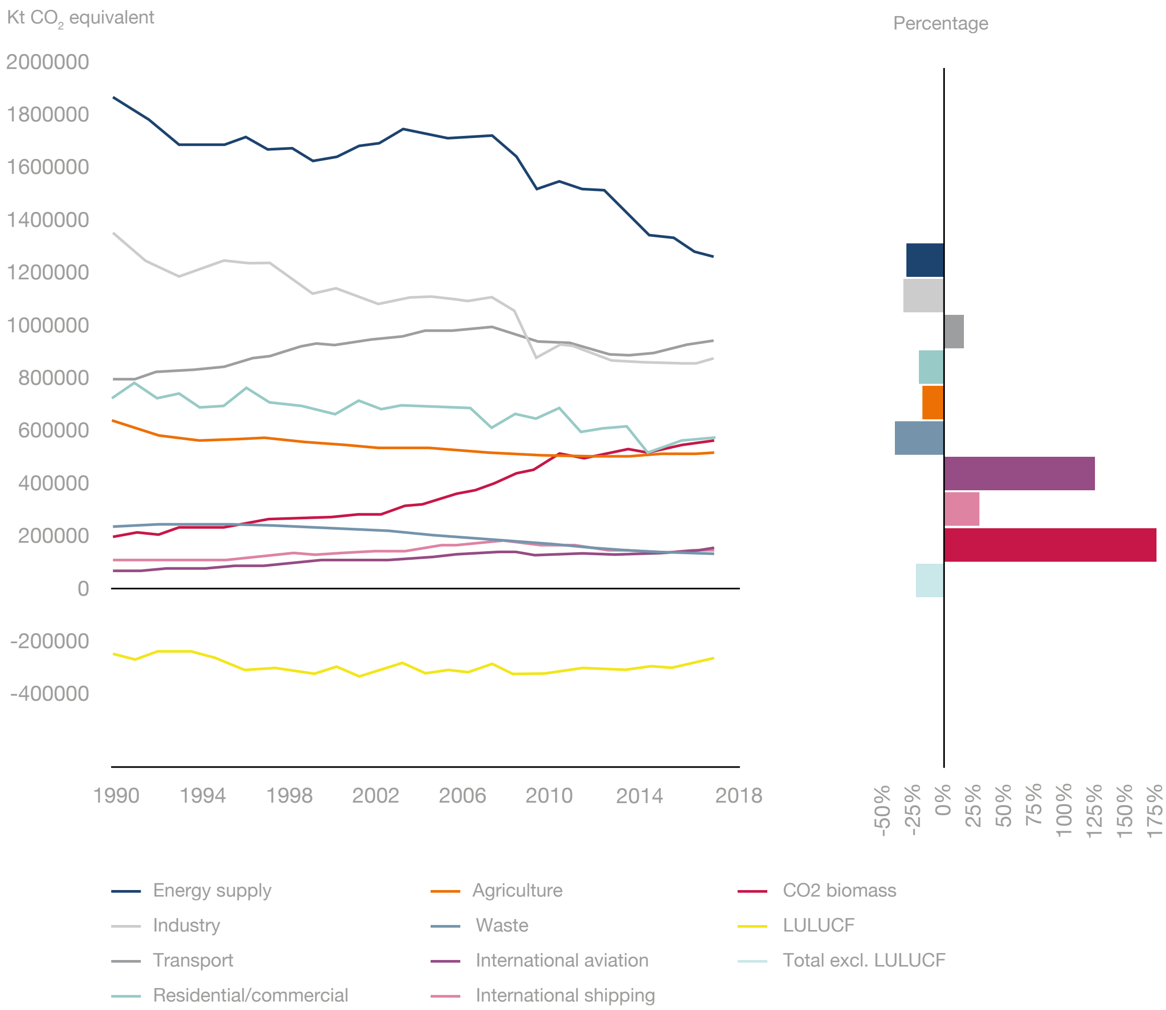

Figure 5. Greenhouse gas emissions from European Union countries, for 1990 to 2018, by aggregated sector (Source: **European Environment Agency, 2019**).

However, the IPCC (2022) notes the review of European climate change acts by Nash and Streurer (2019), and their conclusion that overall targets may not be aligned with planning, reporting, evaluation or sanction mechanisms, thus limiting the effectiveness of legislation.

In its assessment of the National Energy and Climate Plans of the Member States, the European Union notes that Luxembourg, Slovakia, Slovenia and Sweden have set more ambitious targets than those in the Effort Sharing Regulation (ESR), and that many other Member States have projected that their plans will leas to a greater reduction in GHG emissions than in their ESR targets (**European Commission, 2020a**). Denmark and the Netherlands have set in law national targets for reducing GHG emissions.

Those plans include different approaches to reducing emissions and increasing carbon sinks. For example, some Member States plan 'subsidies for converting organic soils from arable land to protected natural areas, or for afforestation in agricultural land.' The plans vary depending upon national or regional contexts, such as resources for renewable energy, incentives to reduce emissions from land uses, and required changes in human behaviours (e.g. in agriculture, transport and power; **Costa et al. 2021**, H2020 LIFT).

1.3. International and European policy contexts

At COP26, several notable policy initiatives were agreed for reducing GHG emissions: 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% 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.

In line with these commitments, the European Union has targets of an economy with **net-zero greenhouse gas emissions by 2050**, and to reduce GHG emissions to at least 55% below 1990 levels by 2030 as set out in its **2030 Climate Target Plan** (European Union, 2021), supported by legal instruments (e.g. European Union **Climate Law**; European Parliament and the Council of the European Union, 2020). This is the **Fit for 55** package which consists of several legislative proposals which are intended to ensure the realization of the objectives of the **Green Deal**. The overall goal is Europe becoming a climate-neutral continent by 2050, through eight key areas of action, illustrated in Figure 6.

Figure 6. Overview of key **areas of action** for the EU Fit for 55 Package (European Union, 2021).

The set of legislative and policy initiatives in the Fit for 55 Package include aims of reversing the current trend of emissions and removals from land use, land use change and forestry, and enhancing enhance the natural carbon sink throughout the EU. It sets an EU-level target for net removals of GHGs of at least 310 million tonnes of CO_2 equivalent by 2030, which is distributed among the member states as binding targets. It also seeks to extend, from 2031, the scope of the regulation to include agriculture non-CO_2 emissions, and set an EU-level objective of climate neutrality by 2035 for that new combined land sector.

The Intergovernmental Panel on Climate Change (2018) set out the pathways required to achieve the agreed aim through to 2100. Their conclusion was that anthropogenic emissions of CO_2 would require to half by 2030, be net-zero by 2050 and continue to reduce through the remainder of the century. Those pathways were updated to reflect 'cumulative societal choices and actions within multiple arena', founded on societal choices that accelerate and deepen key system transition' (**IPCC, 2022**; Figure 7). They distinguish between pathways in which: i) adaptation enables sustainable development and warming limited to 1.5°C, that focus on ecosystem stewardship, inclusion, equity and justice and a diversity of knowledge; and ii) those in which path dependency and limits to adaptation undermine sustainable development, with higher levels of global warming, with characteristics of ecosystem degradation, exclusion, inequity and injustice, and singular knowledge.

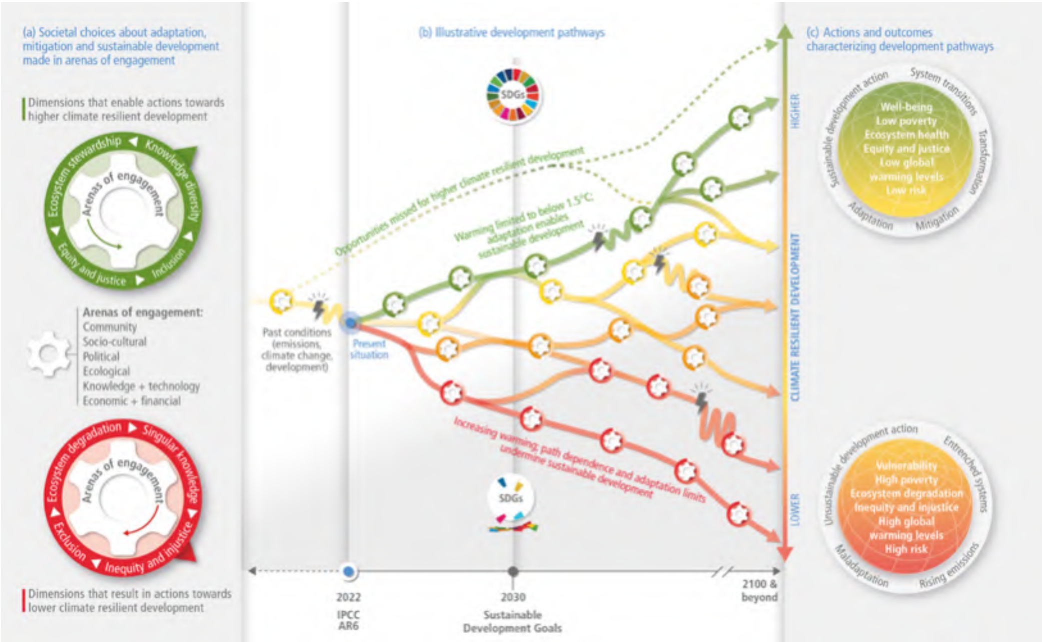

Figure 7. Illustrative climate resilient development pathways which implement GHG mitigation and adaptation measures to support sustainable development (Source: **IPCC, 2022**).

However, modelled projections by the IPCC (2022) of pathways that limit warming to 1.5°C are of are that global greenhouse gases will peak between 2020 and at the latest by 2025. Therefore, that aim is now unlikely to be met and the IPCC expresses doubt that the current development pathways and acceleration of climate mitigation are adequate to achieve the Paris mitigation objectives.

The IPCC (2022) note that the prospects of designing climate resilient development pathways are enhanced when 'supported by formal and informal institutions and practices that are well-aligned across scales, sectors, policy domains and timeframes.' Such pathways need to recognise the differences in vulnerability between ecosystems and people to climate change, reflecting historical and contemporary socio-economic contexts, and governance and uses of natural resources, land and waters, governance.

The IPCC (2022) also identify the fundamental role of safeguarding biodiversity and ecosystems in adaptation and mitigation climate change citing evidence that 'maintaining the resilience of biodiversity and ecosystem services at a global scale depends on effective and equitable conservation of approximately 30% to 50% of Earth's land, freshwater and ocean areas, including currently near-natural ecosystems.' **Pörtner et al. (2021)**, in the joint report by IPCC and IPBES, argue that the 'mutual reinforcing of climate change and biodiversity loss means that satisfactorily resolving either issue requires consideration of the other', observing that more than 50% of anthropogenic CO_2 emissions are absorbed through photosynthesis and subsequent storage of carbon in biomass and organic material. Consistent with the identification of climate resilient development pathways (Figure 7), they recommend multi-actor and multi-scale governance approaches to the management of multifunctional 'scapes' at different scales.

Designing climate resilient development pathways face challenges of how to plan and manage land and water resources, in an inclusive and equitable way, such that they contribute meaningfully to protecting vulnerable places and people from extreme impacts of climate change, and preparing and implementing steps to reduce GHG emissions and land uses which are adapted to climate change over the long-term. New H2020 and Horizon Europe projects can be expected to inform the design of such pathways (e.g. **H2020 REGILIENCE**; **H2020 ARSINOE**; **H2020 PATHWAYS**). Further evidence of approaches to tackle biodiversity and climate change in a coherent way can also be expected to come from the EU Co-fund Partnership **BiodivClim**.

2. Risks due to climate change

The **IPCC (2022)** AR6 frames the assessment and discussion of impacts of climate change on ecosystems, biodiversity and human systems in terms of risk. It recognises the dynamic interactions between climate-related hazards, exposure and vulnerability. The report identifies 127 key risks, direct and indirect, operating at different geographic and temporal scales, across the biophysical, social and economic dimensions.

The **European Environment Agency (2021b)** provide an overview of 16 hazards, using 32 indices, aligned with the hazard types of the IPCC of heat and cold, wet and dry, wind, snow and ice, coastal, and open ocean (Figure 8). In response to the IPPC ARP6, **H2020 RECEIPT** note that "Weather and climate extremes are causing economic and societal impacts across national boundaries through supply-chains, markets, and natural resource flows, with increasing transboundary risks projected across the water, energy and food sectors." They highlight the significance of cause and effect of climate change in one area on others through trade and supply chains.

