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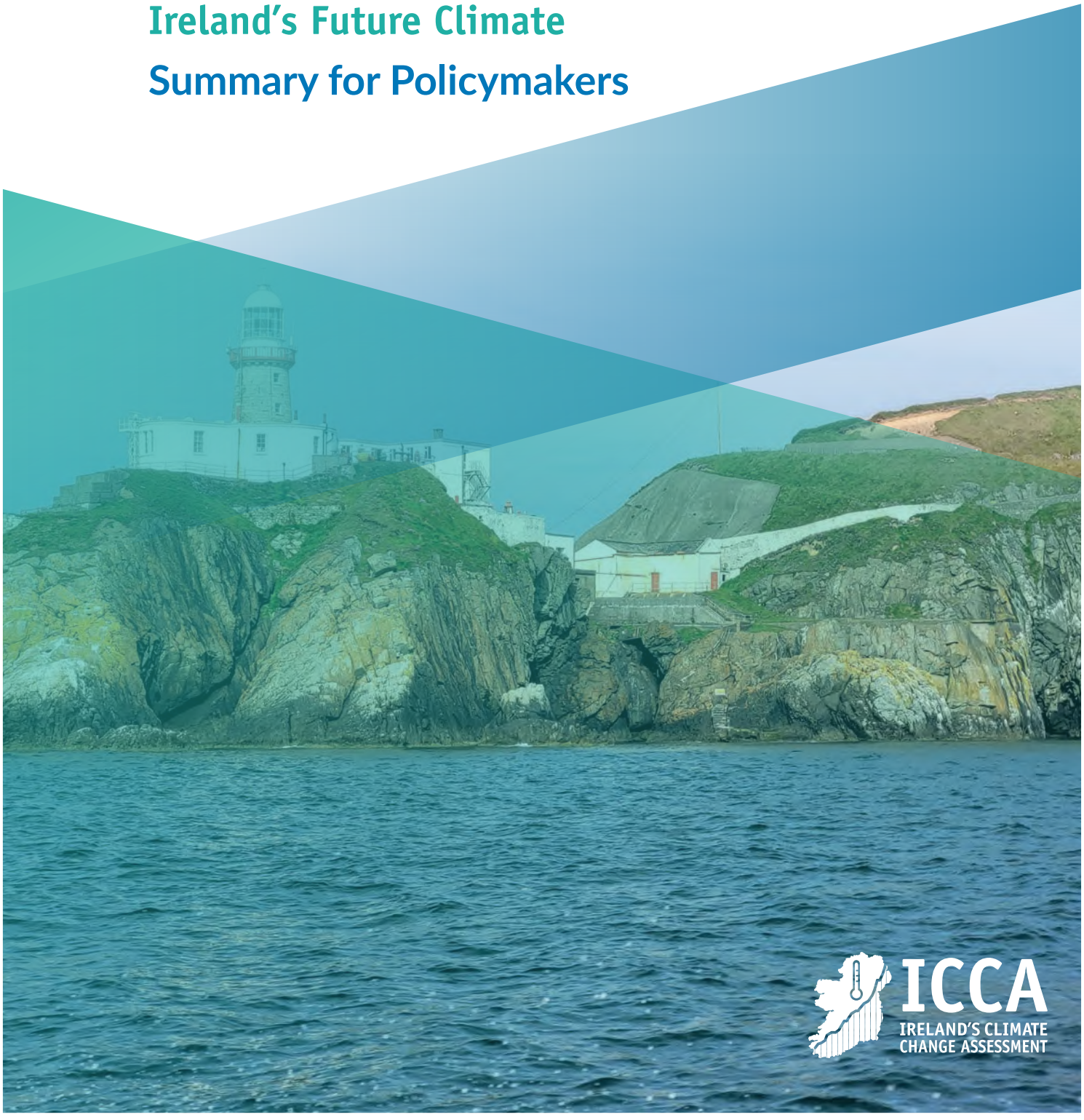
An Ghníomhaireacht um Chaomhnú Comhshaoil

