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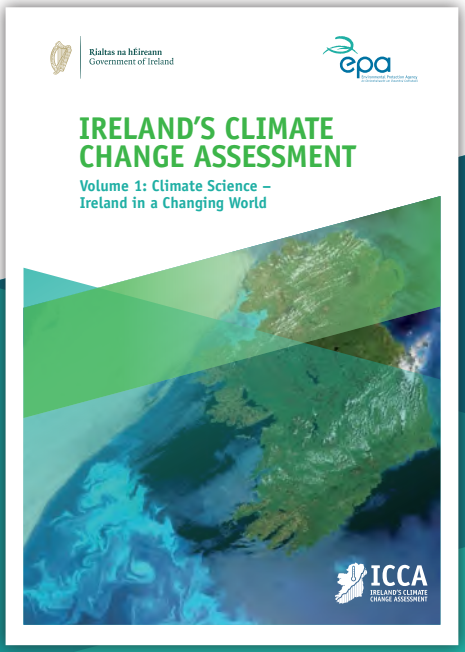
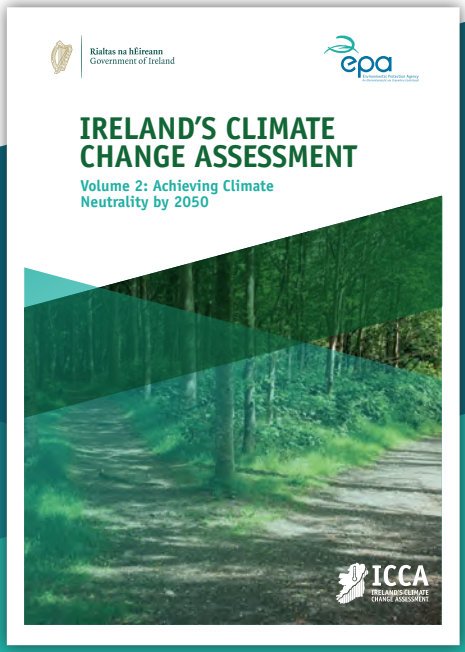
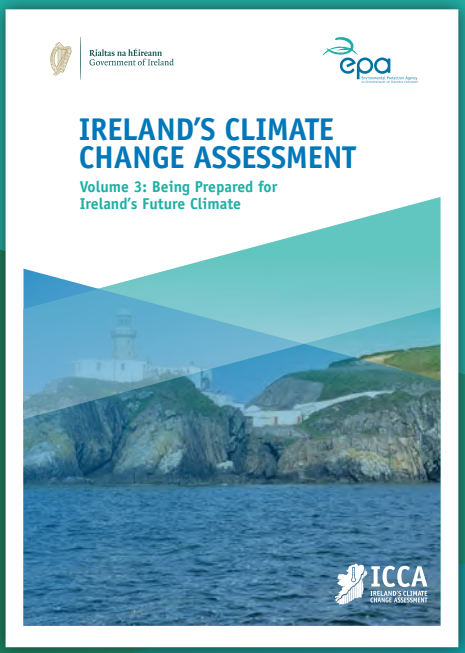
IRELAND'S CLIMATE CHANGE ASSESSMENT

Synthesis Report







ICCA
IRELAND'S CLIMATE CHANGE ASSESSMENT

Ireland's Climate Change Assessment 2023

Environmental Protection Agency

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Synthesis Report

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Foreword

This is the first Ireland's Climate Change Assessment (ICCA) and is a major contribution to the national dialogue and engagement on climate change. It tells us what is known about climate change and Ireland. It also provides key insights on gaps in our knowledge. The development of ICCA was modelled on the work of the Intergovernmental Panel on Climate Change and the Sixth Assessment Cycle, completed in 2023, with the use of and localisation of its information for Ireland.

ICCA will support the national response to climate change, ensuring that it is informed by the best available science. It also points to how and where that science can be improved through further investments in innovation, in research and in systematic observations. These collectively form the essential backbone of the science and data required to understand how Ireland is being impacted by and responding to the climate change challenge.

The full Assessment has been developed through a co-creation process between leading academics in Ireland and officials from across state agencies and government departments. Funding was provided by the Environmental Protection Agency, Sustainable Energy Authority of Ireland, Science Foundation Ireland and Department of Transport. The process was collaborative, involving mutual development and agreement of the scope, preparation and review of drafts, wider stakeholder consultation through a series of workshops and meetings, and a detailed sign-off process.

We see the publication of ICCA as a real innovation for Ireland and as a resource for understanding climate change in an Irish context across the underlying science, mitigation and adaptation measures, and opportunities. It is a starting point for further dialogue on the findings and their utility for policymakers, practitioners, researchers, research funders and people. This engagement phase should continue far beyond the publication of this Assessment and support climate action in Ireland.

Dr Eimear Cotter
Director of the Office of Evidence and Assessment, EPA
Chair of the ICCA Steering Committee

Summary for Policymakers

Key findings

A. A changing climate

Human activity has resulted in widespread and rapid changes in climate which are already impacting us all today.

A.1	Human activity has led to widespread and rapid changes in all components of the global climate system, which are unprecedented over many centuries to many thousands of years. Atmospheric greenhouse gas concentrations are higher than at any point in millions of years. Globally, the most recent decade was likely warmer than any sustained period in at least the last 100,000 years. Global sea level has risen by 0.2m since 1900, and the rate of global sea level rise is accelerating.
A.2	The best estimate of human-caused global warming from 1850–1900 to 2013–2022 (1.14°C) matches almost exactly the best estimate of observed global warming (1.15°C). This warming is mainly due to increased atmospheric greenhouse gas concentrations, partly masked by cooling due to short-lived atmospheric aerosols (small particulates) co-emitted with fossil fuel combustion. Human-induced climate change is also modifying climatic extremes globally, with robust evidence in particular that it is increasing the frequency and intensity of heatwaves and extreme precipitation events.
A.3	Over Ireland, annual average temperatures are now approximately 1°C higher than the early 20th century with 16 of the 20 warmest years occurring since 1990, and 2022 being the hottest year on record to date. Overall, when aggregated, there has been an increase in heavy precipitation extremes over Ireland across a range of indicators. Recent studies have highlighted higher rates of sea level rise than the global average since the late 20th century in Cork and Dublin.
A.4	Recent extreme events in Ireland highlight the vulnerability of individuals, communities, sectors and ecosystems to climate change and indicate an adaptation deficit.

B. Climate futures and their impacts

The future climate is in our collective hands. To halt warming globally and in Ireland requires rapidly reaching at least net-zero carbon dioxide emissions and substantially cutting other greenhouse gas emissions. Every action matters: with every additional increment of warming, impacts for Ireland will increase substantially.

B.1	Deep, rapid, immediate and sustained emission reductions are required to keep global warming in line with the key Paris Agreement temperature goal. To stabilise the global climate requires global carbon dioxide emissions to reach at least net-zero, with emissions of other greenhouse gases substantially reduced on a sustained basis. If we can reach net-zero global carbon dioxide emissions by mid-century, then components such as temperature and precipitation, which react within years to decades to changes in radiative forcing, would stabilise within the lifetime of many of today's younger citizens. However, sea-level will continue to rise and will take thousands of years to stabilise, even once net zero emissions are reached.
B.2	Early and rapid global action on emission reductions would likely leave an Irish climate that is still broadly recognisable in comparison to today, whereas delayed action would very likely leave an Irish climate that is increasingly unrecognisable as the century progresses. Under Early action scenarios, the temperature increase averaged across the island of Ireland relative to the recent past (1976–2005) would reach 0.91°C [0.44–1.10°C] by mid-century before falling back to 0.80°C [0.34–1.07°C] at the end of the century. Whereas under Late action scenarios, by the end of the century it is projected that the temperature increases could be 2.77°C [2.02–3.49°C]. Intense precipitation extremes become more frequent and extreme with further warming in most regions of Ireland across a range of extreme precipitation indices. Storm surges and extreme waves will pose an ever-increasing threat to Ireland as sea levels continue to rise.

B.3 Future changes in climate will have impacts greater than those already experienced for all aspects of Irish society, the environment and economy. Significant potential sectoral impacts and challenges arising from further climate change include:

- Significant impacts on biodiversity on land and in the ocean are projected with additional warming. Changes in temperature and precipitation are likely to increase the occurrence and spread of invasive species and the competitive pressures faced by Ireland's native species.
- Climate change will impact all aspects of Irish agriculture. While increases in productivity can be expected for some crops, decreases can be expected for others.
- With all major cities and many regional towns located close to the coast, Ireland is highly exposed to sea level rise, storm surges and coastal erosion, especially in softer sediment coastal zones.
- Projected changes in future river flows show a wide range; however, increases in extremes of both floods and droughts are expected, based on findings from the majority of available studies. Impacts on water resources, water quality and floods are likely to cascade across other sectors.
- Ireland's built environment is exposed to flood risks from rivers, the sea and rainfall extremes. Increases in extremes present challenges for the integrity of built environments and heritage sites.
- Ireland depends on critical infrastructure for delivering public services, economic development and a sustainable environment. These are exposed to a range of climate extremes. Failures in critical infrastructure can cascade across other sectors and present a multi-sector risk.
- Climate change impacts will directly and indirectly affect health and wellbeing, while vulnerability is likely to increase as Ireland's population ages over the coming decades. Critical health infrastructure, including hospitals and care homes, faces increased risks from heat and flood extremes.
- Tourism is highly exposed and vulnerable to climate change. Warmer summers are often perceived as an opportunity for Irish tourism through increasing visitor numbers. However, without careful management, this could create damaging and unsustainable pressures on sensitive heritage sites and environments.

C. Delivering a climate neutral Ireland

Having peaked in 2001, Ireland's greenhouse gas emissions have reduced in all sectors except agriculture. However, Ireland currently emits more greenhouse gases per person than the EU average. A legal basis for deep, rapid and sustained national emissions cuts now exists, although current policy and action remain insufficient to meet these aims. The pathway forwards is clearer for energy, transport and the built environment than for agriculture and land use. For all sectors there are many challenges to overcome.

C.1 Ireland has made limited progress in reducing greenhouse gas emissions to date and there is a very long way to go. Ireland is currently ranked second highest across the EU when all greenhouse gas emissions are considered on a per person basis.