The effects on agriculture are of particular significance, with nine key products identified that provide raw materials for food processing and economies of Europe of soybeans, palm oil, bananas, sugar cane, sunflower, coffee, cacao, rice and cotton. Rural areas of Europe are exposed to all of those hazard types (noting the locations of Europe's Outermost Regions such as the Azores, Madeira and the Canary Islands in the Atlantic Ocean; see Section 3).

Figure 8. Classification of 16 hazards affecting Europe, grouped into 6 hazard types (**European Environment Agency, 2021b**).

Venäläinen et al. (2014; **FP7 FUME**) report that between 1980 and 2012, the risk of forest fire increased significantly for Europe overall, as measured by the Fire Weather Index (FWI), particularly in southern and eastern Europe. The total area of forest fires in southern Europe, across Portugal, Spain, France, Italy and Greece, varies considerably year on year. In 2017 it was 8,957 km2 (Figure 9a). Wildfire can be considered an “emergent risk” for the UK, which could change in future with adaptation actions being required to manage the risk (**Perry et al, 2022**). New understanding of the vulnerability of communities to wildfires, and the socio-economic circumstances that affect the occurrence of extreme wildfires (in addition to biophysical conditions) is emerging from the research programme of **H2020 FirEUrisk**.

A geographic indication of the number and extent of wildland fires is provided by the **European Forest Fire Information System (EFFIS) (Figure 9b)**. This provides resources to inform authorities and businesses responsible for protecting forests against fires in the EU and neighbouring countries, and records and near real-time information on wildland fires in Europe. Such data can be augmented by real-time information provided by sensors (internet of things), aerial observation (e.g. drones), and citizen reporting (e.g. social media, **Piscitelli et al., 2021**; **H2020 Safers**).

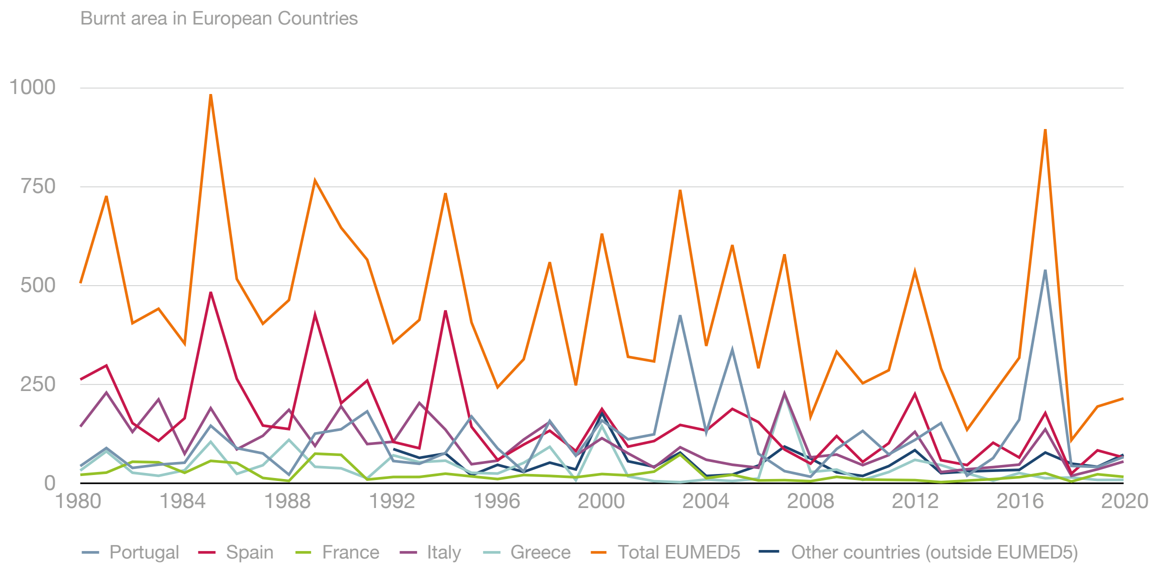

Figure 9a. Extent of forest fires in southern Europe 1980 to 2020 (Source: European Environment Agency, November 2021).

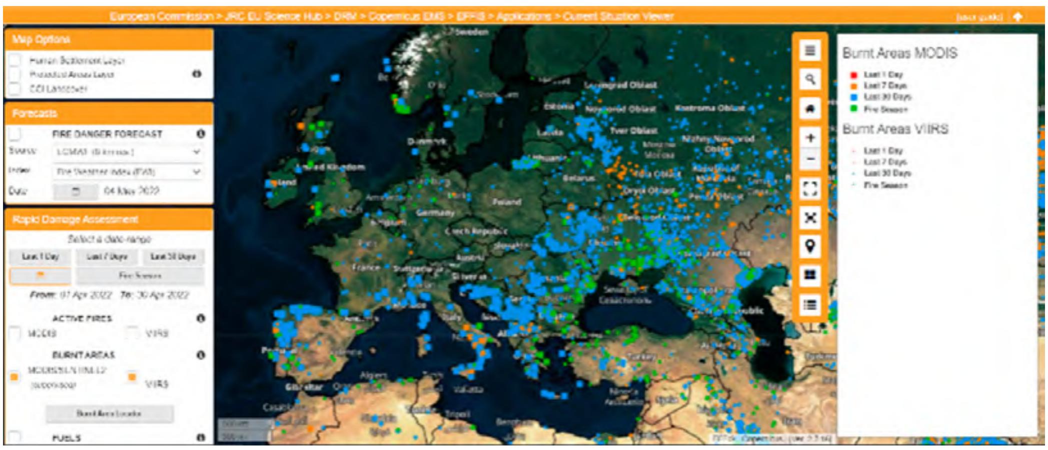

Figure 9b. View of distribution of wildfires in Europe for April 2022 (Source: **European Forest Fire Information System (EFFIS), EU Copernicus Emergency Management System**)

Examples of two of these hazards, mapped Europe-wide, are provided in Appendix 2. One is of the prospective change in risks of forest fire under two scenarios of climate change, of 2°C global warming and of high GHG emissions. The second is the projected change in meteorological droughts, between observed data for 1981 to 2010 and climate scenarios RCP 4.5 and RCP 8.5 for 2041 to 2070 (**European Environment Agency, 2021a**). These images are examples of the online resources, which are becoming increasingly available on various dimensions of climate change, its impacts, mitigation and adaptation.

A Europe-wide, geographically explicit, **typology of climate risk assessment** provides an indication of the types of risks associated with the characteristics of those areas (Figure 10a; **H2020 RESIN**). Designed with a view to informing the EU Adaptation Strategy, the online spatial tools provide information for describing, comparing and analysing some aspects of climate risk in European cities and regions. It comprises a set of indicators provide information for the typology as a whole, and detailed information which can be interrogated for individual geographic areas at NUTS 3 levels (e.g. Figure 10b).

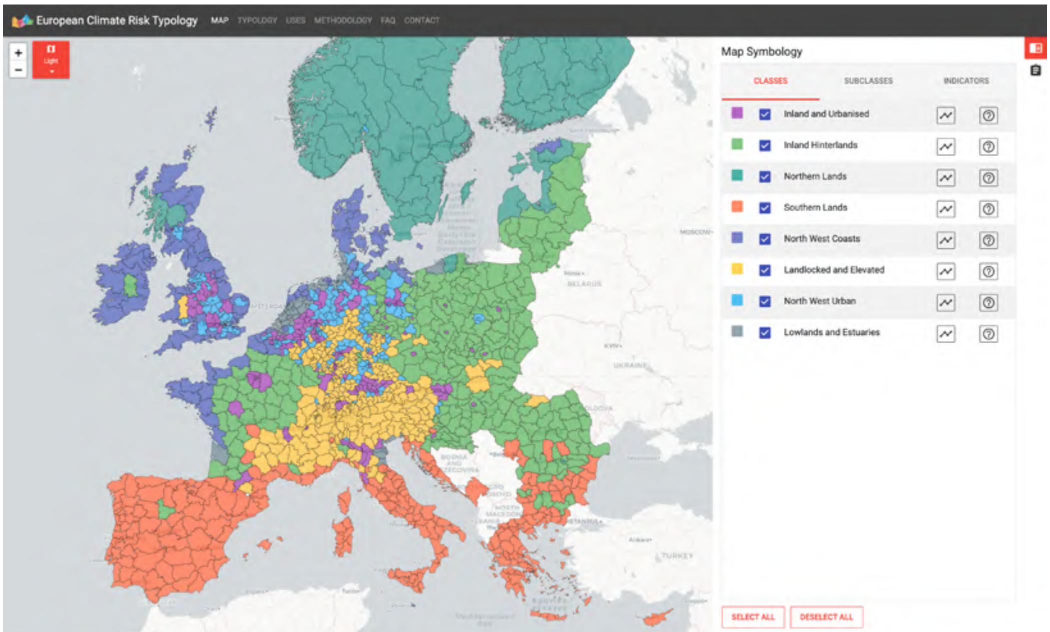

Figure 10a. European Climate Risk Typology interactive interface (Source: Carter et al., 2018; **H2020 RESIN**)

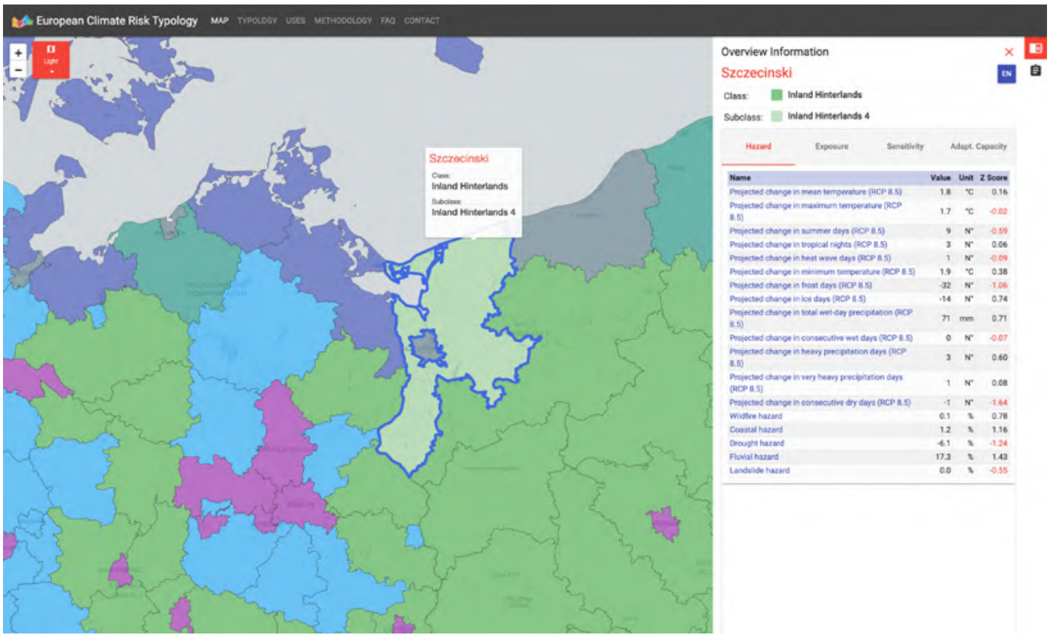

Figure 10b. European Climate Risk Typology details for Szczecinski NUTS3 zone (Source: Carter et al., 2018; **H2020 RESIN**)

The data that underpin the typology tool can be expected to need updating with the latest projections on climate change, and assessments of hazards (e.g. wildfire, drought, flooding). Such an update could form the basis of new research or implementation of the method published. However, its current data can still be used to inform stakeholders at levels from local to EU wide about aspects of hazards due to climate change, regional exposure, sensitivity and adaptive capacity, examples of which are in Figure 11. Such spatially explicit information can inform spatial strategic planning for disaster risk recovery, and of land uses to mitigate the impacts of climate change.

Figure 11 shows an example of the indicator sets for Hazard, Exposure, Sensitivity and Adaptive Capacity as reported for the Inland Hinterlands of Europe, showing the assessments for that area compared to that for Europe as a whole. This shows the greatest hazards to be wildfire and fluvial flooding, and the highest exposure being to fluvial flooding. These areas have a slightly lower sensitivity to changes in population density that Europe as a whole, possibly reflecting the greater proportion of rural areas in this category of the typology, and lower scores for 11 of the 16 topics under adaptive capacity (e.g. lower GVA per head, transport node density, NGA broadband). Such characteristics would be consistent with many rural areas of Europe.