IRELAND'S CLIMATE CHANGE ASSESSMENT

Volume 3: Being Prepared for Ireland's Future Climate

Summary for Policymakers



ICCA
IRELAND'S CLIMATE CHANGE ASSESSMENT

Ireland's Climate Change Assessment 2023

Environmental Protection Agency

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Volume 3: Being Prepared for Ireland's Future Climate

Summary for Policymakers

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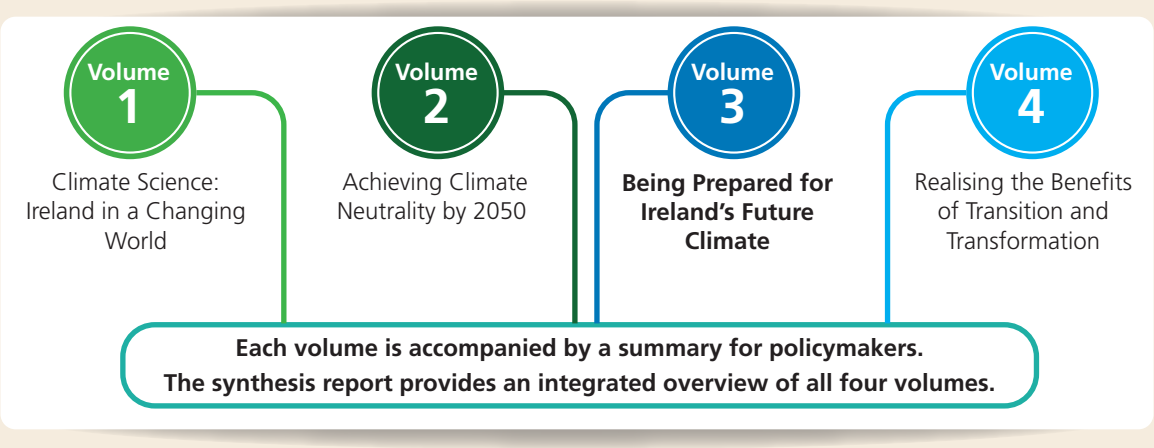
Introduction

Ireland's Climate Change Assessment (ICCA) delivers a comprehensive, Ireland-focused, state of scientific knowledge report on our understanding of climate change, its impacts on Ireland, the options to respond to the challenges it poses, and the opportunities from transitions and transformations to a climate-neutral, climate-resilient and sustainable economy and society. This serves to complement and localise the global assessments undertaken by the Intergovernmental Panel on Climate Change (IPCC) reports (see www.ipcc.ch). The findings presented build upon these global assessments and add important local and national context.

The report is presented in a series of four thematic volumes accompanied by an overarching synthesis report. The volumes are as follows:



Volume 3

The Summary for Policymakers (SPM) provides key insights from Volume 3 of Ireland's Climate Change Assessment: Being Prepared for Ireland's Future Climate. Volume 3 provides a synthesis of research on climate change impacts and progress on adaptation in Ireland. The SPM is organised as follows. We start by defining adaptation as part of climate action and national policy on climate change. Section A considers the current state of play on adaptation in Ireland. Section B summarises key climate risks across sectors before Section C distils key messages on building momentum to realise a climate-resilient Ireland. Section D sets out key knowledge gaps that need to be addressed.

What is adaptation?

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 understanding and implementing adaptation are the interrelated concepts of risk, exposure and vulnerability. Risks emerge from the interactions between climate change and related hazards (e.g. heatwaves, floods, droughts), exposure and vulnerability (see Figure SPM.1). Risk is dynamic and in constant evolution as the frequency and intensity of hazards increase and as exposure and vulnerability change through many drivers. Adaptation, therefore, should be seen as iterative risk management (Ara Begum et al., 2022), with emphasis placed on an ongoing process of assessment, action, monitoring, evaluation, learning and improvement.