C.2 In 2021, Ireland legislated for 5-yearly carbon budgets and sectoral emissions ceilings which set a limit on the amount of greenhouse gas emissions that can be released over defined periods. These budgets were consistent with a target for a 51% reduction in total greenhouse gas emissions (including in land use, land use change and forestry (LULUCF)) by 2030, compared with 2018, and a long-term national climate objective of climate neutrality by 2050 at the latest. Currently deployed policies and actions are insufficient and Ireland is not presently on track to meet these statutory greenhouse gas emission reduction targets. Greenhouse gas emission estimates for 2021 and 2022 indicate that 47% of Ireland's first carbon budget has been emitted within 40% of the budget's time frame (2 years of the 5-year budget period).

C.3 There is a significant gap in the literature available for climate-neutral pathways in Ireland. These knowledge gaps, especially in the LULUCF sector, make understanding and achieving Irish climate neutrality highly challenging and need to be urgently addressed.

C.4 Achieving net zero carbon dioxide emissions by 2050 requires significant and unprecedented changes to Ireland's energy system. Policies tailored to suit different stages of technology development are critical for achieving a net zero energy system. Established technologies, such as wind energy, solar photovoltaics and bioenergy, will be key in meeting short-term emission reduction targets (i.e. 2030), whereas offshore wind infrastructure is expected to be the backbone of future energy systems. This can only be achieved with appropriate support schemes, regulation and investments for synergistic growth of offshore wind and other renewable technologies. Future energy choices post 2030 need greater exploration to plan for the required transition. In sectors such as transport and the built environment, reaching net-zero principally, although not exclusively, is going to be achieved through electrification.

C.5	Deep emission reductions within the agriculture and land use sectors are a critical aspect of Ireland's efforts to mitigate climate change and to transition to a low-carbon economy. Optimal use of no-regret livestock management measures, including increasing the dairy Economic Breeding Index, improving herd genetics, improving animal health and promoting efficient feeding strategies, will help in reducing greenhouse gas emissions. Despite the recognition of the importance of agricultural emissions and land use removals, there is a critical research gap in determining the specific levels of emissions that can feasibly be balanced with land use practice. The research on land use, land use change and forestry suggests that the primary means to get to net zero for this sector is through unprecedented rates of afforestation and the rewetting of organic soil along with a significant reduction in herd numbers. The majority of the mitigation options available in Ireland are still in the early implementation stages, and there is an urgent need for Ireland to explore various diversification strategies to enable deep mitigation.

D. Adapting to climate change and ensuring a climate resilient Ireland

Ireland needs to be resilient to ongoing and future climate change impacts. This requires increased focus upon and investment in adaptation that can protect us from future climatic impacts. Current implementation of adaptation is too slow and fragmented. Doing better requires financing, working with people and nature, monitoring and evaluating outcomes, and increasing public and private sector involvement.

D.1	Ireland has set the national objective to transition to a climate resilient, biodiversity-rich, environmentally sustainable and climate-neutral economy by 2050 at the latest. Resilience refers to the ability to absorb and respond to climate change by implementing effective adaptation actions and sustainable development to reduce negative climate impacts, while also taking advantage of any opportunities. Looking to the future, aside from climate change, social, environmental and economic challenges in energy, health, housing, and an ageing population, together with biodiversity loss, all increase vulnerability to climate change impacts.
D.2	Climate change is happening now, and therefore adaptation needs to be given increased attention. Actions taken today to reduce vulnerabilities and exposure and increase resilience will have benefits now, while shaping the future, and should be seen as an investment rather than a short-term cost. We are not starting from an ideal position for adaptation due to ageing infrastructures and significant and ongoing deterioration in environmental quality, including declines in water quality, biodiversity, and ecosystem quality.
D.3	Mitigation and adaptation are inherently linked. The more warming experienced, the greater the challenge of adaptation. At the same time, even if the world is successful in meeting the temperature goal of the Paris Agreement, adaptation to a changed climate will still be required. Adaptation actions can entail 'response risks', which may result in maladaptation. These include the risk of adaptation actions being ineffective and / or unjust or having unintended adverse effects. Opportunities need to be created to evaluate and learn from experience to avoid maladaptation.
D.4	Adaptation is mandated in national legislation and integrated with EU policy. Governance structures and oversight mechanisms have been developed. Many sectors nationally and local authorities have developed their first iteration of adaptation plans, while investment in climate action regional offices (CAROs) is supporting capacity development. Research is advancing, and the National Framework for Climate Services is delivering more tailored and user-friendly climate services. Community engagement and widening of adaptation actions to include nature-based approaches and non-structural measures is being increasingly recognised.
D.5	While many sectors have developed adaptation plans, many have shown limited progress on implementation of these. Other sectoral plans are missing, including critical areas such as the built environment, tourism and sport, and financial services, while cross-cutting issues such as coastal environments also need to be addressed. Critically, developing a climate-resilient Ireland will require sufficient public and private investment and financial support in ways that recognise the value of ecosystem services and the importance of societal wellbeing. Knowledge gaps for adaptation and resilience also remain to be addressed. Assessments of impacts are uneven across sectors and need to be regularly updated. As a small, open economy in an increasingly interconnected world, Ireland is also exposed and vulnerable to climate change impacts and policy responses in other parts of the world.
D.6	Key actions necessary to build momentum and develop a pathway to a climate-resilient Ireland across scales include: defining objectives; ensuring just adaptation / resilience; increasing finance and moving beyond the limits of traditional cost–benefit analysis; placing a greater focus on monitoring and evaluation; understanding the social dimensions of adaptation; working with people and nature; minimising response risks; integrating climate uncertainty into decision making; and avoiding lock-in and maintaining flexibility.

E. Driving transformation forward

Effective and just transformative actions will have mitigation and adaptation benefits and bring broader benefits for health, wellbeing, nature and sustainable economic development. The state has a central role to play in enabling the necessary transformations, supported through action across society. Decisions taken this decade will reverberate for generations to come.

E.1	The decisions made and actions taken this decade will have long-term consequences affecting many generations into the future. Immediate and sustained transformative mitigation and adaptation actions are likely to yield substantial benefits for health, wellbeing and biodiversity in Ireland while reducing vulnerability to the adverse impacts of climate change. Pursuing transformative change allows the realisation of opportunities that would be missed if such a holistic and systemic approach is not followed.
E.2	Tackling climate change and biodiversity loss together enhances the many synergies that exist between actions to address these crises while minimising and managing any remaining trade-offs.
E.3	Ireland's current policy direction predominantly emphasises technology transitions, rather than wider systemic transformations and shifts in development pathways. Taking action to address the direct drivers of emissions may challenge vested interests that have a strong interest in maintaining the current status quo. To enact this transformation, it is essential to broaden the scope of measures aimed at accelerating emissions reduction, including by addressing indirect drivers of emissions such as institutions, economic models, settlement and infrastructure, governance, demographics and sociocultural factors.
E.4	Fairer and more equal societies are more resilient to impacts and are more likely to adopt progressive transformative policies. Prioritisation of wellbeing and equity in development and climate policy could bolster the democratic social contract in support of transformation, including improved quality of life, decent work and the value of care. Emissions-intensive activities are likely to face growing pressures to change or contract, which increases the need for just transition, and to enable opportunities for economic diversification.
E.5	Understanding the potential impacts of alternative economic models, such as degrowth, in the Irish context is crucial for developing sustainable policies and strategies. Understanding the implications and potential impacts of these economic models, as well as the necessary transformations, can inform policy development and contribute to a more sustainable and resilient future.
E.6	Transitions and transformations are a strategic opportunity. The transformative approach of shifting development paths offers extensive economic opportunities for Ireland. Opportunities exist in expanding the scope of policy efforts to include structural transformation to services and low-emissions industry. Opportunities also exist in widening and deepening the range of emissions-reducing and environmentally enhancing activities, with examples including renewable energy; afforestation and forest management; active and public transport; production of alternative proteins; and restoration of nature, biodiversity and ecosystems.
E.7	The state has a central role to play in transformative change. This role can involve stimulating new policy, coordinating actors, mediating interests and shaping outcomes. Transition and transformation can be enabled through: adopting a holistic and systemic way of thinking to maximise win–win outcomes; developing an integrated long-term vision; addressing fragmented governance; developing integrative policy approaches; capacity building and broad stakeholder engagement; and enabling a strong social contract with citizens and communities. Finance is an important enabler of transitions and transformations, and public policy can set the conditions to steer investment in socially agreed directions.
E.8	Public engagement and participation in development and implementation of transition management is essential. Further research is necessary to improve the recommendations from citizens' assemblies and outcomes from subsequent engagement processes into policy, to enhance local deliberative processes, and to inform a just transition that protects and includes vulnerable groups in the shift to a climate-neutral society. Research is also needed to identify effective strategies and interventions to effectively engage with citizens and communities, build societal capacity, and mobilise society-wide climate action.

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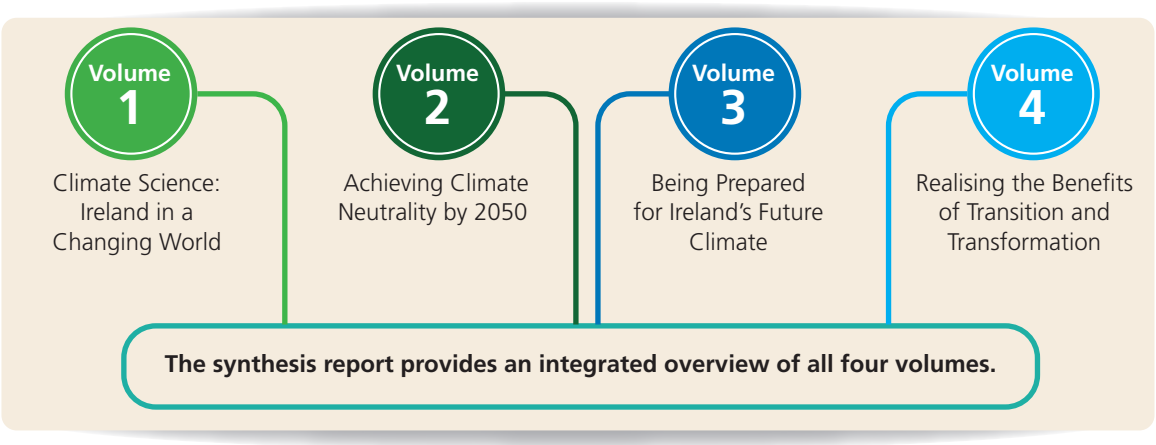
Setting the scene

Ireland's Climate Change Assessment provides a comprehensive review of what is currently understood about one of the most substantial challenges facing society collectively over the rest of our lives. It considers how Ireland can respond to meet its climate change obligations, both national and international, to create a better future for all. This assessment distils our knowledge of climate change and its impacts at the Irish scale and highlights the choices before us and the potential consequences of our actions (or inactions) over this century and beyond. The challenges presented by climate change encompass political, social, economic, and cultural dimensions and require innovative and long-term planning. Effective climate action would also accrue substantial economic, environmental and societal benefits.