Figure 11a. European Climate Risk Typology: Inland Hinterlands - Hazard (Source: Carter et al., 2018; **H2020 RESIN**)

Figure 11b. European Climate Risk Typology: Inland Hinterlands - Exposure (Source: Carter et al., 2018; **H2020 RESIN**)

Figure 11c. European Climate Risk Typology: Inland Hinterlands - Sensitivity (Source: Carter et al., 2018; **H2020 RESIN**)

Figure 11d. European Climate Risk Typology: Inland Hinterlands – Adaptive Capacity (Source: Carter et al., 2018; **H2020 RESIN**)

The European Climate Risk Typology and online tool may have a contribution to make to the Rural Observatory envisaged in the LTVRA to support analysis of rural areas to support policymaking (**European Commission, 2021a**). However, the data that underpin the typology tool can be expected to need updating with the latest projections on climate change, and assessments of hazards (e.g. wildfire, drought, flooding). Such an update could form the basis of new research or implementation of the method published.

Responses to pressures on coastal areas, as identified and assessed in **H2020 RESIN** and **H2020 SOLIMPACT**, are being designed to reduce risks and provide biodiversity gains for vulnerable coastal ecosystems (e.g. wetlands, seagrass beds). Newly commissioned projects can be expected to provide evidence on planning and implementation of protection for coastal areas, such as **H2020 REST-COAST** which aims to test the potential for upscaled coastal restoration providing low-carbon adaptation.

Sesana et al. (2021; FP7 **ClimateforCulture**) report on the impacts of climate change on cultural heritage. They note that "climate change can exacerbate exposure of cultural heritage to climatic stressors due to gradual changes in climate, sea level rise, and the occurrence of extreme events." These stressors also impact on historical land uses, including land use patterns and spatial organization. Frameworks for planning disaster risk management and climate change adaptation for historic areas have been designed for assessing and improving the resilience of historic areas to climate change and natural hazards (e.g. **H2020 ARCH, Advancing Resilience of Historic Areas against Climate-related and other Hazards**). The tools developed provide means of identifying opportunities to increase resilience of heritage areas, resilience implementation pathways, and potential sources of funding.

3. Islands and neighbouring areas

Research for the European Parliament (Hasse and Maier, 2021) conclude that “islands are highly vulnerable in the face of climate change and extreme weather events, such as hurricanes.” They also note that in EU legislation, islands are addressed as areas facing particular challenges (e.g. together with mountain areas and sparsely populated areas), and as Outermost Regions (e.g. Azores and Madeira, Portugal; Canary Islands, Spain; French Guiana, Guadeloupe, Martinique, Mayotte, Reunion Island and Saint-Martin, France).

Modelling by **H2020 SOLIMPACT** provides assessments of potential impacts of climate change, such as drought, rising sea levels, extreme weather events and land erosion, on islands in different geographic and socio-economic contexts. Amongst its climate impact indicators, findings show that a high emission scenario **RCP8.5** could lead to an increase in sea level in the Azores of 0.69m by 2100, and 0.24m under RCP2.6, and equivalent estimates for Cyprus of 0.58m and 0.2m, and for Fehmarn (Germany) of 0.57m and 0.2m respectively (Figure 12). The analysis of modelled risk includes the effects of perceptions of climate change on tourism (e.g. wild fires, storm intensity, impacts on wildlife), with impacts on choices of likelihoods of visiting, with some consequences on planning and uses of land (Appendix 2. Figures 1 and 2).

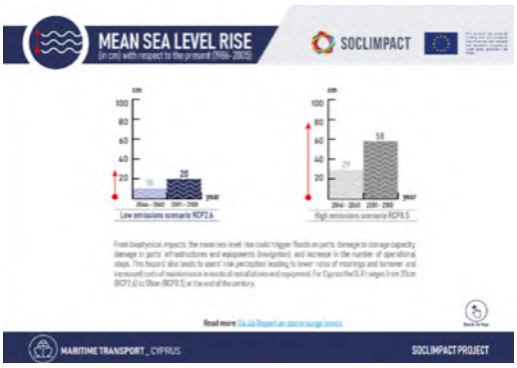

Figure 12a. Cyprus - Mean sea level rise for 2046 to 2065 and 2081 to 2100 under low emissions scenario RCP2.6, and high emissions scenario RCP8.5.

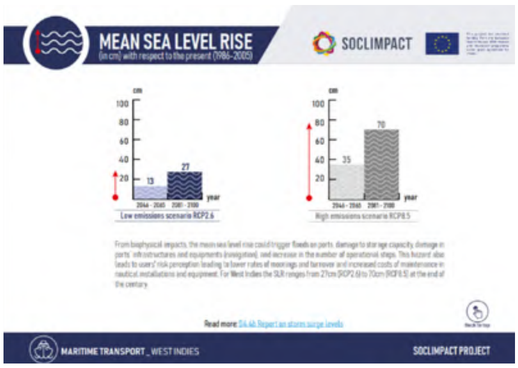

Figure 12b. West Indies - Mean sea level rise for 2046 to 2065 and 2081 to 2100 under low emissions scenario RCP2.6, and high emissions scenario RCP8.5.

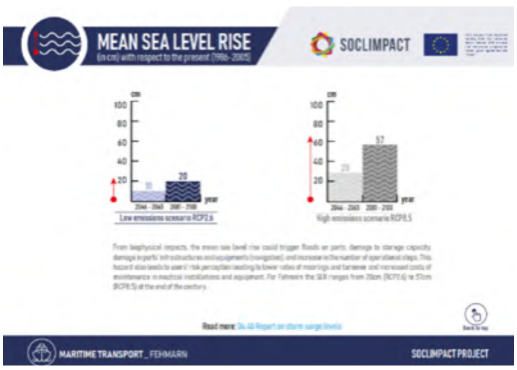

Figure 12c. Fehmarn (Germany) - Mean sea level rise for 2046 to 2065 and 2081 to 2100 under low emissions scenario RCP2.6, and high emissions scenario RCP8.5.

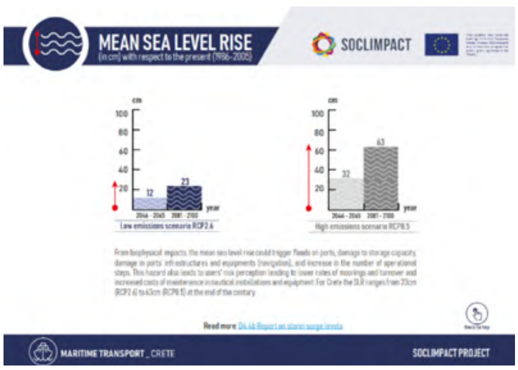

Figure 12d. Crete - Mean sea level rise for 2046 to 2065 and 2081 to 2100 under low emissions scenario RCP2.6, and high emissions scenario RCP8.5.

Alongside developing renewable energy production within the European Union, the EU is supporting the development of human capital and supporting smallscale renewable energy development in other areas of the world. **H2020 LEAP-RE** is an example of how mechanisms of EU research and development programmes builds upon the technical and social knowledge associated with developing renewables, assessments of environmental impacts, and the provision of finance mechanisms, in this case focusing on sub-Saharan Africa.

Similarly, the **EU Neighbours East programme**, part of the Neighbourhood Communication Programme (2020-2024) in which **EU4Climate** helps governments in Eastern Partner countries (Armenia, Azerbaijan, Belarus, Georgia, the Republic of Moldova and Ukraine) for which approximately 80% of energy requirements is from fossil fuels. The aim is to design climate-sensitive policies and reduce greenhouse gas emission to mitigate climate change and adapt to its effects, such as **forest restoration in Armenia**, and **mainstreaming climate change in the energy sector in Moldova**. The technical assistance provided delivers on the strategic priorities of the EU of **Promoting European interests and values on the global stage**, and its neighbourhood policy with the countries closest to its east and south.

4. Renewable energy

The European Union has a target of at least 32% of renewable energy sources in the overall energy mix by 2030 (**European Parliament and the Council of the European Union, 2018**). The EU Fit for 55 package proposes an increase in the target to at least 40% by 2030 (**European Union, 2021**). As described in the SHERPA Discussion Paper on Climate change and environmental sustainability to achieve the targets of climate neutrality by 2050 will require an increase in the rate of development of renewable energy (Miller et al., 2021; **H2020 SHERPA**), including initiatives led by communities (**Hewitt et al., 2018**; **H2020 SIMRA**).

In 2020, 22.1% of energy consumed was from renewable sources, achieving the target in the Europe Energy Strategy 2020 of 20% (**European Environment Agency, 2022**). The impact of the operationalising of renewable energy has been to reduce the amount of GHG emissions from energy generation by 24.3 Mt CO_2 in 2005 up to a provisional estimate of 470.1 Mt CO_2 in 2020 (Figure 13). Sweden (-3.471 Mt CO_2 per capita), Denmark and Finland have the largest absolute amount of avoided GHG emissions per capita due to renewable energy production, and Slovenia and Malta (-0.364 Mt CO_2 per capita) the least. Since 2006, the total GHG emissions avoided has increased from 24.3 Mt CO_2 to 470.1 Mt CO_2, the greatest contribution coming from Germany (165.9 Mt CO_2).

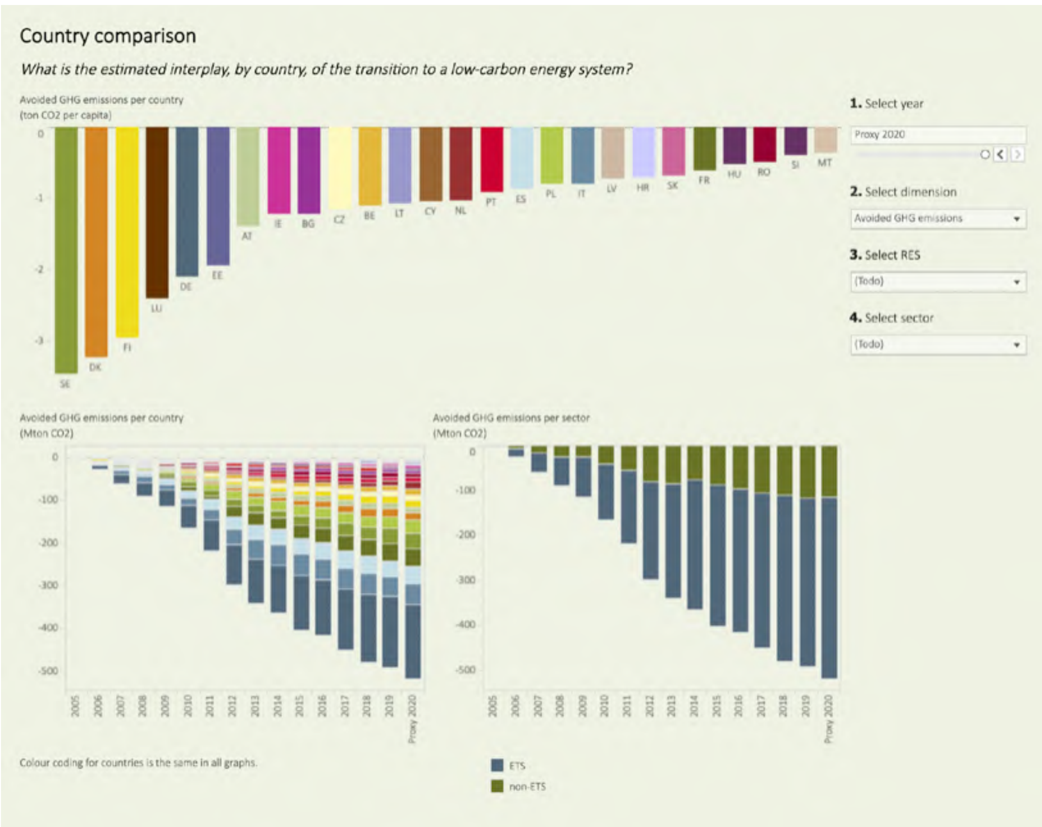

Figure 13. Impacts of renewable energy use on decarbonisation and air pollutant emissions, comparison of countries in EU-27, 2005 to 2020 (proxy) (Note: ETS includes heating and cooling, transport not selected for this figure; source: **European Environment Agency, 2022**, Renewable Energy dashboard).

At a national level, an example of the profile of increased installation of renewable energy is that of Czechia (Figure 14), the impacts of which on avoided GHG emissions (Figure 14, top left) have risen from almost zero in 2005, to 11.282 Mt CO_2 from 17.2% of total energy for electricity and heating and cooling (Figure 14, bottom right). Equivalent profiles are available at national levels for each Member State of the EU (**European Environment Agency, 2021a**).