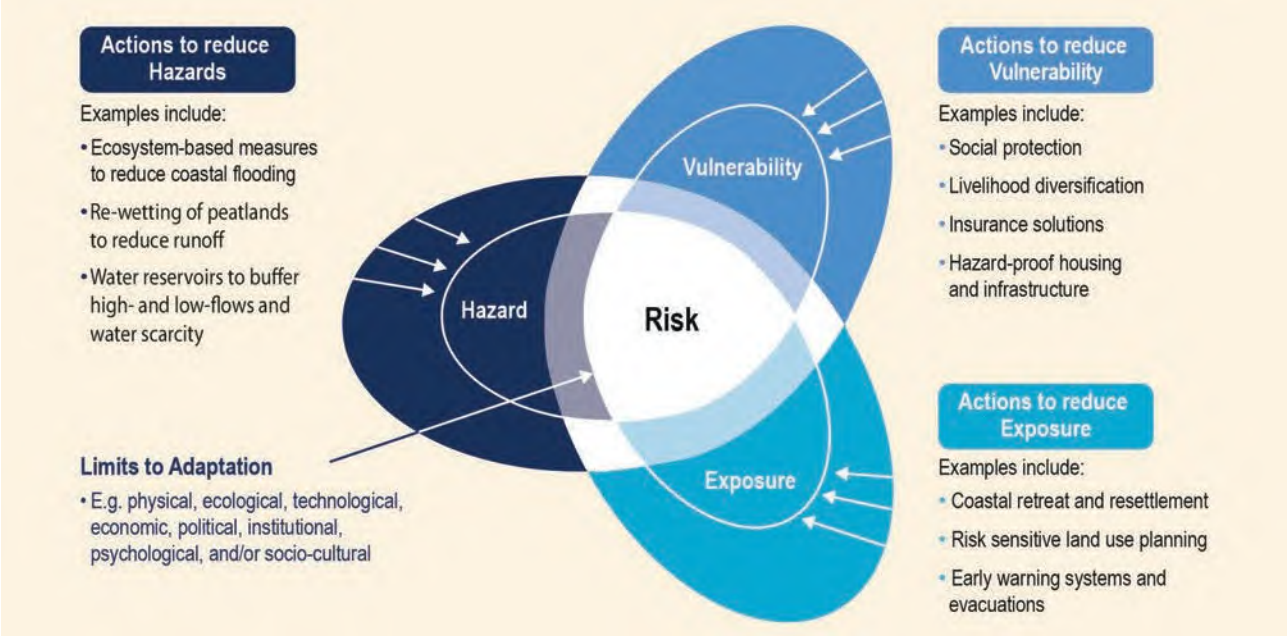


Figure SPM.1 Adaptation can reduce risk by addressing one or more of the three risk factors: vulnerability, exposure and/or hazard. A reduction in vulnerability, exposure and/or hazard potential can be achieved through different policy and action choices over time until limits to adaptation may be reached. Source: IPCC (2019, figure TS.4 (modified with permission))

Adaptation and national policy on climate change

National climate policy establishes the objective of achieving a competitive, low-carbon, climate-resilient and environmentally sustainable economy by 2050. The National Adaptation Framework defines climate resilience as "the capacity of a system, whether physical, social or ecological, to absorb and respond to climate change by implementing effective adaptation planning and sustainable development to reduce negative climate impacts, while also taking advantage of any opportunities". Resilience is closely linked to adaptation as iterative risk management. Adaptation increases resilience by helping us to navigate extremes and surprises, maintaining flexibility and a diversity of responses, learning, and creating and delivering actions that reduce social, ecological and economic vulnerability and exposure.

A. The current state of play on adaptation

A.1 **Climate change is happening now and we need to adapt.** Volume 1 shows that climate change is happening now. Extreme weather events, together with sea level rise and coastal erosion highlight an adaptation deficit in Ireland. Actions taken today to reduce vulnerability and exposure and increase resilience will shape the future and should be seen as an investment rather than a short-term cost. {Chapter 1}

Flooding in Enniscorthy, Co. Wexford, in 2015, just one of many recent extreme events that highlight exposure, vulnerability and the need for adaptation. Source: Reproduced with permission from Wexford Hub (https://wexfordhub.com/enniscorthy-impassable/).