The four underlying volumes of Ireland's Climate Change Assessment have been produced over three years by volume author teams who have devoted a considerable amount of time to create this analysis. The first volume addresses climate science. The second volume assesses the pathways to achieving climate neutrality. The third volume looks at climate change impacts across key areas affecting Irish society, the environment and the economy and how best to adapt to an ever-altering climate. The final volume explores the necessary transformations to come and how to achieve them.

This synthesis report presents an integrated overview of the most important aspects of these underlying assessments. To aid readers to find where to source further details, the trace to the underlying materials from which it arose is given at the end of each paragraph in {brackets} where 'V' refers to the underlying volume number, SPM highlights material arising from a Summary for Policy Makers, and chapter materials are denoted by a number with ES standing for Executive Summary.



1

We are already living in a changed climate

We are already living in a changed climate

It is unequivocal that human activity has warmed the climate system. Globally, widespread and rapid changes in the atmosphere, ocean, land, cryosphere and biosphere have occurred. The scale of recent changes across the climate system as a whole – and the present state of many aspects of the climate system – are unprecedented over many centuries to many thousands of years. The best estimate of human-caused global surface temperature increase from 1850–1900 to 2013–2022 is 1.14°C. This is in close agreement with the best estimate of the observed increase of 1.15°C over the same period. This warming is mainly due to increased atmospheric greenhouse gas concentrations, partly masked by cooling due to short-lived atmospheric aerosols (small particulates) co-emitted with fossil fuel combustion. {V1 SPM A.3, A.4, B.1, Figures SPM.2 and SPM.4}

There has been a rapid rise in atmospheric greenhouse gas concentrations, measured at numerous sites around the world including Mace Head, since the Industrial Revolution. This rapid increase is without precedent in millions of years. Concentrations of methane and nitrous oxide are higher now than for over 800,000 years. Current atmospheric carbon dioxide levels are higher than at any time since the Middle Miocene (14 to 16 million years ago), according to the latest consensus atmospheric carbon dioxide reconstruction. Paleo-temperature estimates for the North Atlantic Ocean off Ireland indicate sea surface temperatures 10 to 13°C warmer than those of the present day during the Middle Miocene. {V1 SPM A.1, C.13}.

Global climate changes that have been observed include the following:

- The most recent decade was likely warmer than any sustained period in at least the past 100,000 years. {V1 SPM A.4}
- Precipitation over land has likely increased since 1950, with a faster rate of increase since the 1980s. {V1 SPM A.6}
- The rate of warming of the ocean was likely faster in the past century than for any century since the last deglaciation event 11,000 years ago. {V1 SPM A.8}
- Sea level increased by approximately 0.20m between 1901 and 2018, and the rate of global sea level rise is accelerating. {V1 SPM A.8}
- Over the last century there have been poleward and upslope movements of many terrestrial species in response to climate changes. There have also been changes in the timing of life cycle events, such as birds migrating and plants flowering, in all mid-latitude regions. {V1 SPM A.10}.

Human-induced climate change is already modifying extreme weather events across the globe. Increases in both the frequency and intensity of heatwaves and extreme precipitation have been consistently linked to human activities. Similarly, cold events have been made less likely and severe. Many notable recent Irish events have not yet been formally studied in the context of this rapidly emerging science of event attribution using state-of-the-art approaches. However, there is high confidence that recent changes in heat extremes and heavy precipitation events in Ireland can be linked, albeit indirectly, to human-induced climate change. From observations and analysis there is no clear evidence to date for human-induced climate change influencing the frequency or intensity of other types of extreme events in Ireland, such as windstorms. {V1 SPM B.3, B.4}

Global climate changes have been modified over Ireland by its proximity to the North Atlantic and by internal climate system variability, mainly, but not exclusively, related to variations driven by the North Atlantic. Over Ireland, annual average temperatures are now approximately 1.0°C higher than they were in the early 20th century. Sixteen of the top twenty warmest years since 1900 have occurred since 1990, with 2022 being the warmest year to date. Over Ireland, median annual precipitation was also 7% higher in the period 1991–2020, compared to the 30-year period 1961–1990. Overall, when aggregated, there has been an increase in heavy precipitation extremes across a range of indicators. Recent studies have highlighted higher rates of sea level rise than the global average since the late 20th century in Cork and Dublin. The reasons for this are unclear and currently under investigation. Consistent with global open ocean changes, Irish marine waters have experienced long-term acidification due to uptake of anthropogenic atmospheric carbon dioxide. The main impacts of climate change on Irish terrestrial species and habitats observed to date have been changes in species abundance and distribution, life cycle events, community composition, and habitat structure and ecosystem processes. These biospheric changes are in addition to much larger changes arising from other human interventions. {V1 SPM A.5, A.7, A.8, A.9, A.11, A.12, Figure SPM.1.}

In recent years extreme events have highlighted the vulnerability of individuals, communities, sectors and ecosystems to climate change and indicated an adaptation deficit. The heat and drought of summer 2018 following on from Storm Emma exposed the vulnerability of agricultural, forestry, transport and water systems to extreme events. Floods and windstorms have impacted individuals, businesses, critical infrastructure (including transport, electricity and health care), ecosystems and human health and wellbeing, including through the contamination of water sources. {V3 SPM A.1, 1.1.2}.

2

What might happen this century and beyond?

2.1 How climate change may further proceed

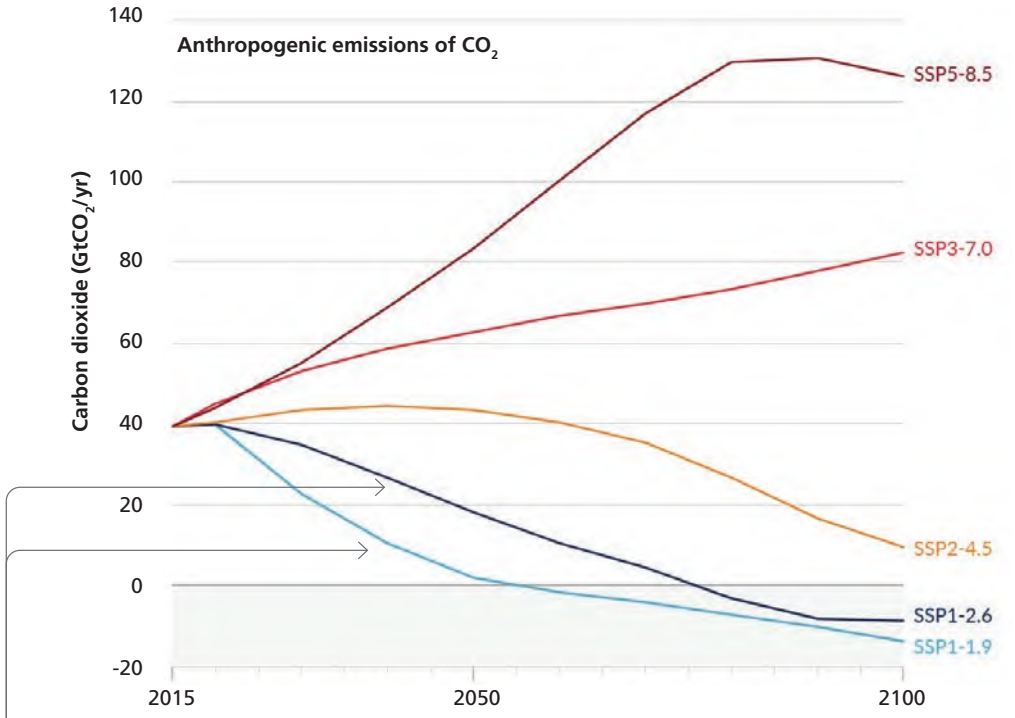
To stabilise the global climate requires global carbon dioxide emissions reduction to reach at least net-zero (Figure SYR.1). Furthermore, emissions of other greenhouse gases would need to be substantially reduced on a sustained basis. Many components of the global climate system, such as temperature and precipitation, respond within years to decades to changes in radiative forcing. If we can reach net zero global carbon dioxide emissions around 2050, these components would globally stabilise within the lifetime of many of today's younger citizens. Some other components of the climate system, most notably sea level rise, will take thousands of years to stabilise even once greenhouse gas emissions reach net zero. {V1 SPM C.1, C.2, Figure SPM.3}.

In the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), the authors assessed that if we are to have a two in three chance of limiting warming to 1.5°C globally, we can emit only 400 additional gigatonnes of carbon dioxide from 2020. This estimate assumes substantial reductions in emissions of remaining greenhouse gases, including a 50% reduction in global methane emissions and a 25% reduction in global nitrous oxide emissions by 2050. If such cuts in non-carbon dioxide greenhouse gases are not fully achieved, the remaining carbon budget would shrink commensurately {V1 SPM C.14}. At current global emission rates of approximately 40 gigatonnes of carbon dioxide a year, only a few years remain before exceeding the remaining budget to limit warming to 1.5°C. Deep, rapid, immediate and sustained emissions reductions are required to keep global warming in line with the key Paris Agreement temperature goal. {V1 SPM C.2, C.14}

Climate change projections under Early, Middle and Late action scenarios show very different potential futures for Ireland beyond the middle of this century (Figure SYR.1). Early and rapid global action on emissions reductions would very likely stabilise many aspects of our climate this century and would likely leave an Irish climate still broadly recognisable as that we experience today. Delayed action on emissions reductions would very likely yield a climate that is increasingly unrecognisable as the century progresses. Projections of Irish temperature changes consistently show warming, with the magnitude of this warming increasing with delays in global mitigation action (Figure SYR.1). Under Early action, the temperature increase averaged across the island of Ireland relative to the recent past (1976–2005) would reach 0.91°C [0.44–1.10°C] by mid-century before falling back to 0.80°C [0.34–1.07°C] at the end of the century. Whereas under Late action, by the end of the century it is projected that the temperature increases could be 2.77°C [2.02–3.49°C]. Heat extremes will become more frequent and more severe and cold extremes will become less frequent and less severe with further warming. Under Late action and high climate sensitivity what are currently considered unusually warm days would be typical days and what are currently considered cold days would be incredibly rare by the end of the century. Truly extreme heat events that are rare in the present climate are projected to become more common under all scenarios. Changes will be larger for the very infrequent 1-in-50-year events (based upon present climate) than for 1-in-10-year events. {V1 SPM C.4, C.5, Box SPM.1, 3ES}