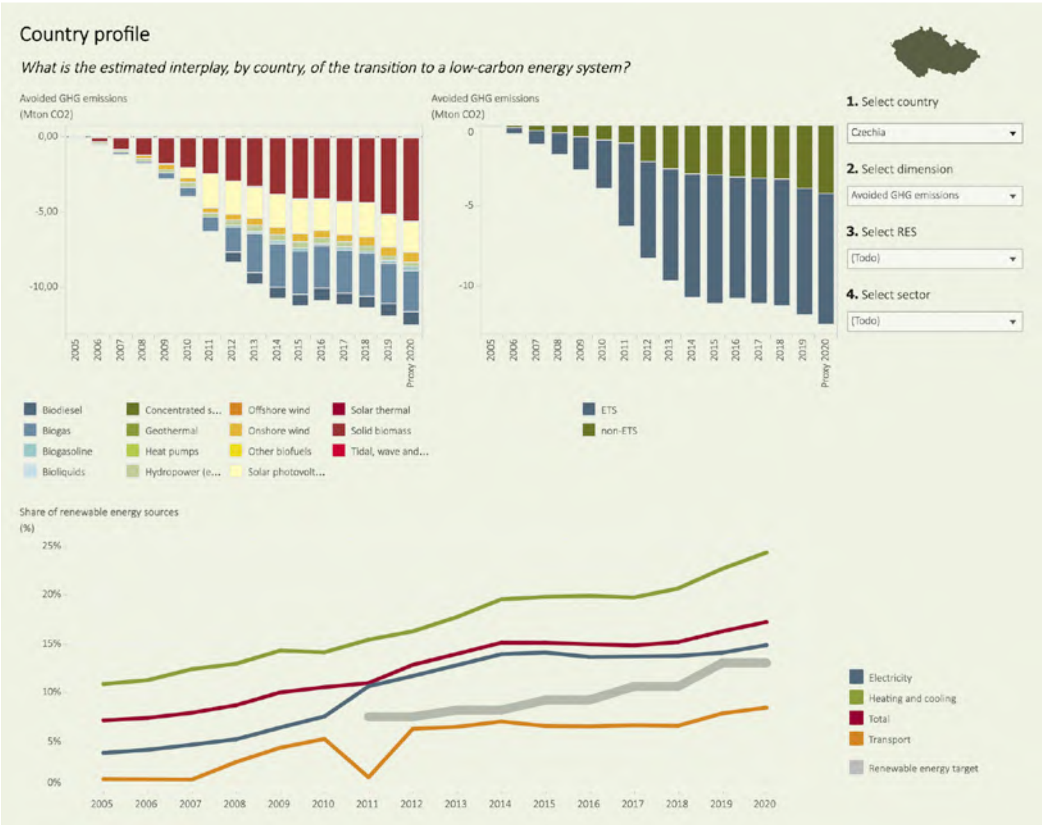

Figure 14. Impacts of renewable energy use on decarbonisation and air pollutant emissions, national assessment for Czechia, 2005 to 2020 (proxy) (Note: ETS includes heating and cooling, transport not selected for this figure; source: **European Environment Agency, 2021a**, Renewable Energy dashboard).

The proportion of energy generated from renewable sources between 2005 and 2020 has been continuing to increase, generally exceeding the targets set in the steps towards 2020 (Figure 15). However, to achieve the proposed new target of 40% of energy generated to be from renewable sources by 2030 will require a significant increase in the deployment of renewable energy systems by 2029 to be fully operational by 2030 (i.e. over approximately 6 years). Industry estimates of the rate of development to commissioned renewable energy is approximately 451 GW installed capacity by 2030, compared to 180 GW in 2021 (**Wind Energy, 2021**). That equates to approximately 30 GW new capacity per year. As of 2021, industry bodies estimated a build rate of 15 GW per year from 2021 to 2025.

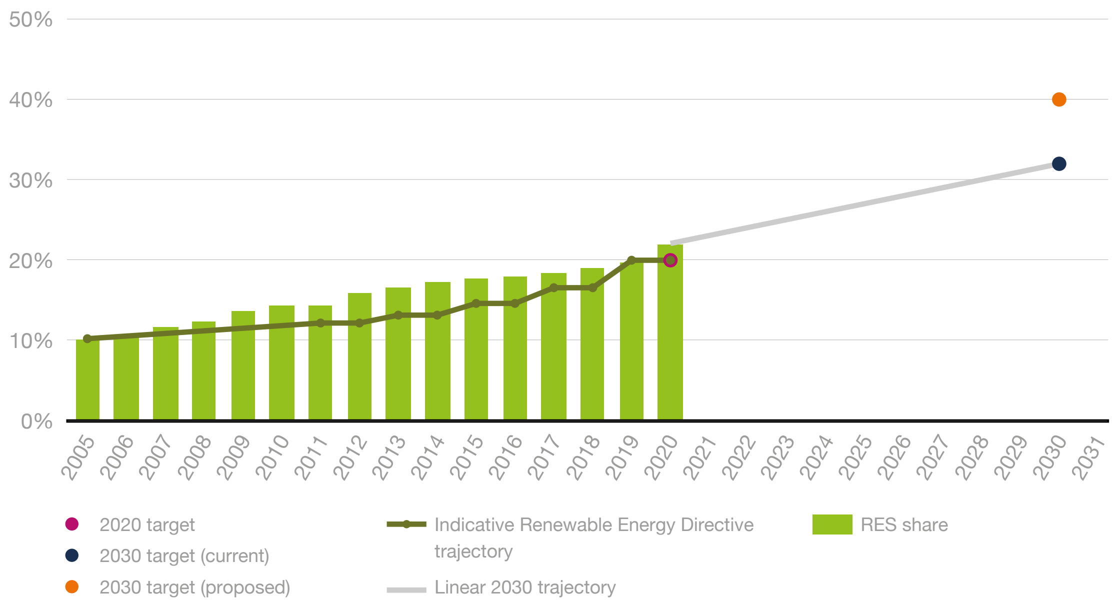

Figure 15. Progress towards renewable energy source targets for EU-27 (Source: **European Environment Agency, 2022**).

Marine renewables (offshore wind, tidal, wave) can be expected to contribute significantly to the contribution of renewable energy by 2030. However, the time lags associated with developments of marine renewable energy new projects proposed in the immediate future would not become operational in the timescale set out.

At the small end of the scale, an indicative timescale for a 500kw wind energy project (e.g. 1 turbine from a leading supplier such as Vestas or Enercon) is 2 years from feasibility study to commissioning (**Renewables First Ltd., 2022**). Such small scale developments may make contributions to energy use by individual farms or rural businesses. They may also be the entry points for civil society led initiations, or social innovations, that contribute to broadening the responsibilities and opportunities linked to generating renewable energy (e.g. **Slee, 2020**; **H2020 SIMRA**).

Figure 16 (a to c) show the trends in production of energy from solar PV and thermal (Figure 16a), onshore wind (Figure 16b) and solid biomass (Figure 16c) for the EU 27 from 2005 to 2020, expressed in kilo tonnes oil equivalent (ktoe). Note that the vertical axes are not the same. Combined Solar PV and thermal have increased from 0.862 ktoe to 13.866 ktoe; onshore wind increased from5.534 ktoe to 27.730 ktoe; and, solid biomass increased from 65.825 ktoe to 88.258 ktoe all between 2005 and 2020. The key observations are that solid biomass has been the dominant source of renewable energy in Europe over this time period, primarily as energy for heating, with 8.422 ktoe for electricity in 2020. This is excepted to continue, identified in some National Energy Carbon Plans (NECPs), such as **Hungary**, which notes “NECP assigns an important role to energy production from biomass.”

Onshore wind has steadily increased in its contribution to energy consumption in Europe, entirely for electricity, and the development of Solar PV and thermal appears to be increasing its rate of development.

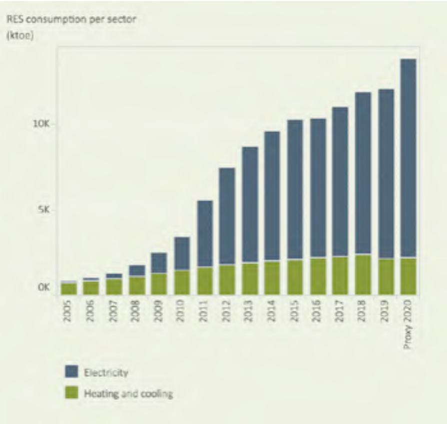

Figure 16a. Uptake of Solar PV and Solar Thermal energy generation in 27 EU Member States from 2005 to 2020 (Source: **European Environment Agency, 2021a**

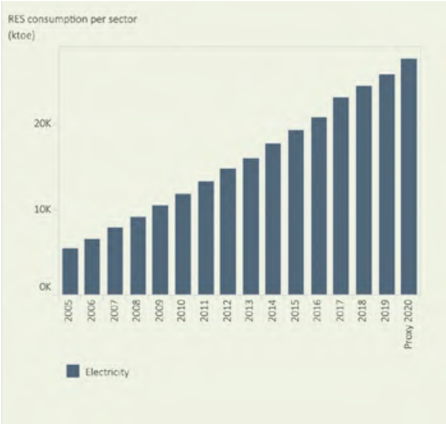

Figure 16b. Uptake of onshore wind energy generation in 27 EU Member States from 2005 to 2020 (Source: **European Environment Agency, 2021a**

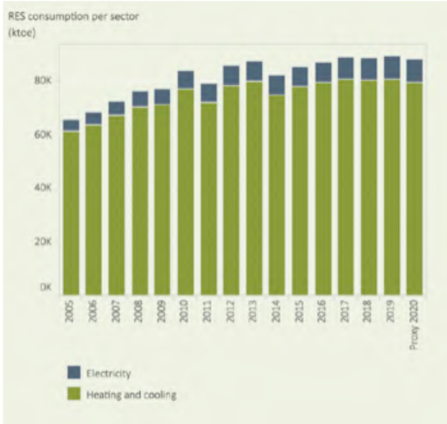

Figure 16c. Uptake of solid biomass for energy generation in 27 EU Member States from 2005 to 2020 (Source: **European Environment Agency, 2021a**

A key challenge for expanding renewable energy in tackling climate change is planning what types are most appropriate where, and in what combinations with other land uses. Not all rural areas have suitable natural resources for the generation of renewable energy. Considerations include appropriate wind or light conditions for wind or solar PV, or soil, terrain and climate suitable for solid biomass. All these sources of renewable energy also require suitable land to be available, taking into account constraints that are environmental (e.g. bird habitat), economic (e.g. renewable energy being competitive with other land uses for food, housing, recreation), social (e.g. acceptability), and infrastructure that enables energy to be exported.

In its assessment of NECPs, the (**European Commission, 2020a**) notes that, as per the EU Biodiversity Strategy 2030, solutions to be prioritised (on shore) include solar-panel farms that provide biodiversity-friendly soil cover, and sustainable bioenergy. It argues for integrated approaches which consider the interactions of solutions with environmental domains such as water and soil pollution, resource efficiency and the water-energy nexus, in line with the "do no harm" principle in the **European Green Deal** (European Union, 2019). In relation to developing bioenergy solutions, the EU also suggest that consideration should be given to its efficiency in terms of land-use and carbon sinks, air quality and other environmental impacts. The need for uses of land to be compatible are explicitly recognised in some NECPs. For example the NECP for **Hungary** notes the importance of satisfying "growing demand for energy from biomass with the lowest possible environmental impact, taking into account optimal conditions for energy, forestry, soil science, agriculture, nature conservation and transport."

The EU also noted that renewable energy may 'provide replacement employment in eligible Just Transition regions and generally in a decentralised manner also opportunities for remote areas and islands.'

One of the 100 research questions for Social Sciences and Humanities identified by **Von Wirth et al.** (2020; **H2020 Energy-SHIFTS**) is how renewable energy installations can support the rural development of the communities hosting them. Lizarralde et al. (2022; **H2020 SocialRes**) provide a guide for successful social innovations in the energy sector. They identify key barriers that include lack of funding, passivity in society, administration and bureaucracy, absence of legal frameworks, lack of access to information needed, and lack of experience in carrying out social innovation projects and stakeholder support, evidence of which is also reported by **Ravazzoli et al.** (2021; **H2020 SIMRA**).

5. Land use and systems

Achieving the targets of net zero GHG emissions by 2050, and reversing the loss of biodiversity, requires innovation in delivering the multiple functions from land uses, and changes in land systems. **Pörtner et al. (2021)**, in the joint report by the IPCC and IPBES, note that 'measures intended to facilitate adaptation to one aspect of climate change without considering other aspects of sustainability may in practice be maladaptive and result in unforeseen detrimental outcomes.'