A.2 **Adaptation offers opportunities and multiple benefits.** Climate change impacts will unfold alongside other social, environmental and economic challenges and development objectives. Project Ireland 2040 sets a pathway for realising national priorities for urban renewal, housing, transport, health, critical infrastructure, rural development and more while transitioning to a climate-resilient, biodiversity-rich and climate-neutral economy. Ireland's population is also expected to grow by at least one million people by 2040[1]. Adaptation to climate change will be crucial to the sustainability of these plans and has the potential to offer win–win opportunities, but only if a systematic approach is taken and actions are scaled up and resourced. {Chapter 1}

A.3 **The policy focus of climate action has been on mitigation over adaptation.** Climate action in Ireland has been focused on mitigation, with less attention given to adaptation. The National Adaptation Framework and the Climate Change Advisory Council have emphasised the need to implement climate adaptation measures as a priority in order to build capacity to cope with the impacts of climate change. The timescale left for doing so is short given the timeline of 2050 to realise climate resilience. The Climate Change Advisory Council concludes in its 2022 annual review that the limited number of sectors showing at least good progress on adaptation is "worrying" and needs to be urgently addressed. {Chapter 1}

A.4 **Adaptation and mitigation are inherently linked.** Ambitious global mitigation is critical to the scale and feasibility of adaptation. The more warming experienced, the greater the challenge and costs of adaptation. Even if global mitigation efforts are successful at realising the goals of the Paris Agreement, adaptation is required. At the same time, adaptation actions should not lead to sustained increases in greenhouse gas emissions. Mitigation actions also have trade-offs and benefits for adaptation that need to be understood. For example, afforestation can have benefits for mitigation and flood risk reduction but, if not properly planned, can also increase drought severity and have negative consequences for communities. {Chapter 1}

[1] As detailed in *Project Ireland 2040 – National Planning Framework* (DHPLG, 2018).

A.5 **We are not starting from an ideal position.** Ireland has seen significant and ongoing deterioration in environmental quality, including declines in water quality, biodiversity and ecosystem quality. Together with a growing population and a lack of investment in critical infrastructure, many natural and human systems on which our wellbeing depend have become less resilient. Social and economic challenges, including in energy, health, housing and an ageing population, all increase vulnerability to climate change. {Chapter 1}

A.6 **We are exposed to climate change risks beyond our shores.** A changing climate presents substantial challenges for all sectors. As a small, open economy heavily dependent on imports and exports, Ireland is highly exposed to transboundary climate risks (i.e. the impacts of and responses to climate change experienced elsewhere in the world). Understanding transmission pathways of transboundary risks, including through trade, finance, people and psychological, geopolitical, biophysical and infrastructure pathways, is an important knowledge gap. Assigning governmental responsibilities for managing transboundary risks and facilitating input from the private sector will be crucial to building resilience to transboundary climate risks. {Chapters 1, 10}

A.7 **There are reasons for optimism and foundations are being built.** Despite the challenges and gaps that exist, there are reasons for optimism; foundations for adaptation are being laid, based on robust information, and actions implemented. Investment in research is addressing knowledge gaps. Adaptation is now mandated in national legislation[2] (section 1.2), integrated with EU policy, and governance structures and oversight mechanisms have been established. Many sectors and local authorities have developed their first adaptation plans. Reflection upon and learning from these will underpin advances in adaptation. Investment in climate action regional offices is supporting development of capacity, from local to national level. The importance of effective climate services, community engagement and widening of adaptation actions to include nature-based approaches, and non-structural measures, is being increasingly recognised. Examples of good and bad adaptation outcomes are emerging and provide the foundation for learning and doing better. {All Chapters}

A.8 **But there are challenges we need to confront and improvements to make.** {All Chapters}

A8.1 Adaptation is not just about technical solutions. Without clear goals that reflect the principles of climate justice, evaluation of adaptation actions and outcomes is difficult.