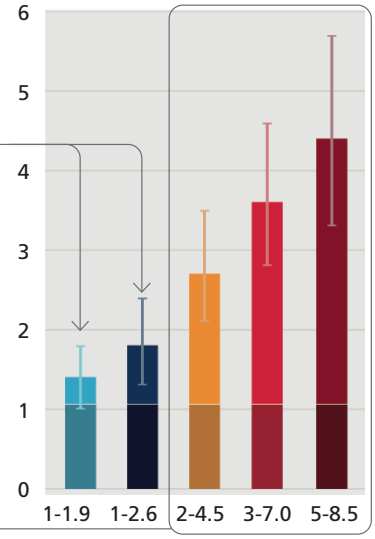
The future is in our hands

Assessment of future emissions and warming under five scenarios



Carbon dioxide is the most important greenhouse gas and the future emissions pathway is not set in stone

Change in global surface temperature 2081-2100 relative to 1850-1900

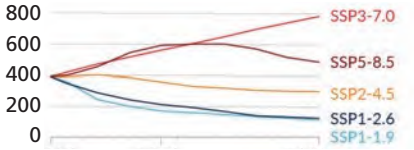


Only if we reach net zero carbon dioxide around mid-century can warming stay well below 2oC

Increases in emissions will result in breaking the Paris Agreement goal of limiting global temperature increase to well below 2oC while pursuing efforts to limit the increase to 1.5oC

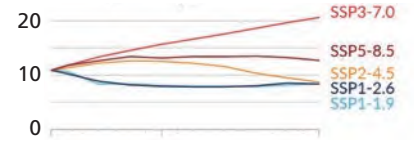
Emissions from three key non-CO_2 drivers

Methane ($MtCH_4$/yr)



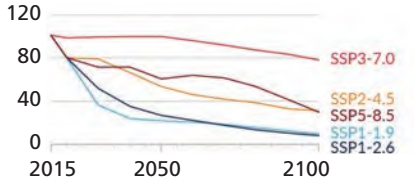
Unlike carbon dioxide, methane does not need to reach net zero but does need to be reduced by 50% by mid-century

Nitrous oxide (MtN_2O/yr)



Nitrous oxide also does not need to reach net zero

Sulphur dioxide ($MtSO_2$/yr)



Annual 2m Temperature Change 2071-2100 with respect to 1976-2005

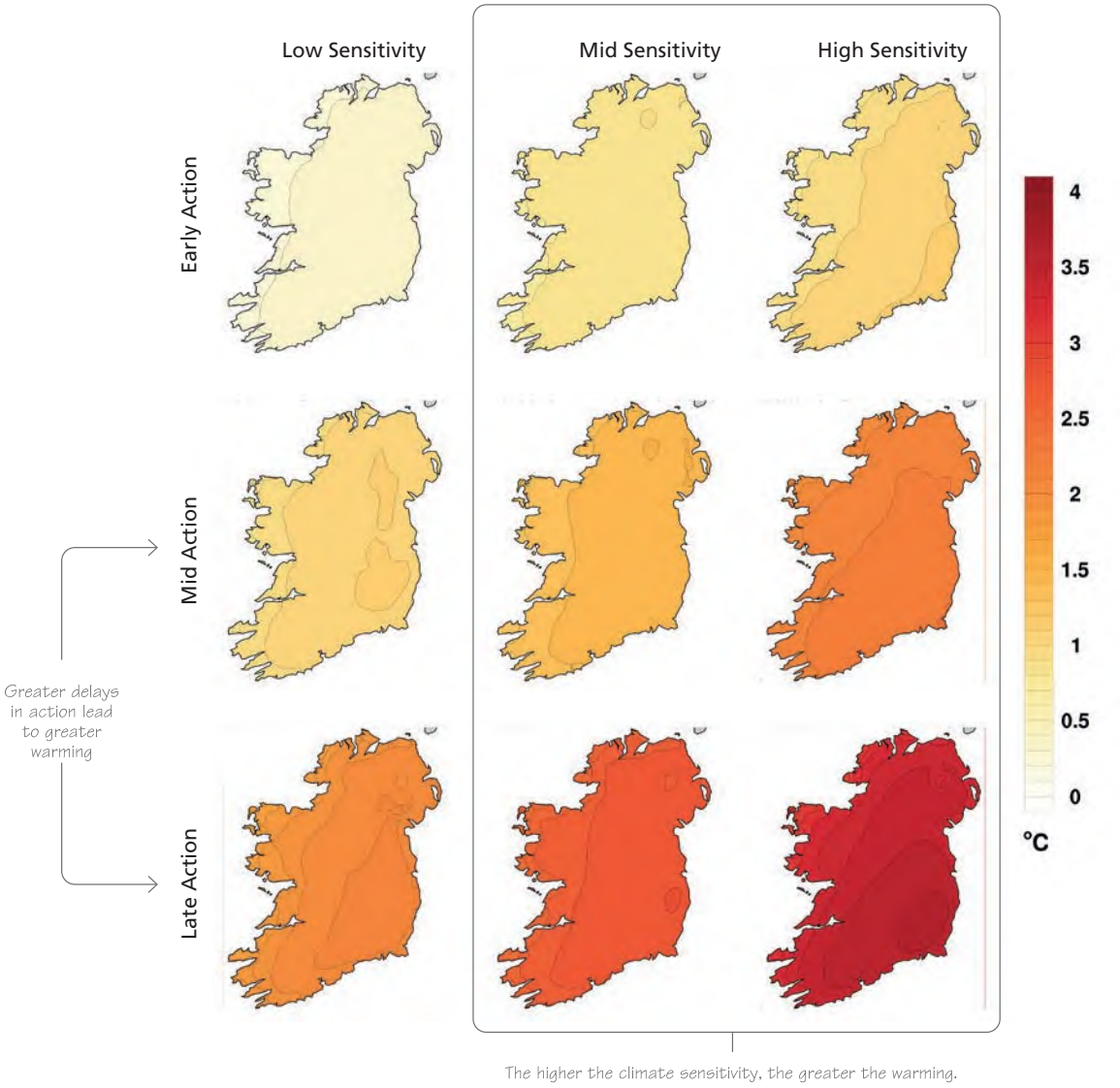


Figure SYR.1. Left panel: illustrative climate scenarios and resulting warming at the end of the century. The five scenarios are SSP1–1.9, SSP1–2.6 (classed here as Early action), SSP2–4.5 (Middle action) and SSP3–7.0 and SSP5–8.5 (Late action). Annual anthropogenic (human-caused) emissions over the 2015–2100 period. Shown are emissions trajectories for CO_2 from all sectors ($GtCO_2yr^{-1}$) (top graph) and for a subset of three key non-CO_2 drivers contributing to anthropogenic aerosols considered in the scenarios: methane, $MtCH_4yr^{-1}$ (top-right graph); nitrous oxide, MtN_2Oyr^{-1} (middle-right graph); and sulphur dioxide, $MtSO_2yr^{-1}$ (bottom-right graph), contributing to anthropogenic aerosols. The bottom-left graph shows resulting warming by scenario in global surface temperature (°C) in 2081–2100 relative to 1850–1900, with indication of the observed warming to date in darker fill. Bars and whiskers represent median values and 5-95% range, respectively. Right panel: TRANSLATE projections for Ireland for Early action (representative concentration pathway (RCP) 2.6), Middle action (RCP4.5) and Late action (RCP8.5) scenarios and for three distinct sets of driving Earth System Models with different transient climate sensitivities over Ireland (see See V1 Cross-volume box1). {V1 Chapters 1,2,3} Sources: Left panel – IPCC (2021[1], figure SPM.4 (modified with permission)). Right panel – ICCA authors.

[1] From: IPCC (2021) 'Summary for policymakers.' In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (Masson-Delmotte, V. et al., eds.). Cambridge University Press. pp. 3–32. https://doi.org/10.1017/9781009157896.001

Regional projections of precipitation for Ireland are highly uncertain because they are dominated by model uncertainty and internal variability, even at the end of the century. While winters tend to get wetter and summers tend to get drier, this signal is not consistently found across all projections. Changes averaged across the island of Ireland show a slight increase of less than 10% in annual mean accumulated precipitation amounts but with large uncertainty. Projections of changes in precipitation extremes are even more affected by model uncertainty and internal variability than annual average precipitation. It is likely that the available model projections considerably under-represent the range of possible outcomes for extreme precipitation indices. Nevertheless, intense precipitation extremes become more frequent and extreme with further warming in most regions of Ireland across a range of extreme precipitation indices. {V1 SPM C.6, 4ES}

Global sea level increases will be modified locally around the island of Ireland by ongoing isostatic rebound – the north-east of the island is slowly rising and the south-west slowly sinking (<0.2mm per year in most regions) in response to the last glacial period; multi-decadal ocean basin variability (of the order of several centimetres in a decade); and the relative contributions to sea level change arising from the Greenland and Antarctic Ice Sheets over time. Larger relative contributions from Greenland would result in smaller increases in sea level for Ireland and vice versa due to the gravitational effects of the two ice sheets. {V1 SPM C.8}

Storm surges and extreme waves pose an ever-increasing threat to Ireland as sea levels continue to rise, including for many coastal cities such as Cork, Dublin, Galway and Limerick and to critical infrastructure. Particularly at risk are soft sediment shorelines. Projections of changes in storminess are highly uncertain and translate into large uncertainties in the future frequency and intensity of extreme waves. {V1 SPM C.9; V3 SPM B.13, B.31}

Ireland will continue to experience seasonal to multi-decadal variability arising from natural internal variations in the climate system. These will serve to modulate aspects such as temperature, precipitation and storminess on seasonal to multi-decadal scales and, in doing so, periodically may reduce or enhance long-term global climate trends arising from human activities. {V1 SPM C.12}