Land use, "The social and economic purpose to which we put the earth's surface" (Mather, 1986), should be interpreted in the context of the multiple functions provided (see SHERPA Discussion Paper, **Miller et al., 2021**), at different geographic and temporal scales. **Meyfroidt et al. (2022)**, in a major review of literature, note that land use generally entails trade-offs between benefits delivered (e.g. food, habitats, recreation), rather than win-wins, and that the "level of congruence between different environmental indicators such as biodiversity and carbon stocks is highly heterogeneous across scales and geographies." However, changes in land use should still be consistent with the biophysical and cultural contexts of local areas, and cognisant of the roles they have in wider natural, economic and social systems (**Meyfroidt et al. (2022)**).

Public policies and strategies for combating climate change, such as increasing the level of sequestration of carbon in the Land Use Land Use Change and Forestry sector (Section 1), predominantly require the use of land in rural areas. The EU Forestry Strategy states that "forests are a natural ally in adapting to and fighting against climate change and will play a vital role in making Europe the first climate neutral continent by 2050" (**European Commission, 2021b**). The **EU Biodiversity Strategy for 2030** (European Commission, 2020b) sets an aim of planting at least 3 billion additional trees in the EU by 2030. This would extend current forest cover of 42% of Europe's land area (**H2020 ONEforest**), and double the rate of planting from 300 million to 600 million trees a year.

Forests can sequester carbon by capturing CO_2 from the atmosphere, and transforming it into biomass. The carbon sequestered accumulates as biomass, deadwood, litter and in forest soils. Carbon can be released from forests through natural processes of respiration and oxidation, and due to the results of human activities (i.e. harvesting, fires, deforestation) (**UNECE**, 2006; Nijnik, 2010). Research findings suggest that total mitigation of forests and the forestry sector could approach 20% of total EU emissions in the base year (**Nabuurs et al.**, 2017; **FP7 SIMWOOD**), with estimates that climate smart forestry could sequester 441 Mt CO_2/year by 2050. To achieve this level of sequestration, they identify key requirements to be: i) reducing and/or removing greenhouse gas emissions; ii) adapting and building forest resilience; iii) sustainably increasing forest productivity and income.

From published literature, **Nabuurs et al.** (2017) compiled an estimate that improved forest management in forests and wood chains could add 172 Mt CO_2/year by 2050, including a shift to hardwoods from productive mixed deciduous and coniferous woodland. They also estimate that changing land use from abandoned farmland to woodland (approximately 150,000 km2 of land by 2030) would increase sequestration by approximately 64 Mt CO_2/year, and that energy from biomass could avoid emissions of approximately 141 Mt CO_2/year. However, decisions are required of the types of species and where they should be planted. Del Rio et al. (2020) report that, in mountain regions, for buffering climate change impact, spruce-fir-beech mixtures should be preferred against mono-specific forests (**H2020 CARE4C**). For some land managers, forestry may be a new crop, so their decisions also require to be informed by understanding of risks relating to plantation forests, which are noted as increasing due to growing abiotic, biotic and financial hazards (**Freer-Smith et al., 2019**).

Müller et al. (2016), in their report by FAO on integrating forests and wood products in climate change strategies, highlight a key challenge for policymakers is in identifying 'combinations of options that provide optimal social, environmental and economic outcomes.' They provide indications of whether, where and how forestry can offer a socially acceptable and low-cost opportunity for carbon uptake. However, **Freer-Smith et al. (2019)** also note the diversity and regional differences across Europe for establishing and managing plantation forests, and that there is 'no one-size-fits all solution to maximize socio-economic benefits'.

Initiating, planning and managing carbon smart forests can be led by public agencies, business or civil society. Where the public and private sectors have been inhibited in taking such initiatives, civil society led social innovations have emerged in forest dependent communities (**Nijnik et al., 2019**; **H2020 SIMRA**). Examples of such social innovations are: i) the management of natural environments with an aim of mitigating climate change (e.g. in the **Nizke Tatry National Park Slovakia**; **H2020 SIMRA**), a key finding from which is the importance of, and adherence to, accepted guidelines for managing forests (e.g. EUSTAFOR, 2020); ii) the use of carbon accounting in the promotion of economic development in forest-dependent indigenous communities (**van Kooten et al., 2019**; **H2020 SIMRA**).

Consistent with the EU LTVRA and **Biodiversity** strategies, several National Energy and Climate Plans (NECPs) include commitments to expanding forest cover. **Lithuania** proposes the promotion of carbon accumulation in forest stands by forming more productive forest areas through sustainable forestry measures, with similar proposals for extending forest areas in the NECP for **Romania**. The NECP of the **Netherlands** plans climate neutral production of food and non-food by 2050. This is proposed to include expanding the extent of natural areas, restoring landscape structures, limiting deforestation and planting new trees. It proposes the climate proofing of nature to increase the amount of CO_2 sequestration capture while preserving biodiversity, and increasing biomass harvests by 2050.

Policies in European countries towards limiting deforestation should include consideration of how to influence reductions in emissions from deforestation and degradation (REDD) in other areas of the world, notably tropical regions. The FOA identify this as 'one of the most efficient activities for reducing GHG emissions within the forest sector' (**Müller et al., 2016**). However, policy measures have proven challenging for addressing issues such as how to allocate responsibilities, distribute burdens and benefits, and whether co-benefits should be required, or can be expected (**Nijnik et al., 2014**; **FP7 REDD-ALERT**).

The NECP of **Denmark** recognises the necessity of understanding the potential implications of biomass production, and that the sustainability of the land system. It notes the voluntary Danish industry agreement on sustainable biomass, which aims to ensure that biomass used in Denmark fulfils internationally recognized sustainability demands (i.e. biomass must come from forests that are operated in a sustainable way, and the use of biomass has to lead to real CO_2 reductions). Achieving this objective requires an understanding of the system, not only the land use currently or planned for a site (as also explained by **Pelkonen et al., 2014**).

Schäfer et al. (2015; FP7 EuTRACE) note the requirement of understanding entire systems when designing climate interventions such as Bioenergy with Carbon Capture and Storage (BECCS). They note that understanding needs to include the significance of the displacement of current land uses, lock-ins for land owners and managers, supply chains of raw materials through to processing and product uses, and the attitudes of stakeholders (e.g. on trade-offs between land uses and landscapes under widespread uptake of forestry or bioenergy crops).

In its NECP, **Greece** plans to strengthen the primary sector through the promotion of energy crops of woody biomass or coppice plantations, agri-livestock waste and agricultural/forest residues. It envisages the primary sector contributing to the production of biomass (solid biofuels) using short-rotation forest species and other perennial plants (e.g. reeds).

The NECP of **Portugal** sets out a plan for increasing the natural carbon sink capacity of agriculture and forestry, and soils. This aims to increase the carbon sink through afforestation, agro-forestry, riparian planting, and the management of land. The measures for increasing carbon sinks include landscape plans that have concomitant increases in the resilience of the landscape to rural fires and reduce their rate of occurrence, improving forest and agricultural land to reduce soil erosion, and increasing the biodiversity of the landscape. The planning of land uses recognises its multiple functions and design mechanisms that protect and enhance those functions as part of the planning for mitigating and adapting to climate change.

The NECP of **Sweden** notes that the two overall objectives for forestry in Sweden are of equal importance. These are: i) the production objective of using forests and woodlands efficiently and responsibly so that they provide a sustainable yield; and ii) the environmental objective, which is to preserve the natural productive capacity of woodlands, managing them to enable viable populations of naturally occurring plant and animal species to survive under natural conditions, and protecting endangered species and habitats and heritage forests and their aesthetic and societal value.

However, the expansion of forestry, under conditions which lead to increasing risks of wildfires, requires appropriate management of that land. The **H2020 DRYLANDS** project notes the need for more resilient and informed land managers, and communities which may have increased exposure to fire risks. It is developing social and technical tools to monitor and prepare for wildfires (e.g. using internet of things, drones, and artificial intelligence).

In contributing to combating climate change, and in response to COVID-19, the **Report of the Advisory Group on Economic Recovery** (Scottish Government, 2020a) focuses recommendations on investments in natural capital. They support the design and implementation of carbon positive businesses and multi-functional land use. Examples of the types of investments proposed are in nature-based solutions of increasing woodland cover, reducing flood risk, and increasing the sequestration of carbon in peatlands and soils. These areas of investment are also reflected in the EU Rural Action Plan of the LTVRA (e.g. rewetting wetlands and peatlands and carbon farming), and **EU Biodiversity Strategy for 2030** (European Commission, 2020b) (e.g. expansion of woodland).

Globally, peatlands contain approximately 25% of the carbon locked in soils, albeit this estimate is subject to considerable variation depending upon the definition of peatland, and the approach to its mapping. Beaulne et al. (2021) summarise estimates of carbon stocks in the Boreal Biome (i.e. including most of Scandinavia) as 272 ± 23 Gt of carbon in forests (approximately 8% of the world's land surface) and 415 ± 150 Gt in peatlands (approximately 2% of the world's land surface).

The extent to which intact peatlands will be able to withstand future climate change is unknown, and much depends on the pattern of seasonal changes in temperatures and precipitation as well as aggregate changes. The protection or restoration of peatlands and wetlands is identified in the **EU Biodiversity Strategy for 2030** (European Commission, 2020b), and in NECPs of several countries. For example, **Germany** plans the 'creation of new funding instruments, including the necessary financing for programmes to permanently re-wet peat soils and restoration of peatlands'; Ireland, with measures in its updated **National Peatlands Strategy**. Estonia and **Lithuania** will support the conversion of arable land on peat soils to permanent grassland, and **Lithuania** will support the restoration of approximately 8,000 ha of wetlands in replacement of arable land.

Chapman et al. (2003, **FP5 RECIPE**) highlight the importance of combining a wide range of indicators and measurements of ecosystem processes (e.g. vegetation, microorganism diversity, chemical and physical markers, and ecosystem level measurements) for monitoring successful restoration. This enables clarification of the relationships between water table, vegetation, microbiology, and chemistry favourable to the re-establishment of peatland biodiversity, C sequestration, and long-term restoration. The potential for abatement of GHG emissions from restoration is dependent on the starting condition. Building on the results of the **FP5 RECIPE** project, **Artz et al. (2013)** note that over the long term "... actual C gains can be expected if restoration achieves a return to a functional peatland", and that "carbon savings from a severely drained peatland may take longer to materialise than from a less affected peatland" **Artz et al.** (2013) also note benefits of early intervention on less damaged bogs with an aim of preventing a process of degradation and so to a higher emitting state. Severely damaged sites are likely to take longer to progress to a state of good hydrological and ecological function. An indication of timescales is for every 10 cm the watertable is raised, there could be a reduction of 3 tonnes CO_2 ha-1y-1 (**Evans et al., 2021**). Potentially, it may take 50 years for the restoration of peat drained to 1m depth, and putting the site on a road to recovery.

In the UK funds are being dedicated to peatland restoration as part of climate change plans. The Scottish Government has allocated £250 million over 10 years to support peatland restoration, with a target of restoring 250,000 hectares of degraded peatland by 2030, managed through its **Peatland Action** programme (Scottish Government 2020b). Practice evidence emerging from that programme highlights 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 (e.g. Artz et al., 2019). Such monitoring requires the development of human capital, knowledge and skills.

New Horizon 2020 and Horizon Europe research projects will provide evidence to support the planning and implementation of peatland restoration, co-creation of restoration plans, mechanisms for finance and governance, engagement with communities and business, means of and means of sharing knowledge (e.g. **H2020 Waterlands**, which commenced in December 2021). More evidence can be expected to emerge on the processes and outcomes of nature-based solutions such as peatland restoration from case studies in current projects (e.g. in the Netherlands, **H2020 LANDMARC**), new projects such as **H2020 MERLIN** and Horizon Europe WETHORIZONS, and **LIFE project People and Peatlands**. Prospectively, such projects can create 'peat citizens' similar to the envisaged emergence motivation and empowerment of **energy communities** and energy citizens.

Actions to change land use, such as peatland restoration and woodland expansion, are subject to interactions with other uses of the land and its management (e.g. managing wild deer, UK). To understand such potential impacts, and plan and implement approaches to achieve the benefits sought for tackling climate change, and the co-benefits (e.g. reversing loss of biodiversity, job creation) necessitates engagement across stakeholders with responsibilities for policy, business, civil society, communities, and providers of training, education and continuing professional development.