A8.2 While many sectors have developed adaptation plans, others are missing, including critical areas such as the built environment, tourism and sport, and financial services; cross-cutting issues such as coastal environments also need addressing.

A8.3 Adaptation to date has been largely undertaken by national and local government. Widening inclusion of private sector actors and further encouraging and facilitating community involvement can benefit adaptation.

A8.4 A sectoral focus on adaptation, without opportunities for integrative assessment, increases the prospect of underestimating cascading risks – how risks can transfer or flow from one sector to another. For example how flooding of critical infrastructure such as a water treatment plant can impact water services for businesses and have health impacts for individuals and households.

A8.5 Socioeconomic vulnerability, community participation in decision making and the concept of just adaptation or just resilience need to be better embedded in adaptation policy and actions.

A8.6 Developing a climate-resilient Ireland will require sufficient public and private investment and financial support in ways that adequately recognise the value of ecosystem services and the importance of societal wellbeing.

While much is happening, increased ambition, learning and improvement are essential for better adaptation. Section B turns attention to climate change risks and adaptation in key sectors.

[2] The Climate Action and Low Carbon Development Act 2015 and the Climate Action and Low Carbon Development (Amendment) Act 2021 (henceforth Climate Act 2021) constitute Ireland's policy framework to deliver on the national climate objective to pursue and achieve, by no later than the end of the year 2050, the transition to a climate-resilient, biodiversity-rich, environmentally sustainable and climate-neutral economy.

B. Climate change risks and adaptation in key sectors

Climate change risks and adaptation affect all aspects of Irish life. This section presents key findings across eight core sectors ranging from ecosystems to business and finance.

Ecosystems: marine, terrestrial and freshwater

B.1	Biodiversity in Ireland is declining, and continued biodiversity loss will undermine capacity to adapt to climate change across all sectors. Without early and significant adaptation, climate change will result in severe impacts on many species and habitats.
B.2	Ireland's biodiversity has intrinsic value and conservatively contributes at least €2.6 billion annually via ecosystem services to the Irish economy. Despite this, current conservation efforts are not adequately funded. The maintenance of ecosystems in good condition, or their restoration to good condition, enables them to resist pressures and threats, recover from disturbance and reconfigure in response to new conditions. These are all elements of resilience.
B.3	Significant impacts on biodiversity are projected to increase with additional warming. Temperature dictates the timing of growing seasons and ecosystem productivity, while sea level rise impacts our coastal ecosystems. The frequency and intensity of rainfall affects vegetation and crops and indirectly affects ecosystem structure through changes in river flows and lake levels. Projected 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. Changes in ocean temperature are likely to change the distribution of marine species, from phytoplankton to marine mammals.
B.4	Up to 20% of Ireland's total native flora is estimated to be vulnerable to climate change in the period up to 2050, with more than half of species on the Irish threatened plants list at risk of being adversely affected by climate change (DCHG, 2019a). Observed impacts of climate change on Irish species and habitats include changes in species abundance and distribution, phenology (such as the timing of bird migration and plant flowering), community composition, habitat structure and ecosystem processes. Increases in spring temperatures in recent decades have been demonstrated to impact the timing of key life cycle events in a range of plant, bird and insect species in Ireland.
B.5	There is not yet a clear picture of how offshore marine ecosystems are, and will be, affected by changes in climate. Globally, ocean warming, acidification and oxygen loss are well understood, but regional and local changes in temperature, acidification, salinity, and nutrient and oxygen levels display significant natural variation. The geographical ranges of some species in Irish waters are predicted to shift northwards to cooler waters. Fish stocks of commercial interest to Ireland may be adversely impacted by climate change. This could have implications for quota sharing and fisheries management. Key adaptation actions for marine ecosystems include protection from overfishing, and the development of refuges for species recovery. Ireland's current network of protected areas in the marine needs to be more coherent, representative and connected[3].
B.6	It is vital that all sectors recognise their role in reducing pressures on biodiversity and contributing to adaptation measures. Actions to protect and restore biodiversity are valuable adaptation strategies for other sectors that either rely on ecosystems or work with nature through the deployment of nature-based approaches. Examples of synergistic nature-based actions include restoration of peatlands and native woodlands, rewetting grasslands on peat soils, salt-marsh and sea-grass meadow restoration, urban greening, landscape regeneration, climate-integrated land use planning and regenerative agriculture. Central to all these are funding, education and capacity building, together with stronger community participation so that actions can be mainstreamed and benefits distributed fairly.