2.2 Impacts of future climate changes on Ireland

Future changes in climate will have impacts for all aspects of Irish society, the environment and the economy. Volume 3 assessed climate change impacts across eight key sectors. Without significant mitigation and adaptation efforts, climate change will result in significant impacts for many marine, terrestrial and freshwater species and habitats, potentially undermining capacity to adapt to climate change in other sectors. Ireland's biodiversity conservatively contributes over €2.6 billion annually to the Irish economy via ecosystem services. Climate change impacts on biodiversity will be felt through changes in growing season length, phenology and species distribution, loss of and damage to ecosystems, and increases in invasive species. In the oceans, changes in ocean temperatures, acidification, salinity and nutrient levels mean that the distributions of some species are likely to shift, with implications not just for ecosystems but also for Irish fisheries. It is vital that all sectors recognise their role in reducing the pressures on biodiversity and protecting ecosystem health.
{V3 SPM B.1, B.2, B.3, B.4, B.5, B.6}

Climate change will impact all aspects of Irish agriculture. While increases in productivity can be expected for some crops, decreases can be expected for others. Pests and pathogens are likely to have increased impact on arable and livestock farming, while increases in precipitation amounts and intensity would increase nutrient washout from land with consequent impacts on water quality. The lengthening of the growing season is often given as an example of a positive aspect of climate change for agriculture; however, gains could be offset by extreme events such as longer and more intense droughts increasing crop losses, especially in spring and summer seasons.
{V3 SPM B.8, B.9}

For forestry some species are likely to fare better in a changing Irish climate (e.g. Scots pine, beech and birch), while some are likely to experience decreased yields (e.g. oak and other deciduous trees). Agroforestry has the potential to provide multiple benefits, including shelter for livestock, water and carbon retention, and increased biodiversity, but adoption rates are low.
{V3 SPM B.11}

With all major cities and many regional towns located close to the coast, Ireland is highly exposed to sea level rise and coastal erosion, especially in softer sediment coastal zones. Significant increases in sea level beyond 2100 are already inevitable, even under the most optimistic scenarios for reducing greenhouse gas emissions. Over the next 2,000 years, global mean

sea level will rise by about 2–3m if warming is limited to 1.5°C, 2–6m if limited to 2°C and 19–22m with 5°C of warming. Superimposed on the current 100-year flood, mid-range estimates of sea level rise are projected to quadruple the number of properties affected by flooding in some coastal locations. Coasts are also home to critical infrastructure (e.g. ports) and a rich cultural and natural heritage, and they provide important recreational resources that underpin tourism, all of which are highly exposed to climate change. Yet, there is no clear governance structure for managing climate change in coastal zones. {V1 SPM C.7, C.9; V3 SPM B.13, B.15, B.16, B.18, B.19}

In Ireland, climate change impacts on the hydrological cycle are unfolding in the context of increasing water demands, decreases in water quality and a lack of resilience in water infrastructure. Projected changes in river flows show a wide range; however, increases in extremes of both floods and droughts are expected. Groundwater responses to climate change are strongly influenced by local settings, with some aquifers likely to see an increase in droughts and others an increase in floods. Increases in water temperature and changes in rainfall patterns and extremes are likely to increase pressures on water quality. Climate change is also likely to increase demand for water resources from households, businesses and agriculture. Impacts on water resources and floods are likely to cascade across other sectors.
{V3 SPM B.22, B.24, B.26, B.27, B.29}

Ireland's built environment is exposed to flood risks from rivers, the sea and rainfall extremes. Large cities such as Dublin have a higher temperature than the surrounding rural areas due to the urban heat island effect and are thus more exposed to future heat extremes. Increases in extremes present challenges for the integrity of built environments and heritage sites. It is critical that workplaces, hospitals, schools and care homes are resilient to changes in extreme events.
{V3 SPM B.31, B.32, B.43}

Ireland depends on critical infrastructure for delivering public services, economic growth and a sustainable environment. Transport infrastructure is exposed to increases in sea level and flooding. For energy infrastructure, the key risks are extreme wind speeds, increased precipitation and saturated soils, given their impacts on the electricity distribution network, with flooding also of concern. For information, communications and technology (ICT) infrastructure, extreme wind speeds and increased storminess are key concerns. Failures in critical infrastructure can cascade across other sectors and present a multi-sector risk. {V3 SPM B.36, B.38}

Climate change impacts will directly and indirectly affect health and wellbeing, while vulnerability is likely to increase as Ireland's population increases and ages over the coming decades. Fewer cold extremes in winter may be positive in terms of reducing excess cold mortality rates, but climate change may also increase existing pressures on the public health service from respiratory diseases such as asthma through increased circulation of aeroallergens in a longer growing season. Without adaptation, increases in extreme rainfall event and floods through their associated impacts on water quality are likely to impact public health. Loss of valued places, flooding and other extremes have consequences for mental health and wellbeing. Critical health infrastructure, including hospitals and care homes, faces increased risks from heat and flood extremes. Adaptation actions themselves can have unequal health and wellbeing outcomes for affected populations and should be routinely assessed. {V3 SPM B.40, B.41, B.43, B.44}

Ireland, as a small and open economy, is vulnerable to supply chain risks and climate change impacts and responses that occur in other parts of the world. Local risks to businesses are likely to arise from changes in extreme events. The scale of climate change risks for the banking and financial sectors are yet to be quantified, and climate risks are not currently well reflected in insurance, investment and lending. Tourism is highly exposed and vulnerable to climate change. While warmer winters are often highlighted as an opportunity for Irish tourism, increased visitor numbers, without careful management, could put at risk sensitive and increasingly exposed and fragile heritage sites, environments and ecosystems.
{V3 SPM B.46, B.47, B.48}

2.3 Low-likelihood but high-impact outcomes

It is important that low-likelihood high-warming outcomes are taken into account in risk assessments of future climate change impacts in Ireland, as there is a high level of risk associated with them. For Ireland, a low-likelihood high-warming outcome (which is predicted under high climate sensitivity) is likely to lead to greater warming and commensurately larger changes in precipitation and associated extremes than the equivalent best estimate for any given scenario. {V1 SPM D.1}

Climate system tipping points represent thresholds beyond which components of the Earth system permanently switch

to new states. Tipping points, were they to be breached, would have considerable impacts, including sea level rise from collapsing ice sheets, dieback of the Amazon rainforest and carbon release from thawing permafrost. Several such tipping points would have implications for Ireland, either through further shifting the global climate or through altering the regional climate in the North Atlantic and north-western Europe. For Ireland, the collapse of the Atlantic Meridional Overturning Circulation (AMOC) is the most immediately important potential tipping point, given the importance of the North Atlantic in determining our climate and agricultural productivity. {V1 SPM D.3, D.4}.

Unpredictable and rare natural events not related to human influence on climate may also lead to low-likelihood, high-impact outcomes. For example, a sequence of large explosive volcanic eruptions within decades has occurred in the past, causing substantial global and regional climate perturbations over several decades. A future including such a sequence of eruptions over the coming decades would increase the stress on ecosystems and society. {V1 SPM D.7}

3

Delivering climate neutrality in Ireland

3.1 The national and legal context

The transition to a climate-neutral society is both an urgent challenge and an opportunity to build a resilient future for all. All parts of society will play a role – from the power sector to industry, mobility, buildings, agriculture and forestry. This will require leadership from government (policymakers, policy enforcers, etc.), business, communities and individuals. {V2 1.0}

Ireland and other Parties to the Paris Agreement have committed to collectively reaching a global 'balance' of greenhouse gas emissions and removals during the second half of this century on the basis of equity, reflecting common but differentiated responsibilities and respective capabilities, in light of different national circumstances. Ireland's commitments have been agreed with its EU partners and submitted as a collective EU nationally determined contribution under the Paris Agreement. These are framed by national long-term emissions reduction strategies. Ireland's Climate Action and Low Carbon Development (Amendment) Act 2021 interprets a "climate neutral economy" as a "sustainable economy and society where greenhouse gas emissions are balanced or exceeded by the removal of greenhouse gases". {V2 SPM A}

Ireland has made limited progress in reducing greenhouse gas emissions to date, and there is a very long way to go. Ireland is ranked second highest across the EU when all greenhouse gas emissions are considered on a per person basis. Compared with other EU Member States, Ireland has higher than average emissions of methane and nitrous oxide because we have the highest contribution from agriculture to our national total emissions. Having peaked in 2001, Ireland's greenhouse gas emissions reduced in all sectors except agriculture. In 2021, Ireland's total greenhouse gas emissions were estimated to be 62 million tonnes carbon dioxide equivalent (69 million tonnes including the land use, land use change and forestry (LULUCF) sector), which is approximately 11% higher than emissions in 1990 and 14% lower than emissions in 2001. {V2 SPM A.1, A.1.1}

Carbon dioxide is the most significant contributor to greenhouse gas emissions in Ireland at 60.5% of total greenhouse gas emissions excluding the LULUCF sector in 2021. The electricity and transport sectors were responsible for 27% and 29% of total carbon dioxide emissions (excluding the LULUCF sector) in 2021, respectively. There was a 14% increase in carbon dioxide emissions from 1990 to 2021, due to a doubling of emissions from fossil fuel combustion in the transport sector over the period. Ireland's energy system is heavily dependent (86%) on fossil fuels. Ireland's large livestock population is the main driver of methane and nitrous oxide emissions, the second and third most significant contributors to greenhouse gas emissions in Ireland. The LULUCF sector in Ireland is currently a source of greenhouse gas emissions rather than a sink. {V2 SPM A1.2}

In 2021, Ireland legislated for 5-yearly carbon budgets and sectoral emissions ceilings that set a limit on the amount of greenhouse gas emissions that can be released over defined periods. These budgets are consistent with a target for a 51% reduction in total greenhouse gas emissions (including the LULUCF sector) by 2030, compared with 2018, and a long-term national climate objective of climate neutrality by 2050 at the latest. Ireland is not on track to meet these statutory targets, and current policies are not sufficient to meet the carbon budgets of 2020–2025 and 2025–2030. Greenhouse gas emission estimates for 2021 and 2022 indicate that 47% of Ireland's first carbon budget has been emitted within 40% of the budget's time frame. {V2 SPM A.2.1, A.3.2, A.3.3}

There is a significant gap in the literature available for climate-neutral pathways in Ireland. Although there have been studies on incorporating agriculture into the energy models, the mitigation options explored do not achieve net zero. These knowledge gaps, especially in the LULUCF sector, make achieving Irish climate neutrality highly challenging and need to be urgently addressed. {V2 SPM C.1.1}

3.2 The changes required in energy

Achieving net zero carbon dioxide emissions by 2050 requires significant and unprecedented changes to Ireland's energy system. There will be difficult choices ahead. Infrastructure such as the electricity grid must be built, large investment must be sought, renewable fuels found, and homes and businesses transformed. Without these changes and societal and political support, a net zero energy system cannot be achieved. {V2 SPM A.4.1, 7.0}.