Such development of human capital is also required for the realisation of the contributions to be made in agricultural systems to mitigate climate change by reducing greenhouse gas emissions (GHGs), and increase carbon capture in ecosystems (**The Royal Society and Royal Academy of Engineering, 2018**). As noted in Section 1, GHG emissions from agricultural practices have been reducing in Europe since 1990. However, as envisaged in the **European Green Deal** (European Commission, 2019), proposed **EU Mission on a Soil Deal for Europe**, and foreseen to be supported through the **Horizon Europe Partnership on Agroecology** (**H2020 ALL-Ready**) a transition to agro-ecological farming systems is expected to offer significant potential for carbon sequestration in woody biomass and other sustainability benefits (e.g. reduced water use, pesticide inputs, N and P runoff). However, instruments and measures supporting the uptake of such systems need to be designed to be relevant to each stage in the transition (e.g. efficiency increase, energy efficiency, input substitution, system redesign), and encourage the next step to be taken, in the right place at the right time. For example, increased human capital may initiate a transition, informing investment in infrastructure, and then uptake of incentive payments for agri-environment schemes, an output of which is quality produce for consumers that attracts an economic margin benefiting all steps and actors in the value chain. A transdisciplinary approach is increasingly advocated and supported by funders, end users of research, and scientists working in food systems to understand and consider the interests and values of different types of actors, power imbalances, and the scale dynamics of transformation (**Schwarz et al., 2021a**; **H2020 UNISECO**) (see also SHERPA Discussion Paper 4, Sustainable and Resilient Supply Chains).

Several countries have plans to support the development of climate-friendly or carbon positive farms and farming practices. In its NECP, **Germany** proposes the reduction of nitrogen surpluses, ammonia emissions, targeted reduction of nitrous oxide emissions, and the preservation and accumulation of humus on arable land. Plans are to introduce measures to encourage carbon enrichment; the expansion of organic farming; and the formation of humus through planting of hedges, hedgerows and avenues of trees; and support for agro-forestry systems. Agro-forestry is also identified in the **Portugal** NECP, prospectively being an essential element for reducing burnt areas, increasing productivity, reinforcing ecosystem services, and providing a pillar of territorial cohesion.

NECP of the **Netherlands** proposes increasing smart and sustainable uses of agricultural land and soils. It aims to reduce nitrous oxide emissions by 0.3 Mt by 2050, focusing on: i) emission reduction in soil and land use (nitrous oxide and peat meadows); ii) emission reduction for livestock farming (rumen fermentation and manure storage). 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 and beyond. The ability for farmers and others to generate this valuable information is being made more accessible and cost-effective through technical innovations.

To inform the management of soil carbon requires tools for its measurement, monitoring and assessment. New tools are emerging for testing the potential for carbon sequestration and N2O emissions from soils under different management practices (e.g. **Landert et al., 2020**, **H2020 UNISECO**; Van de Broek et al., 2019, **H2020 LANDMARK**; Iocola et al., 2020, **H2020 DiverIMPACTS**). Tools are also in development for quantifying, verifying and promoting soil carbon capture, using earth observation data accessed through Copernicus (e.g. **H2020 AgriCapture**, testing processes and analysis in pilot farms in Crete, Poland, UK, Serbia and Kenya). In the UK a **Farm Soil Carbon Code** is being developed 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. However, **Schröder et al.** (2020; **H2020 LANDMARK**) note that without mandatory regulations, "most European farmers give limited attention to other functions than primary productivity." despite recommendations or pressures from scientists, policy makers and society.

The contributions of changing land uses and land management practices to tackling climate change (essentially supply of goods and services) cannot be isolated from the demand for those goods. For example, changes in human behaviour in relation to choices of food and diet can be expected to contribute to reducing GHG emissions over time, with positive impacts on the contribution from the land-based sector (e.g. **Morais et al., 2021**; **H2020 UNISECO**). A synergistic evolution of agro-ecological farming systems and dietary preferences that supports the uptake of plant-based and low carbon foods (e.g. Kesse-Guyot et al., 2021), noting that legume-modified rotations deliver nutrition at lower environmental cost (Costa et al., 2021; **H2020 TRUE**). Changes in land use linked to supply chains can also lead to new drink products. For example, by adapting the farm system and development of products in tandem, the Arkbikie distillery and farm (Arbroath, UK) has reduced its GHG emissions, improved the conditions for biodiversity, and created a new product marketed as carbon positive (**Nadar gin**, **Nadar vodka**; **H2020 TRUE**). New evidence on carbon and nutrient efficiency in agriculture is expected to emerge from projects such as **H2020 Nutri2Cycle**.

Although not a barrier to transitions, there is almost always a requirement for economic benefits to accrue to land managers from the adoption of agro-ecological practices, and thus the realisation of benefits for tackling climate change to alongside the contributions to enhancing biodiversity, the quality of life of farmers, and health of rural communities and the environment. However, such adoption has to be at scales commensurate with achieving the magnitude of impacts required to tackle climate change. This necessitates governance arrangements that have authority to enable changes at scale, such as in land use or practices across jurisdictions (e.g. planning authorities), governance, land ownership or tenure, and mechanisms that motivate, encourage and support such changes.

In its NECP, **Portugal** advocates 'designing a solution that is flexible in time and space that enables an environmentally sustainable means of operation and allows producers to make investment decisions'. Related is the plan in the NECP for **Greece**, of revisions to land use planning such that development of crops on degraded soils, nitrified soils, or on restored quarries post-mining such competition with other markets (food, feed, materials) are understood and informed decisions can be made. In this, different types of actors have roles to play in relation to influencing the planning of land uses, including public agencies, business and civil society (e.g. Gugerell et al., 2019; **H2020 MinLand**).

6. Stakeholder cooperation and knowledge sharing

Climate change is a global issue, requiring collaborative approaches to responding to its impacts, and planning suitable mitigation and adaption actions. The **Netherlands** NECP notes the 'responsibilities of all levels of government come together particularly at the interface of energy policy and spatial policy', and the important roles of provinces in 'connecting and directing challenges in the physical environment when there are supralocal and regional interests.' It highlights a Pentalateral context involving Austria, Belgium, France, Germany, Luxembourg, the Netherlands and Switzerland in planning regional collaboration in the design and implementation of measures in NECPs.

Some elements of uptake requires support through policy or businesses, and access to knowledge and advice, to help overcome barriers to transitions such as stimulating demand for produce. The NECP for **Sweden** encourages cooperation "… at all levels and between sectors and operators working on land use planning, risk management, natural disasters and climate change adaptation, to reduce risks and improve preparedness." Approaches need to be coherent and integrated (e.g. NECP **Portugal** identifies the need for promoting integrated solutions to treating livestock and agro-industrial effluents).

One important element in enabling collaborations is the sharing of knowledge. This is consistent with the principles of the Aarhus Convention (**UNECE, 1998**) and European Pillars of Social Rights through the empowerment of citizens through access to information. It is also consistent with obligations to **Open Science** that enhance transparency (e.g. access new environmental data), collaboration (within communities of place; between citizens, civil society, businesses, policy and research), co-creation and foster innovation and transformative visions (both social and technical innovation).

To achieve targets of limiting global warming and the need for transitions in uses of land, strategies are required for communicating and explaining the potential impacts of climate change, and the changes required on ways of life and work of citizens, business and organisations with responsiblities for its planning and uses. Such strategies require being meaningful to everyone, tailored by sectors of business, society, geography and level (global to local), to ensure that messages about the types and rates of actions that need to be made are recognised as relevant in every context.

As illustrated in Section 2, climate change is leading to a wide range of hazards, access to informatiopn about which can provide advance warning, preparation, actions and responses, which can save lives and property (e.g. real time information about forest fire events, Figure 8).

Raising understanding and discourse of the issues relating to climate change and land management amongst stakeholders and the public can contribute to motivating changes in attitudes and practices. Findings from **Galioto et al.** (2021; **H2020 UNISECO**) shows the needs for greater understanding of the significance of every component of land systems (in this case farming systems), with particular emphasis on the importance of collaboration between actors. They concluded that public policy should incentivise actors throughout the supply chains to recognise their shared responsibilities for tackling climate change, reversing the loss of biodiversity, and rebalancing social inequalities.

The need for addressing inequalities can trigger the development of social innovation, leading to the reconfiguration of governance structures. Evidence from **Ravazzoli et al.** (2021; **H2020 SIMRA**) shows how social innovation can provide new solutions to complex and urgent problems, such as transforming existing structures "towards a low carbon society, climate change mitigation, fair distribution of income, sustainable livelihoods, and lifestyles."

Increasingly information is being made available online in a wide variety of forms including spatially explicit (e.g. mapped climatic data, Figure 2), graphical (e.g. annual or monthly data on GHG emissions, at national or continental levels, Figure 4), and thematic articles on dedicated portals (e.g. Copernicus Climate Change Service, Figure 17a). Narratives communicated by video provide scope for short, targeted messages, such as science evidence informing the tackling of wildfire (Figure 17b; **H2020 FirEUrisk**), and developing visions for forest agrobiodiversity (Figure 17c; **Innovation Action, Guadeloupe, France**; **H2020 SIMRA**).

Tools and materials are available for increasing accessibility of information for citizens across a wide range of capabilities, including webtools and quizzes to test people's knowledge of climate change. One example is the interactive quizzes provided by the AgriAdapt project on the vulnerability of agriculture to climate change and adaptation measures at farm scale. (Figure 17d; **H2020 AgriAdapt**).

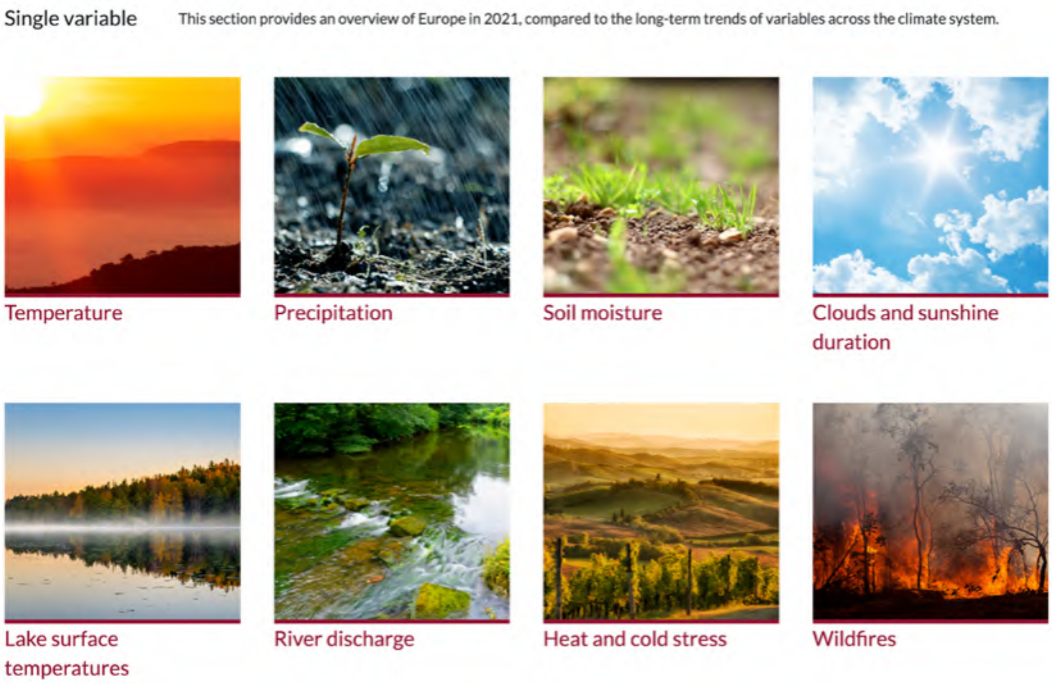

Figure 17a. Overview of Copernicus Climate Change Service, European State of the Climate 2021 (Source: **Copernicus Climate Change Service**)

Figure 17b. Video introduction to science-based strategy to tackle wildfire risk in a nutshell (Source: **H2020 FirEUrisk**)

Figure 17c. Video introduction to the Integrated Ecosystemic value-enhancement of Forest Agrobiodiversity (VALAB) **Innovation Action, Guadeloupe, France** (Source: **H2020 SIMRA**, as used at Rural Vision Week, March 2021)