[3] A bill for the designation and effective management of marine protected areas is currently being drafted, taking into account the findings of the Marine Protected Area Advisory Group (2020) report.

Agriculture, forestry and land use

B.7	Irish agriculture is changing in response to climate change mitigation and biodiversity objectives. Among the farming community, an ageing profile, the pattern of smallholdings and changing access to services and payments are factors to consider as part of a just transition for agriculture. While climate change is likely to impact all forms of agriculture, opportunities for adaptation are emerging around the integration of local knowledge, stewardship of ecosystem services, agroforestry, horticulture, organic farming and urban food systems.
B.8	Climate change is likely to result in increases in productivity for some crops but decreases for others. Increases in humidity will increase the vulnerability of potato crops to blight. Other pests and pathogens (current and novel) are likely to have an increased impact due to warming winters resulting in a lack of die-off. Pests and pathogens are also likely to gain an increased geographical range, gaining a foothold where current climate conditions are not favourable. At present, irrigation is applied to a relatively small proportion of land, but that is expected to increase in future. Changes in precipitation may result in increased nutrient washout from land. Warming is expected to lead to an increase in growing season length; however, any productivity gains may be offset by increases in extreme rainfall events or in drought frequency, magnitude and duration. Risk-sharing instruments can help buffer the negative effects of extreme events on crop yields.
B.9	Soil management will be impacted by climate change, with projected increases in both wet and dry conditions. Wetter conditions will increase compaction and degradation from vehicles and livestock. In response to droughts, peatland and wetland restoration, together with better grassland and cropland management, could increase soil organic carbon content, which has benefits for adaptation and mitigation through an increased capacity for water storage and retention of nutrients in soils, with additional benefits for water quality. Agricultural practices and their timing will change in response to climate change.
B.10	Increasing rainfall can lead to increases in the prevalence of liver fluke and other diseases in cattle and sheep, as well as increasing the risk from exotic pests and diseases. More frequent and prolonged periods of higher temperatures will increase the potential for animals to experience heat stress, affecting fertility, milk production and growth rates. Heat risks can be reduced through silvopasture, i.e. blending pasture and woodland, to provide shelter for animals.
B.11	For forestry, increased yields are projected for some species such as Scots pine, beech, lodgepole pine and birch. Conversely, decreased yields are projected for others including Sitka spruce and other conifers, oak and most other deciduous trees. Agroforestry has the potential to provide multiple benefits, including shelter for livestock, water and carbon retention, and biodiversity, but adoption rates are low. Additional incentives are required to address barriers and increase the uptake of agroforestry.
B.12	Existing studies on climate change impacts on agriculture, forestry and land use are fragmented. A systematic programme of research to assess climate impacts on agriculture, forestry and land use is needed to support adaptation. The emergence of a new generation of tools and decision support systems has value for developing a more resilient sector.

Coastal environments

B.13 Ireland is highly exposed to climate change impacts on coastal environments, with all major cities and many regional population centres located by the sea. Global sea level is projected to rise under all future scenarios and will continue to do so for hundreds to thousands of years. Locally, sea level rise is more complex (see Volume 1). Currently there are no standardised, locally tailored, sea level rise projections available for Ireland. For adaptation, it is important to consider projections of sea level rise up to and beyond 2100 to avoid increasing exposure. Significant increases in sea level out to 2300 are already inevitable, even in the most optimistic mitigation scenarios.