There are well-established 'no-regret options' that need to happen now, which can get us most of the way to net zero carbon dioxide emissions. Beyond that, there are 'future energy choices' relating to the scale and magnitude of technologies that will help get us all the way. Ireland's no-regret options are demand reduction (e.g. through energy efficiency and reduced consumption), electrification (e.g. electric vehicles and heat pumps), deployment of market-ready renewables (e.g. wind energy and solar photovoltaics) and low-carbon heating options (e.g. district heating), while our future choices include hydrogen, carbon capture and storage, nuclear energy and electrofuels. Renewable energy can increasingly provide our

future energy needs but will need to be complemented with carbon dioxide removals to achieve a net zero energy system in hard-to-abate sectors. There is a need to quantify the extent of carbon dioxide removals required to provide a clear pathway for climate neutrality, which should take into account the climate impacts of emissions as well as the risks associated with the adoption of removal solutions, particularly nature-based approaches. While the scale and mix of these specific technologies is currently unclear, it should not be and is not a barrier to action. Figure SYR.2 provides one indicative pathway for Ireland to achieve a net zero energy system by 2050. {V2 SPM B, B.1.1, B.3.1, D.1.4}

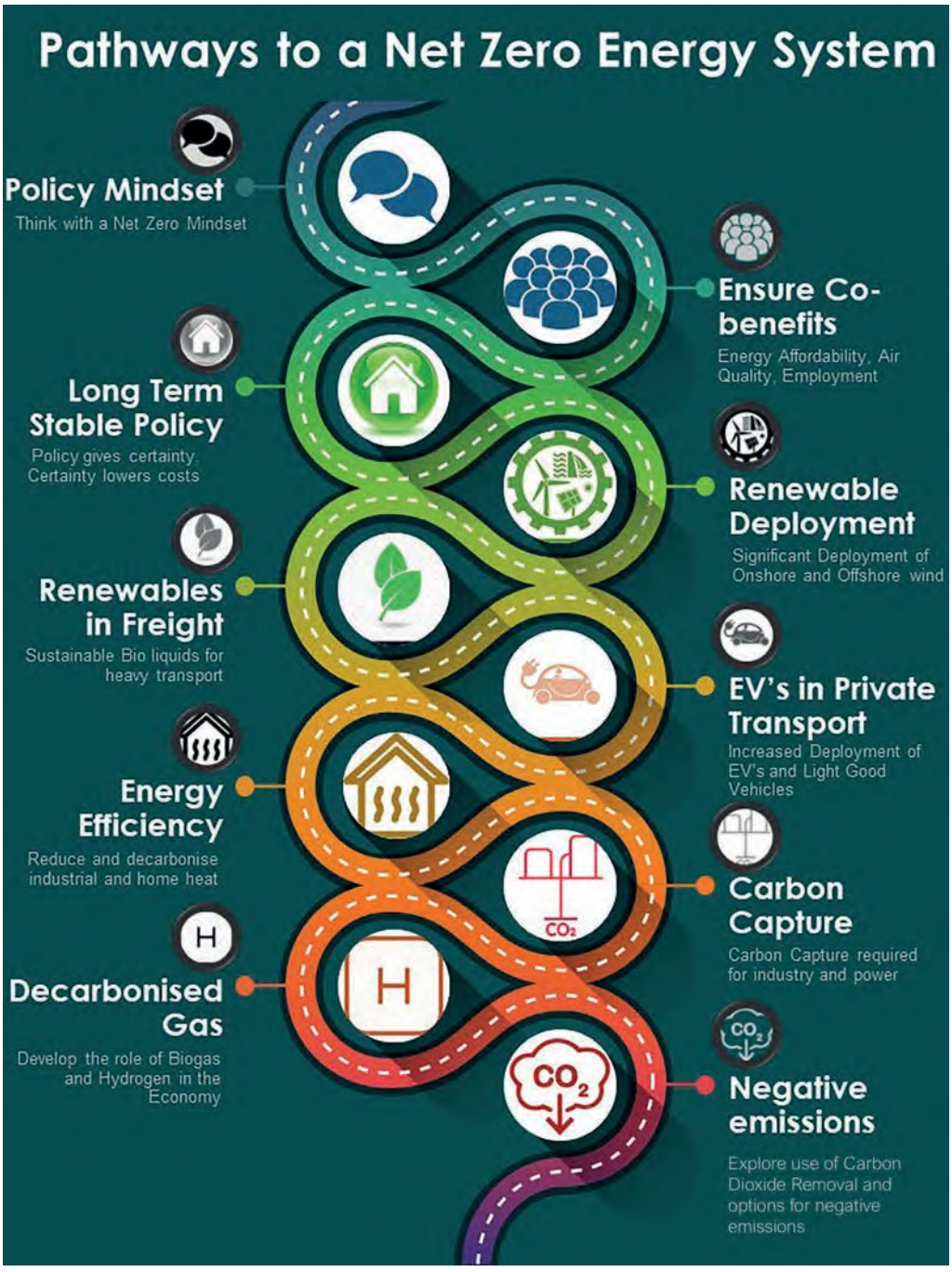


Figure SYR.2. An indicative pathway to achieve a net zero energy system in Ireland. Source: MaREI Centre.

Policies tailored to suit different stages of technology development are critical for achieving a net zero energy system. Established technologies, such as wind energy, solar photovoltaics and bioenergy, will be key in meeting short-term emission reduction targets (i.e. 2030), whereas offshore wind infrastructure is expected to be the backbone of future energy systems. This can be achieved only with appropriate support schemes for, regulation of, and investment in, the synergistic growth of offshore wind and other renewable technologies. Future energy choices post 2030 need greater exploration to plan for the required transition. {V2 SPM C.3}

There are many additional societal co-benefits, including those for human health and air quality. Renewables open up opportunities in the green economy, including those for coastal communities and farmers; and distributed energy enables homeowners to be producers of energy, lowering energy bills. The transition requires paying attention to environmental, societal, economic and governance – along with technical – dimensions. An enhanced regulatory and planning framework is required to accelerate the deployment of renewables, realise co-benefits and manage trade-offs. Renewable energy developed on land and at sea creates competition with other land uses, including biodiversity, food production and carbon sequestration, and may negatively impact biodiversity. Historical energy transitions, such as Bord na Móna's pivot from peat extraction to peatland rehabilitation and renewable energy generation, offer lessons for the future, particularly for just transitions.
{V2 SPM B.1.3; V4 SPM C.1}

In the built environment, there is a need for a holistic strategy to reduce energy consumption that includes curbing the demand for energy and materials, optimising efficiency and shifting to low- and zero-carbon energy sources. Implementing building energy standards, greater use of timber and other low-/zero-carbon materials and components, passive designs, district heating, retrofitting and heat pumps are effective solutions to achieving energy-efficient, resilient buildings. Well-informed management of buildings and places is needed over their lifetimes. An integrated spatial planning, built environment and transport strategy is required for a meaningful urban transformation that can create a better living environment while simultaneously reducing emissions. Co-design of placemaking interventions with local communities can empower diverse voices and offer practical solutions. Adopting compact urban development principles, such as increased density, diverse land use, improved street connectivity, redistributing the public realm away from the car, destination accessibility and shorter distances to public transport, can cut transport emissions, lower urban energy use and enhance resilience in the long run. {V4 SPM C.2}

In addition to settlement planning, a transformational approach can be enabled by combining demand management with shifts to active and public modes of transport, alongside technological improvement. The shift to sustainable mobility cannot be achieved immediately; a long-term strategic commitment is needed. Transitioning to sustainable mobility is a gradual process that demands a sustained strategic commitment. Strategies that align with wellbeing and climate objectives can drive significant positive change. While public and active transport infrastructure requires initial investment, the long-term benefits are likely to surpass these costs. Innovative and promising initiatives, such as digitalisation and shared mobility, need support, as they could act as catalysts for a sociocultural shift away from reliance on private cars. {V4 SPM C.2, D.1, E.2}

3.3 The changes required for food, agriculture and land use

Significant mitigation is needed in agriculture, Ireland's largest sectoral source of greenhouse gas emissions. Despite the recognition of the importance of agricultural emissions and land use removals, there is a critical gap in research determining the specific levels of emissions that can feasibly be balanced with land use practice. {V2 SPM B.4, D.1.5}

The challenges of agricultural mitigation include the slow rate of uptake, cost of equipment, knowledge transfer and enabling the market, along with the wide array of barriers faced by farmers and land managers. Innovations such as feed additives to reduce biogenic methane emissions and the use of protected urea to reduce nitrous oxide emissions are still in the early stages of implementation in Ireland. Teagasc has developed solutions to enhance reductions in emissions from the Irish agricultural sector. The mitigation actions prescribed have mainly focused on measures such as the dairy Economic Breeding Index, beef genomics and extending the grazing season. To reduce nitrous oxide emissions, no-regret mitigation measures include changing to low-emission fertiliser types and optimal use of slurry and legumes to increase the efficiency of nitrogen use. No-regret mitigation measures for methane include increasing the dairy Economic Breeding Index, beef genomics, improving animal health, extending the grazing season and using sexed semen in the beef and dairy sectors. Promoting and incentivising diversification strategies within the sector are important because reducing livestock numbers and adopting different land use strategies and bioenergy are likely to be necessary to achieve and maintain deep emission cuts. Legumes, including clovers, can provide nitrogen to a sward through a symbiotic relationship with Rhizobium bacteria, which fixes atmospheric nitrogen into plant-usable forms.