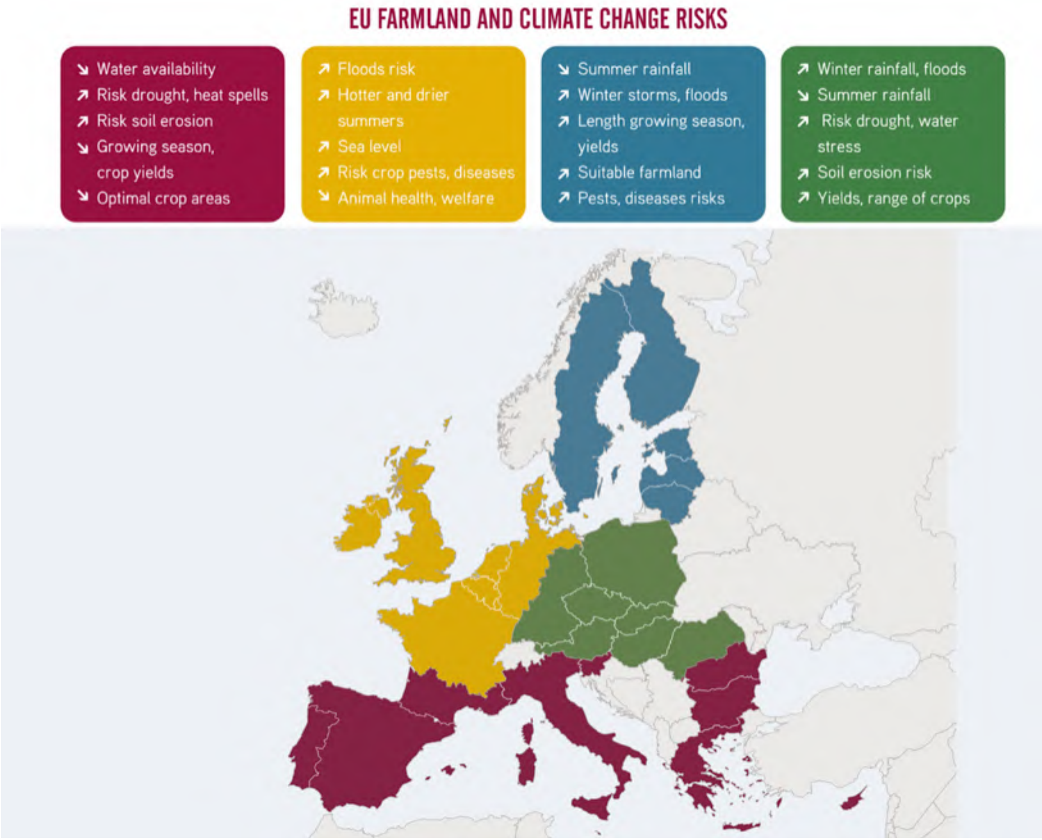

Figure 17d. AgriAdapt Webtool for Adaptation, Overview of climatic risks as they apply to farmland in four areas of Europe (Source: **AgriAdapt**)

In Scotland, UK, the Land Use Strategy 2021 to 2026 (**Scottish Government, 2021**) sets out new forms of governance 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. In 2021, five pilot RLUPs were set up in different types of rural areas. The Scottish Land Use Strategy (**Scottish Government, 2021**) notes that the set of 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 requirements, and that facilitate and signpost funding opportunities for land owners, managers and community groups. Access and use of spatial data is one core element to planned working of these partnerships, with different types of engagement to be tested, including using online and mobile media. However, those tests have to include equitability of access to information, and identify issues that might arise such as geographic, socio-economic, gender, or demographic inequalities.

Findings from **Schwarz et al. (2021b**; **H2020 UNISECO**) identified the need for alignment of education, training and funding in support of transitions to agro-ecological farming systems. Links are required across responsibilities (e.g. education, training, Rural Development Programmes), leading to: i) on-farm peer-to-peer learning; ii) actor-led knowledge and innovation and active sharing of place-based knowledge; iii) principles and practices of agro-ecology in school curricula covering principles of food production and consumption, agricultural practices, and social responsibility. In such transitions, the role of consumers goes beyond that of a passive buyer to one of proactive co-creator of value chains (e.g. Food Policy Councils or producer-consumer associations). This is through the mobilization of social learning, increased awareness and knowledge, participation in governance, and creation of common goals and meaning among different actors in the value chain, which can empower consumers and citizens to have shared social values (Mehrabi et al., 2022) (**H2020 Co-Fresh**).

A challenge for public bodies is recognises the benefits for linking across responsibilities, and tackling the barriers to such connections being made.

7. Just transition to climate neutrality

Planning approaches to achieve the targets relating to climate change need to recognise the interconnectedness of the climate crisis and the biodiversity crisis, and the close links between climate justice and social justice. The European Commission recommended policy tools and actions to make a **Just Transition a reality in the EU**, including measures designed to realise the social potential of the green transition and covered policy areas of employment, skills, social and distributional aspects of the green transition. Amongst those measures are aims to help Member States design their own Just Transition policies by proposing actions that respect the principle of subsidiarity. These include Member States taking policy measures and actions which suit their own circumstances such as:

- support quality employment and facilitate job-to-job transition;
- support equal access to quality education and training;
- support fair tax-benefit and social protection systems;
- support affordable access to essential services;
- coordination of policy action, following a whole-of-economy approach;
- optimal use of public and private funding.

As discussed in the SHERPA Position Paper on Climate Change and Environmental Sustainability, 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).

The **Netherlands** NECP recognises the need for some of the current workforce to retrain or upskill, and the importance of enhancing professional knowledge and ability to adapt to new tasks in new or emerging sectors. Increasing capabilities of land management enterprises has to be accompanied by ongoing, but effective, support for attracting new entrants to farming and forestry. Such support should comprise mechanisms that enable younger generations, women, and minorities into farming as a career Requirements include facilitating access to land (i.e. a suitable and empowered form of land tenure), and advisory services tailored to new entrants (e.g. including mentoring). The outcome would deliver to the LTVRA Flagship of environmental, climatic and social resilience, and **SDG Target 1.4** of ensuring, by 2030, equal rights and access to economic resources, basic services, and ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services.

There is a need to ensure that transitions away from industry sectors that supported employment in rural areas do not leave people and places left behind, with opportunities created to be actors in new or emerging sources of employment. For example, the NECP of the **Netherlands** identifies the need for special attention to regions with specified clusters of industrial activities from which GHG emissions originate, with chanmges required to their raw materials and operational processes. The NECP for **Greece** notes that it will continue its Just Transition Support initiative from 2021 to 2030 using a potential surplus of auctioning revenue, and fund co-financing from the 'Special Account'.

Just transitions towards climate neutrality and reduced environmental footprints of primary industries such as agriculture, mining and quarrying, and forestry need to be stimulated and accelerated. Such acceleration may require facilitated by suitably designed tax reliefs. Opportunities could be created to develop new areas of business such as 'green' tourism, capitalising on the transitions to climate neutrality and reversing the loss of biodiversity.

Chang et al. (2021; **H2020 SENTINEL**) report trends of modelling synergies across sectors, improved temporal detail to enable the planning of future scenarios with high levels of variable renewable energy sources, and increased attention to open access data and science. The design of the different types of transitions required would benefit from further such research that maps the characteristics of the environmental, social and economic changes onto the types of climate resilient development pathways introduced in Section 1, to inform the thinking of what and how processes of change can be undertaken equitably.

8. Public attitudes to climate change

Miller et al. (2022) summarise findings on attitudes of European citizens towards climate change, drawing from Eurobarometer surveys (H2020 SHERPA). The Eurobarometer Survey on "**Attitudes of European citizens towards the Environment**" (European Commission, 2020c) 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, 2021c), continued to be identified as a 'Very serious problem' by 78% of respondents.

The Eurobarometer Survey 490 on Climate Change (**European Commission, 2019b**) 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 18).

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%.

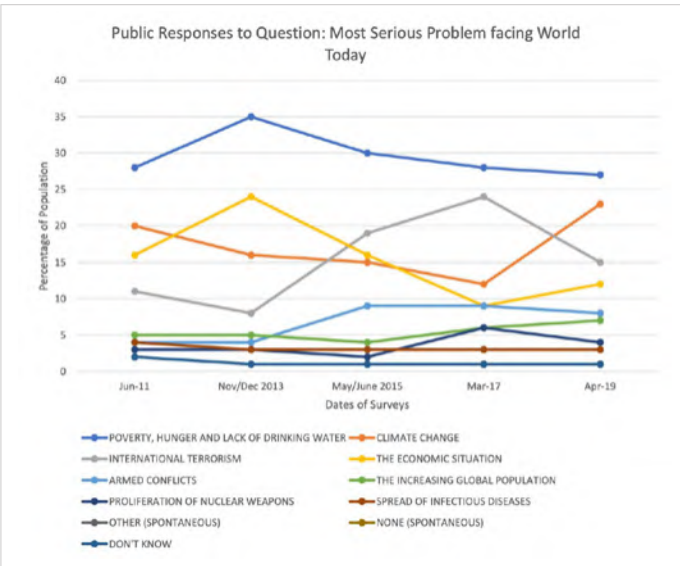

Figure 18. Public identification of the most serious problem facing the world as a whole, in 5 surveys from 2011 to 2019 (Source: **European Commission, 2019b**; number of respondents, Eurobarometer 490: 27,655)

In the Special Eurobarometer 513 (**European Commission, 2021c**; 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 18 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 19). Note that these surveys were undertaken before conflict in Ukraine, from February 2022.

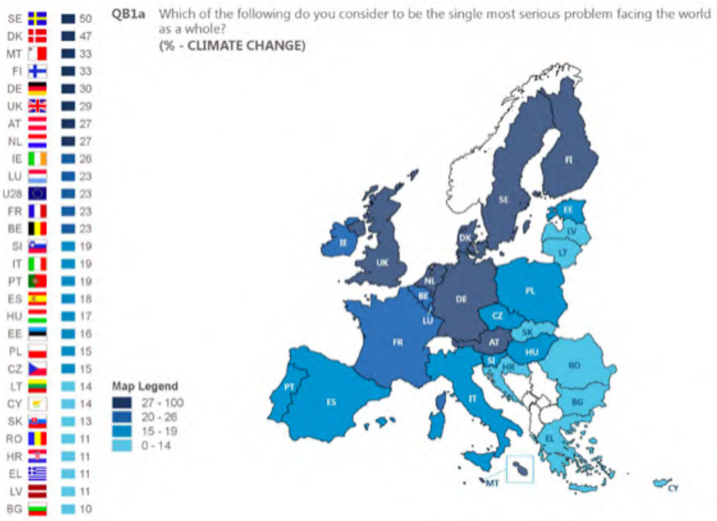

Figure 19a. Percentage of people, by country, who think that climate change is the most serious problem facing the world as a whole in 2019 (Source: **European Commission, 2019b**).

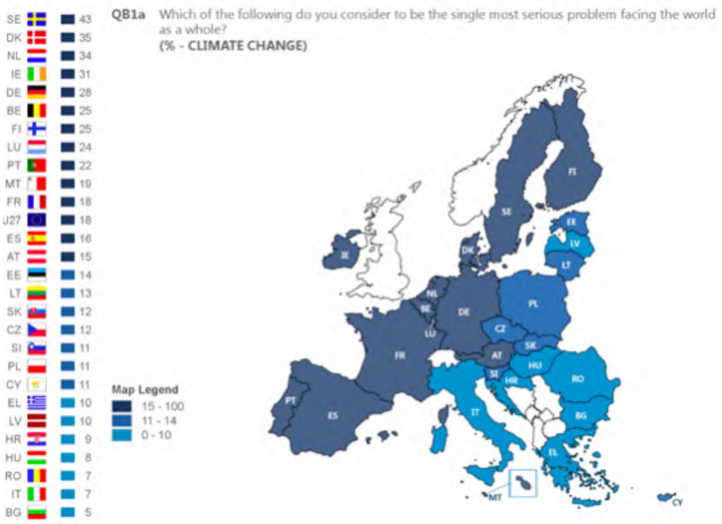

Figure 19b. Percentage of people, by country, who think that climate change is the most serious problem facing the world as a whole in 2020 (Source: **European Commission, 2021c**).

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 choosing 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, 2021c**). 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.

To achieve the target of climate neutrality by 2050 will require changes in behaviours for all individual and organisational responsibilities. As such, tracking public attitudes through time can inform the planning of climate mitigation strategies, and types of adaptations that would have greater or lesser levels of societal support. New forms of capturing such information could be explored to provide more targeted information gathering and targeted messaging in relation to the types of actions being designed in the NECPs or equivalents.