B.14 The impact of climate change on storm surges and wave heights is unclear, related primarily to uncertainty in changes in storminess, emphasising the importance of robust decision making in coastal areas. Approximately 20% of the Irish coastline is exposed to erosion, with low lying, relatively densely populated coastal zones in the east particularly exposed. In Irish coastal environments, sensitive ecosystems include cliffs, beaches, lagoons, dunes and machair, salt marshes, mudflats and other wetlands.

B.15 Sea level rise and changes in storm surge present large flood risks for urban areas. Superimposed on the current 100-year flood, mid-range estimates of sea level rise are estimated to quadruple the number of properties affected by flooding in coastal locations. For Limerick city alone, the cost of extreme floods under a high-end scenario of sea level rise may increase up to 12.5-fold, amounting to over €1 billion for a single event. Such estimates do not account for future urban expansion and emphasise the importance of adaptation to coastal flood risk.

B.16 Approximately 98% of trade by volume comes through our ports, and they are key gateways for tourism. Climate hazards for Irish ports include sea level rise and changes in wind, wave and tidal extremes and storminess, with risks differing by port location. Currently there is little guidance on how adaptation in ports should be managed. The National Development Plan (2021–2030) sets out over €340 million of infrastructural investment at Irish ports. It is critical that investment is stress tested to the risks posed by climate change.

B.17 Bathing water quality is essential for human health and is an important recreational and tourism asset for local and regional economies. Climate change will affect bathing water quality through increased heavy rainfall on land and associated storm water overflow, warmer ocean temperatures and associated changes in the frequency and extent of harmful algal blooms.

B.18 Our coasts are home to a rich cultural and natural heritage. Cultural heritage includes historical buildings, archaeological sites and monuments. Climate change may increase the rates of physical and chemical erosion affecting the structure and composition of heritage assets, while changes in the frequency and magnitude of events such as droughts, floods and extreme rainfall will impact our cultural heritage. Sand dunes are an important part of our natural coastal heritage, are sensitive ecosystems and play an important role in protecting low lying coastal areas from flooding and erosion. In addition to existing pressures from erosion and human impacts from grazing, recreation, trampling and sand extraction, climate change is likely to increase pressure on dune systems through sea level rise and changes in storminess. This is particularly so for westerly oriented dunes along the Atlantic coast.

B.19 There is currently no clear governance structure for coastal adaptation. There are also challenges for adaptation in terms of private and public land ownership in coastal areas and the designation of many vulnerable locations as protected areas. The Inter-Departmental Group on Managing Coastal Change is considering approaches for the development of an integrated, whole-of-government coastal change management strategy.

B.20	Coastal adaptation responses can be categorised as (1) protect, (2) accommodate and (3) retreat. Protection can take the form of hard engineering (e.g. sea walls, dikes, groynes and revetments) and/or nature-based approaches (e.g. beach nourishment, dune creation and wetland restoration) that seek to keep sea water out and/or reduce erosion rates. Accommodation seeks to increase the ability of humans to live with risks and includes insurance schemes, early warning systems, the design and/or retrofitting of infrastructure and the use of regulatory approaches such as building codes and land use/planning regulations. Where protect and accommodate are not feasible or sufficient responses and coastal loss is inevitable, managed retreat may be necessary. Appropriate actions depend on the nature of impacts experienced, the local physical and social context, exposure and vulnerability and economic constraints.
B.21	The procedural and distributive justice aspects of managed retreat should be carefully considered, including supports for those having to relocate. Minimising the negative impacts of relocation for individuals and communities will require the co-creation of relocation plans and community-centred approaches. Managed retreat raises complex governance issues for adaptation in coastal zones.