Adopting sustainable diets, reducing food waste and rebalancing land use, including a managed reduction in the number of ruminants, can reduce methane and nitrous oxide emissions and make land available for forestry, wetland restoration and nature. {V2 SPM B.4.1, B.4.2, B.4.3, 6.1.1; V4 SPM C.3}

Current research on the LULUCF sector suggests that the primary means to get to net zero for this sector is through unprecedented rates of afforestation, rewetting of organic soils (including water table management and reduced management intensity), enhanced carbon sequestration in mineral soils and peatland rehabilitation. Forests have an important role to play in achieving net zero. However, for forests to contribute to net zero, afforestation may require between 25,000 and 35,000 additional hectares of planting every year, which is a significant increase on the current target of 8,000 hectares a year. Natural regeneration of woodlands, hedgerows and agroforestry also have potential to store carbon and enhance biodiversity. Climate-smart forest management and afforestation can allow forests to become important hubs for highly skilled jobs, innovation and ecotourism, bringing new opportunities for those living in rural areas. {V2 SPM B.4, 6.2.1; V4 SPM C.3, 2.2.3}

Peatlands, through raising the water table and restoration, can also play an important role in achieving net zero. However, most peatlands in Ireland are moderately or severely damaged, and only 20% remain of conservation value. Conservation of peatlands that have not been degraded can have immediate benefits, while restoration of degraded peatland will see benefits in the longer term. In the near term it is the reduction in avoided emissions – those that would otherwise arise from degraded peat – that is significant for climate change mitigation. {V1 Box 7.1; V2 2.2.3, 6.4; V4 2, 2.1}

Conservation, management and restoration of ecosystems, including peatlands and native woodlands, have potential to provide economic opportunities and improved livelihoods and to enhance the cultural and heritage value of landscapes. Conservation can have immediate benefits for mitigation and adaptation, including enhanced ecosystem resilience, while the benefits of restoration occur over longer terms. Mitigation and adaptation options in agriculture, forestry and other land use can be scaled up over the next decade and beyond, providing opportunities for rural communities. Just transition is key to this transformation, and economic aspects and social, cultural and political dimensions need to be considered. {V4 SPM C.3}

4

Adaptation and resilience: being prepared for climate change

Adaptation and resilience: being prepared for climate change

Adaptation is essential. The Climate Action and Low Carbon Development Act 2015 provides the legal definition for adaptation as "adjustment to (a) any system designed or operated by human beings, including an economic, agricultural or technological system, or (b) any naturally occurring system, including an ecosystem, that is intended to counteract the effects (whether actual or anticipated) of climatic stimuli, prevent or moderate environmental damage resulting from climate change, or confer environmental benefits". Key to adaptation are the inter-related concepts of risk, exposure and vulnerability (Figure SYR.3). Risks emerge from the interactions between climate change and related hazards (e.g. heatwaves, floods, droughts), exposure and vulnerability. Risk is not static but evolves as the frequency and intensity of hazards increase and as exposure and vulnerability change. Adaptation, therefore, can be thought of as iterative risk management, focusing on processes of assessment, action, monitoring, evaluation, learning and improvement. {V3 SPM introduction, C.3}

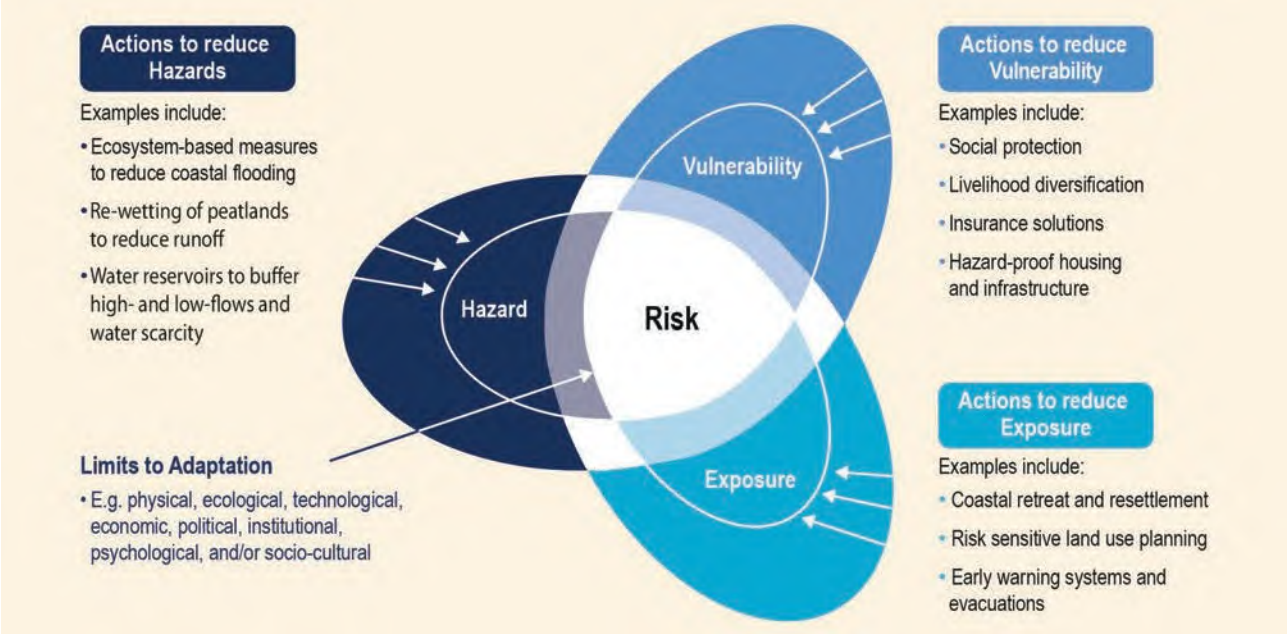


Figure SYR.3. Adaptation can reduce risk by addressing one or more of the three risk factors: vulnerability, exposure and/or hazard. A reduction in vulnerability, exposure and/or hazard potential can be achieved through different policy and action choices over time until limits to adaptation may be reached. Source: IPCC (2019, figure TS.4 (modified with permission)).[2]

Ireland has set the national objective of transitioning to a climate-resilient, biodiversity-rich, environmentally sustainable and climate-neutral economy by 2050 at the latest. Resilience refers to the ability to absorb and respond to climate change by implementing effective adaptation actions and sustainable development to reduce negative climate impacts while also taking advantage of any opportunities. Adaptation aims to increase resilience by helping us navigate extreme events, and maintain flexibility and a diversity of responses in delivering actions that reduce social, ecological and economic vulnerability and exposure. {V3 SPM introduction, 3}

To date, the focus of climate action has predominantly been on mitigation. Climate change is happening now, and therefore adaptation needs to be given increased attention. Recent extreme events (e.g. storms, floods and droughts) highlight our vulnerability and exposure and the consequences of an adaptation deficit. Mitigation and adaptation are inherently linked. The more warming experienced, the greater the challenge of adaptation. At the same time, even if the world is successful in meeting the temperature goal of the Paris Agreement, adaptation to a changed climate will still be required. Actions taken

[2] From: IPCC (2019). 'Summary for policymakers.' In IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (Pörtner, H.-O. et al., eds.). Cambridge University Press, Cambridge, UK, pp. 3–35. https://doi.org/10.1017/9781009157964.001

today to reduce vulnerabilities and exposure and increase resilience will have benefits now, while shaping the future, and should be seen as an investment rather than a short-term cost. {V3 SPM A.1, A.3, A.4, C.13}

We are not starting from an ideal position for adaptation because of ageing infrastructures, declining quality of the built environment, and significant and ongoing environmental deterioration, including declines in water quality, biodiversity and ecosystem quality. Together with a growing population and a lack of investment in critical infrastructure, this has meant that many natural and human systems upon which wellbeing depend have become less resilient. Looking to the future, aside from climate change, social, environmental and economic challenges in energy, health, housing, and an increasing and ageing population, together with biodiversity loss, will all increase vulnerability to climate change impacts. {V3 SPM A.5}

Foundations for adaptation are being laid, and there are reasons for optimism. Adaptation is now mandated in national legislation and integrated with EU policy. Governance structures and oversight mechanisms have been developed. Many sectors nationally and local authorities have developed their first iteration of adaptation plans, while investment in climate action regional offices (CAROs) is supporting capacity development. Research is advancing, and the National Framework for Climate Services is delivering more tailored and user-friendly climate services. Community engagement and widening of adaptation actions to include nature-based approaches and non-structural measures is being increasingly recognised. {V3 SPM A.7}

However, there are challenges that need to be confronted and improvements made. While many sectors have developed adaptation plans, other sectoral plans are missing, including critical areas such as the built environment, tourism and sport, and financial services, while cross-cutting issues such as coastal environments also need to be addressed. The Climate Change Advisory Council has highlighted that the limited number of sectors showing at least good progress on implementing adaptation is 'worrying'. Widening the participation in adaptation needs to be extended to include private sector stakeholders, while greater integration of adaptation planning across sectors is required to better account for possible cascading risks. Social and economic vulnerability, community participation in decision making and the concepts of just adaptation or just resilience need to be better embedded in adaptation policies and actions. Critically, developing a climate-resilient Ireland will require sufficient public and private investment and financing in ways that recognise the value of ecosystem services and the importance of societal wellbeing. {V3 SPM A.3, A.8, A.8.2, A.8.3, A.8.4, A.8.5, A.8.6}

Volume 3 highlights key actions necessary to build momentum and develop a pathway to a climate-resilient Ireland across scales. Key among these are:

Defining objectives. Successful adaptation is contingent on negotiating and defining goals around what success looks like and that account for competing values and worldviews. {V3 SPM C.1}

Ensuring just adaptation/resilience. Adaptation should reflect the principles of justice, including distributive (fair distribution of the benefits and burdens of adaptation), procedural (fair participation in decision-making processes) and recognitional (fair consideration of diverse values, cultures, perspectives and worldviews) justice. {V3 SPM C.2}

Placing a greater focus on monitoring and evaluation. In Ireland and internationally, the primary focus of monitoring and evaluation is currently on tracking progress in implementing adaptation actions. Greater focus needs to be placed on monitoring and evaluating adaptation processes and outcomes. This is the information that will form the basis of learning and doing adaptation better in the future. {V3 SPM C.4}

Understanding the social dimensions of adaptation. Successful adaptation depends on reducing vulnerability, necessitating a better understanding and integration of the spatial, temporal and socioeconomic nature of vulnerability. {V3 SPM C.5}

Working with people and nature. Widening adaptation actions to include nature-based approaches opens opportunities for realising co-benefits for people and nature, with potentially positive outcomes for environmental quality, biodiversity, health and wellbeing. The potential for nature-based approaches for climate action (adaptation and mitigation) should be more fully explored. A greater focus on non-structural measures and opportunities for better governance will help open pathways to transformation. {V3 SPM C.6, D.7}

Minimising response risks. Adaptation actions themselves can entail risks, including actions being ineffective and/or unjust or resulting in increased vulnerability or unintended consequences. Feedback opportunities for those affected by adaptation actions, together with monitoring of outcomes, can help us learn from experience and minimise response risks. {V3 SPM C.8}