9. Conclusions

International agreements on the urgency of tackling climate change have evolved from the Rio Summit of 1992 through to COP26 at Glasgow, UK, in 2022. Commitments have been made at multi-national and national levels to limiting global warming to not more than 1.5°C (set out in the Paris Agreement), targets for reducing GHG emissions, and mechanisms for assessing and implementing changes have been formalised and implemented. The EU, its Member States, and other countries or regions of Europe have incorporated climate related actions into appropriate legislation.

Modelling of the latest NDCs and scenarios of global warming indicates that achieving the targets of the Paris Agreement requires an acceleration of actions across all sectors of society, in all places. The types of actions cover the planning and management of current natural and cultural resources to deliver multiple benefits (biophysical, social, economic) at levels from site up to global. The nature of the changes may be radical or progressive, with small or large spatial footprints, take place over different timescales, with different pathways in different places. The common theme is that they should all contribute to achieving shared aim of tackling climate change, in equitable ways.

In Europe, rural areas will be to the forefront of the changes required and taking place:

1. Risk is particularly high for: i) natural and cultural heritage, and people, are exposed to increased risk of extreme events and damage to infrastructure and property due to climate change; ii) the existing sinks of carbon are most extensive, and require management to reduce risks of triggering GHG emissions.

2. Mechanisms for mitigating climate change can be particularly significant through: i) the generation of renewable energy; ii) changes in land use to sequester carbon (e.g. woodland expansion, peatland restoration and adoption of other nature-based solutions).

3. Innovative approaches to adapting to climate change can: i) create new economic activity linked to the planning, implementation and management of approaches to tackling climate change through investment in natural capital; ii) human and social capital can be enhanced and centres of scientific and practice knowledge be created; iii) communities and small businesses take leading roles in scaling out approaches to living and working under changed climatic conditions.

Policy at EU and national levels recognises that the steps to mitigate and adapt to climate change necessitate transitions in uses of land, ways of working, and lifestyles. However, not all places or people are equally positioned to take the same types of actions, handle the consequences of changes being made, or to take advantage of opportunities arising. A key principle is that these transitions must be just, with no area or people disadvantaged. In reviewing the Member States NECPs, the (**European Commission, 2020a**) notes gaps in relation to 'identifying investment needs, mobilising funding, research and innovation and competitiveness, regional cooperation, land use land use change and forestry, just transition and energy poverty.'

The exposure to risk, mechanism of mitigation and adapting to climate change vary across Europe. The geographic areas and contexts of the MAPs considering this topic are anticipated as having different priorities of actions and needs in relation to tackling climate change and uses of land. They are invited to reflect on those needs and consider the current policy interventions of relevance and what new instruments or measures would be appropriate to design and introduce. In those reflections MAPs are expected to identify gaps in knowledge as they relate to their areas and levels or responsibility, and what new research evidence is needed for informing the development of policies and actions by all sectors of business and society.

Regarding the **IPCC (2022)**, **H2020 RECEIPT** observe …

> ***"…the sheer complexity of climate change impacts and risks. It's not a slow trend in risks, it's an uncoordinated gallery of extreme events and slow onset risks with impacts cascading across the entire planet. "***

Policies to tackle climate change also contribute to cross-sectoral aims of territorial justice and regional support (**Wieliczko et al., 2021**; H2020 SHERPA). An overarching challenge for policy, science and civil society is how to motivate, facilitate and monitor actions designed to tackle climate change, and the impacts they are having in relation to the trajectory required to achieve net zero GHG emissions. To address that challenge, the MAPs are invited to reflect on the strategies, technologies and mechanisms suitable for monitoring impacts, tailored to the contexts of their areas, and the means of engagement that would be most effective in reaching out to all their citizens.

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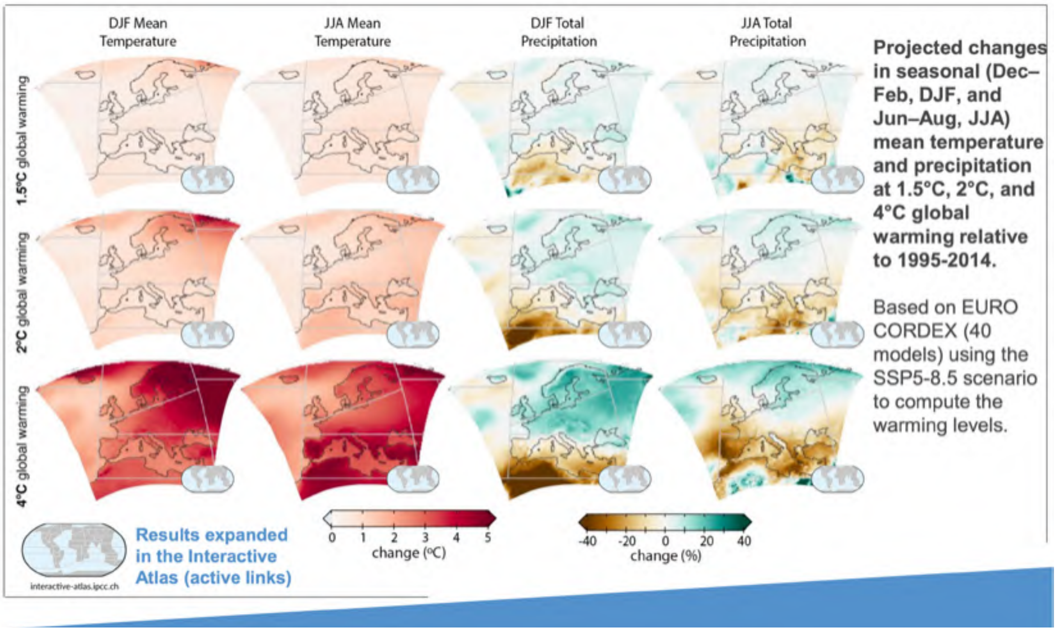
Appendix 1.

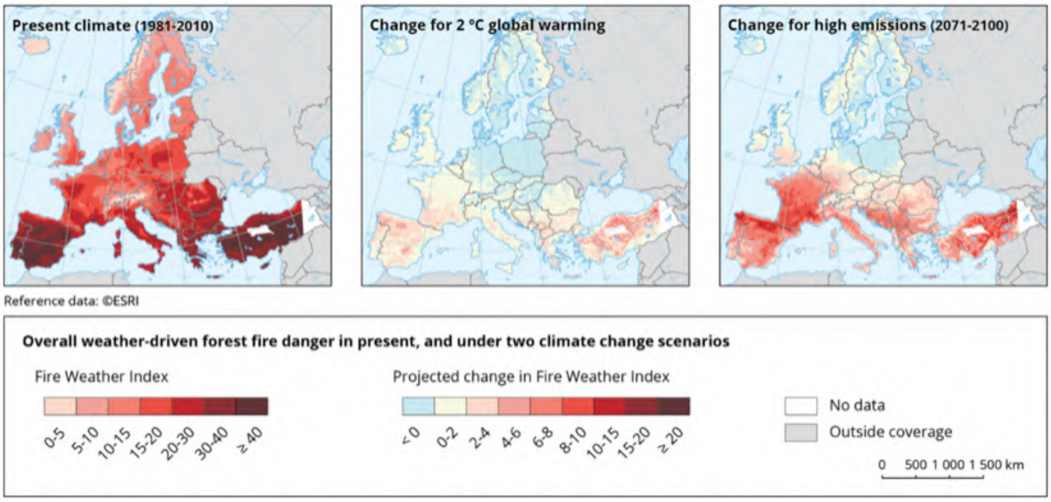
Projected changes in seasonal mean temperature and precipitation



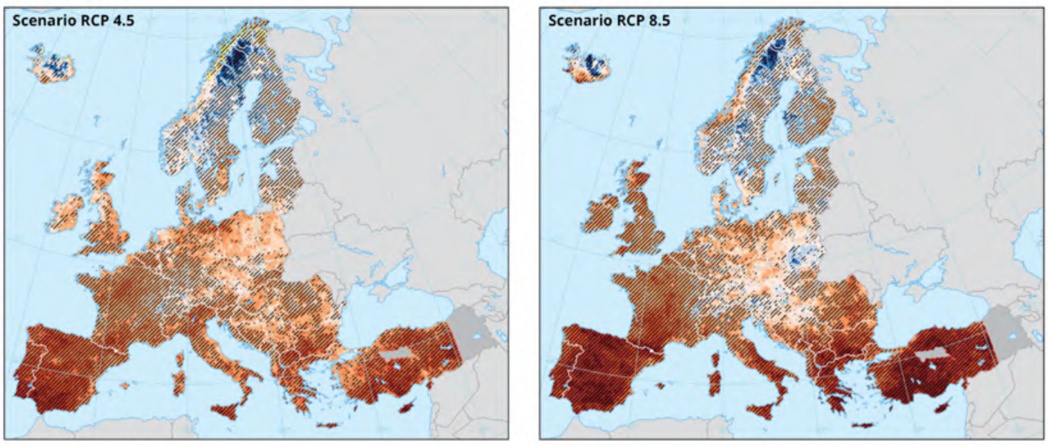
Appendix 1. Figure 1. Projected changes in seasonal (December to February, referred to as DJF), and June to August (referred to as JJA) mean temperature and precipitation at 1.5°C, 2°C, and 4°C global warming relative to 1995-2014. Based on EURO CORDEX (40 models) using the SSP5-8.5 scenario to compute the warming levels.
Source: IPCC (2021a). Sixth Assessment Report Working Group I – The Physical Science Basis; **Regional factsheet, Europe**. pp2.

Appendix 2.

Projected changes in forest fire risk and droughts in Europe under climate change

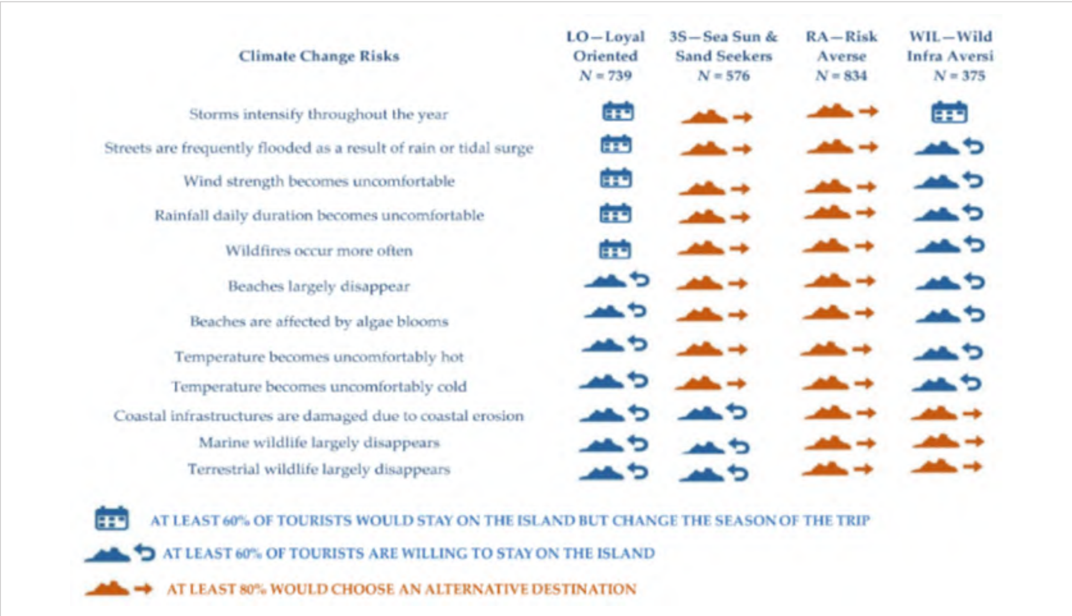


Appendix 2. Figure 1. Overall weather-driven forest fire danger in the present, and under two climate change scenarios (Source: European Environment Agency, **Forest Fires in Europe, 2021**).



Appendix 2. Figure 2. Projected change in meteorological droughts, between observed data for 1981 to 2010 and climate scenarios RCP 4.5 and 8.5 for 2041 to 2070 (Source: European Environment Agency. Meteorological and hydrological droughts in Europe. **https://www.eea.europa.eu/data-and-maps/indicators/river-flow-drought-3/assessment**).

Appendix 3.
Climate risk for islands in Europe



Appendix 3. Figure 1. Assessment of climate change risk factors with respect to tourist opinions on visiting islands. (Source: **H2020 SOLIMPACT**).

Appendix 3. Figure 2. Example of an assessment of climate related risks and significant climate events for Crete. (Source: **H2020 SOLIMPACT**).

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