Integrating climate uncertainty into decision making. Future projections of climate change impacts contain sometimes large ranges of change. It is critical that adaptation decision making recognises this, particularly where adaptation concerns critical infrastructure and/or where exposure and/or vulnerability is high. Frameworks for decision making under uncertainty are needed to support adaptation in Ireland. {V1 SPM C.5, C.6; V3 SPM C.11}

Avoiding lock-in and maintaining flexibility. Climate resilience requires integrating flexibility and diversity into climate adaptation. Adaptation decisions should not lock us into resource allocations and decision pathways that limit future choices. {V3 SPM C.12}

Knowledge gaps for adaptation and resilience also remain to be addressed. Assessments of impacts are uneven across sectors and need to be regularly updated. Knowledge is also lacking on climate change impacts and adaptation on Ireland's islands, which face unique challenges from land and ocean. It is also important that locally tailored sea level rise projections that extend beyond 2100 are developed for informing adaptation. Not everywhere can be protected from impacts such as sea level rise, and consideration needs to be given to understanding the justice and governance implications of relocation and managed realignment. International research shows that barriers to adaptation emerge from neglect of local voices and place-based values, shortcomings in governance structures and a lack of financial resources. Greater research effort is required to supplement our understanding of future impacts with research into the social, economic and political aspects of adaptation processes and outcomes. As a small, open economy in an increasingly interconnected world, Ireland is also exposed and vulnerable to climate change impacts and policy responses in other parts of the world. Such transboundary risks can flow through pathways such as trade and finance links and need to be better quantified and understood. {V3 SPM D.1, D.2, D.3, D.4, D.5, D.6, D.7, D.8}

5

Driving transformation forward

5.1 Benefits and opportunities of transformation

Transformative change is a fundamental, system-wide reorganisation across technological, economic and social factors, including paradigms and goals, that values the climate, the environment, equity and wellbeing in decision making. It can entail mobilising society to fundamentally reorganise the systems driving greenhouse gas emissions, biodiversity loss and vulnerability to the impacts of climate change. This approach can close the gap between ambition and action on climate change mitigation and adaptation by delivering rapid, deep and sustained emissions reductions and by building resilience to climate impacts. {V4 SPM introduction, A}

The decisions made and actions taken this decade will have long-term consequences affecting many generations into the future. Tackling climate change and biodiversity loss together enhances the many synergies that exist between actions to address these crises while minimising and managing any remaining trade-offs. Pursuing transformative change can also deliver social, economic and environmental benefits and opportunities from climate action that would otherwise be missed, including those for the wellbeing of people and nature and for greater equity across society. {V4 SPM A, A.3, D.2}

Achieving these benefits requires aligning national climate policies with a holistic approach to sustainable development and broadening the scope of emissions reduction measures to address root causes, or indirect drivers, of climate change and biodiversity loss, including institutions, economic models, technologies, governance, demographics and sociocultural factors that underpin the national development path. Ireland's current policy direction predominantly emphasises technology transitions, rather than wider systemic transformations and shifts in development pathways. Transformative responses to climate risks that address the indirect drivers of vulnerability may necessitate rapid, non-linear changes to social–ecological systems and the associated institutions. Understanding the potential impacts of alternative economic models, such as degrowth, in the Irish context is crucial for developing sustainable policies and strategies. Understanding the implications and potential impacts of these economic models, as well as the necessary transformations, can inform policy development and contribute to a more sustainable and resilient future. Addressing the direct and indirect drivers of climate change and biodiversity loss may challenge vested interests that benefit from the current status quo. {V2 SPM C.1.8; V4 SPM A.2}

Equity, social inclusion and just transition are crucial considerations in climate policy. Fairer and more equal societies are more resilient to impacts, and are more likely to adopt progressive transformative policies. Prioritisation of wellbeing and equity in development and climate policy could bolster the democratic social contract in support of transformation, including improved quality of life, decent work and the value of care. Emissions-intensive activities are likely to face growing pressures to change or contract, increasing the need for a just transition, which would enable opportunities for economic diversification. Just transition requires inclusive planning and decision making. Reducing subsidies to harmful and potentially harmful activities can provide space to invest in socially and environmentally enhancing activities. A focus on enhancing equity when designing emissions reduction supports can contribute to securing just transition. {V4 SPM B, B.1, B.3, B.4, B.5}.

Rapidly reducing Ireland's greenhouse gas emissions would be an important contribution to climate justice, a concept that focuses on the unequal impacts of climate change, across generations and borders, and on ensuring fairness in climate action. A transformative approach to climate justice would also acknowledge the root causes of historical global inequalities and uneven distribution of power. {V4 SPM B.4}

There is significant potential for Ireland to build prosperous livelihoods in the sustainable and resilient economy of the 21st century. Transitions and transformations can be viewed as a strategic economic opportunity, and this requires further exploration. Opportunities exist in focusing economic activities on services and low-emissions industry and also in widening and deepening the range of mitigation measures, with examples including renewable energy; afforestation and forest management; active and public transport; production of alternative proteins; and restoration of nature, biodiversity and ecosystems. By addressing the underlying causes of unsustainability, transformative climate action can advance broader goals for sustainable development, such as prosperity and equity. Immediate and sustained transformative mitigation and adaptation actions are also likely to yield substantial benefits for health, wellbeing and biodiversity in Ireland while reducing vulnerability to the adverse impacts of climate change. {V4 SPM C, C.4, D.4}

5.2 Enabling transformative change

Realising the myriad benefits of transformative change and unlocking rapid and fair climate action requires better enabling conditions, including strong governance, capacity building, broad stakeholder involvement and continuous learning. {V4 SPM A.4, E, E.6}

Adopting a holistic and systemic way of thinking is a necessary condition to identify and maximise win–win outcomes across multiple social, environmental and economic development priorities. This can be enabled by mainstreaming and prioritising sustainability, equity and wellbeing as fundamental values and goals of transformations, followed by reformulating policy and implementation directly towards achieving these policy synergies. {V4 SPM E.3}

Transformative outcomes can be realised through fundamental change that builds on visions of desirable futures and on systems thinking that aligns immediate actions with long-term goals. Among important actions are the creation of national visions of desirable futures and the adoption of a long term foresight approach to governance of change. An integrated long-term vision can drive transformative change, providing clear pathways to low-emissions and resilient systems. Visions of desirable futures can be a powerful motivator for long-term planning and strategy. {V4 SPM A.4, E.4}

The state has a central role to play in transformative change. This role can involve stimulating new policy, coordinating actors, mediating interests and shaping outcomes. Recent research on the role of the state has pointed to its potential through a mission-oriented approach to climate policy. The state can play a strong role in driving transformation, but for it to do so capacity needs to be increased, along with strengthening mandates and resourcing in state institutions and reworking policy and regulatory frameworks. {V4 SPM E.5}

Fragmented governance constrains climate action. Stronger horizontal and vertical integration can better enable transformative change. Ireland has already made significant progress in strengthening the legislative and governance basis for climate action. To move policy out of silos, horizontal integration requires deepened connections between inter-related policy functions among government departments and agencies. This involves strengthening mandates for climate action and providing the institutional structures and forums that support both policy coordination and policy innovation. Feedback loops in policymaking can facilitate continuous learning and the development of creative solutions. Vertical integration requires better coordinated policies at local, regional and national levels and can ensure effective policy design and implementation across levels. {V4 SPM E.6}

Along with better integration of governance structures, integrated policy approaches can reorient development to enable transformative change. Combined policy packages, rather than individual policies, can better support shifts in development pathways and sociotechnical transitions. Near-term action is critical to avoid deepening lock-in to high-emissions infrastructure and practices. Transformative public policy choices in the near term are required to fundamentally shift pathways. Alignment of immediate actions with long-term goals will enhance capacity to close the implementation gap and expand societal participation to ensure that all voices are heard. Systemic responses enable the achievement of synergies across multiple objectives, going beyond sector-focused siloed approaches. {V4 SPM A.4, E.7}

Finance is an important enabler of transitions and transformations, and public policy can set the conditions to steer investment in socially agreed directions. Possible routes to address the economic costs of policy change include the winding down of harmful subsidies, using environmental tax revenue and reform of general taxation and spending. Further analysis

on the impact of financial incentives and drivers, including carbon pricing on behaviour, investment patterns in low-carbon technologies and the use of revenue to drive an efficient, just transition, is necessary. The use of financing, fiscal instruments and governance of climate mitigation is also a critical area that warrants more attention. {V2 SPM C.1.7; V4 SPM B.5, D.5, E.8}

Public engagement and participation in the development and implementation of transition management is essential. Further research is necessary to improve the recommendations from citizens' assemblies and outcomes from subsequent engagement processes into policy, to enhance local deliberative processes, and to inform a just transition that protects and includes vulnerable groups in the shift to a climate-neutral society. {V2 SPM C.1.8}

Social and cultural transformation is also required to create a sustainable society. Mindsets, including individual and collective values and beliefs, shape cultures and systems through influencing behaviour and decision-making processes. They can act as strong leverage points for systems transformation. Creating places and practices that nurture human capacity for change can support sociocultural transformation. {V4 SPM C.5}

Public perception is an important enabler of transformative change. The Irish public demonstrates strong understanding of and support for climate action, but there is a gap between the desire for action and realising change. The Irish news media is a primary source of information for people to learn about climate change but is struggling to cover climate change to the extent that would fulfil its traditional roles of informing the public, acting as a watchdog, and holding authorities to account. Education can also be an enabler of change if it develops the values, attitudes and skills necessary to achieve sustainable development. {V4 SPM E.10}

Individual and collective action are two sides of the same coin. The collective action of individuals is one of the more effective ways for society to change policy and can enable the required systems transformations. Social movements can frame climate issues in a way that brings the public on board, mobilising resources, human and financial, that can sustain collective action and increase the internal and external pressures that enable political change. Social movements, climate litigation and culture can catalyse change through overcoming inertia and motivating individuals and organisations to act. {V4 SPM E.9, E.11}

Seeds of transformations may be found in Ireland, from a declaration of a climate and biodiversity emergency to fossil fuel divestment, and from citizens' assemblies on climate change and biodiversity loss and a children's and young people's assembly on biodiversity loss to progress on renewables. The potential for a faster, wider and deeper transformation offers the opportunity to enable a sustainable and resilient future, for a prosperous Ireland in a changing world. {V4 SPM E.1}

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