Water

B.22	In Ireland, climate change impacts on the hydrological cycle are happening in the context of increasing water demands, decreases in water quality and a lack of resilience in our water supply infrastructure. Impacts are likely across multiple sectors, including critical infrastructure, settlements, biodiversity, land use and health, raising the importance of cross-sectoral collaboration for adaptation.
B.23	Identifying a clear signal of climate change in observed precipitation and river flows is difficult because of natural variability. Observational records show that the magnitude and timing of floods are changing; however, there is uncertainty in attributing the cause of these changes, whether due to climate change, natural climate variability, data quality or internal catchment modifications (e.g. land use change, arterial drainage).
B.24	Rainfall and river flow projections for mid-century and end of century are uncertain, but suggest increases in flood magnitude and frequency, increases in spring and summer drought magnitude and frequency (future changes in drought duration are uncertain), and increases in river flows in winter and decreases in summer. Ambitious global mitigation measures resulting in less warming are associated with less severe low flows.
B.25	Future changes in temperature, relative humidity and wind speed will lead to changes in evapotranspiration. Increases in evapotranspiration would have significant implications for drought impacts, water resources and agriculture, especially during the spring and summer months. The impact of vegetation responses on evapotranspiration remains open to scientific debate.
B.26	The impacts of climate change on groundwater are strongly influenced by local hydrogeological settings. Some aquifers are projected to experience increases in drought impacts, while the incidence of flooding may increase in others[4].
B.27	Water quality is influenced by air and water temperature, precipitation amounts and intensity, and the occurrence of extreme events. Changes in rainfall amounts, timings and intensities have implications for nutrient washout, erosion, suspended sediment and sediment yields, with sensitivity varying by catchment. Climate change impacts on water quality in urban areas are also dependent on the design and construction standards of water infrastructure. Changes in land use/management are likely to interact with and amplify the impacts of climate change on water quality. Land use management is a critical adaptation pathway for alleviating pollution and improving water quality in catchments.
B.28	Adaptation in the water sector should account for the range of plausible changes in climate variables. Frameworks for decision making under uncertainty, including the development of adaptation pathways, together with integrated catchment management as part of river basin management plans, offer valuable approaches for reducing existing vulnerability and addressing adaptation needs.
B.29	Water supplies face growing pressures resulting in increased water demand. Climate change is likely to further increase water demand from households, businesses and agriculture. A large portfolio of supply and demand side adaptation options are available for water resources management. However, effective adaptation options and appropriate adaptation pathways remain to be devised and assessed. Some supply side options, such as the development of new sources, may involve significant trade-offs and encounter adaptation limits via social or environmental acceptability, technical feasibility or excessive cost.
B.30	The implementation of adaptation actions for flood risk reduction can be categorised as defending against risk, living with risk, and relocation or withdrawing from risk. For defending against risk, actions include retrofitting existing infrastructure, building new infrastructure and integrating safety margins to accommodate climate change into designs. Living with risk includes land use planning and flood zoning, insurance, deployment of nature-based approaches and recognising the important role of flood plains in attenuating floods. Relocation in response to flooding has been rare in Ireland to date but has happened and may become more commonplace in future.

[4] Groundwater aquifers with low storage capacity are thought to be more vulnerable to extremes, particularly rainfall amount, intensity and timing. Aquifers with high recharge coefficients and sufficient recharge acceptance capacity will be impacted by the amplification of rainfall seasonality. Groundwater flooding is likely to increase in scale, frequency and duration.

Built environment, heritage and rural communities

B.31	Flooding from rainfall, rivers and the sea is a major hazard for the built environment. These are expected to increase in future. Increases in rainfall intensity are expected with implications for existing buildings and building design. Sea level rise, in combination with changes in storms and tidal surges, will challenge the management and planning of coastal settlements. Cities and larger urban areas tend to have a higher temperature than the surrounding rural areas due to the urban heat island effect, such that increases in average and extreme temperature will be amplified in dense urban settings.
B.32	Buildings, both domestic and public, such as workplaces, hospitals, schools and care homes, need to be resilient to future climate. Building regulations need to be updated to reflect future changes in climate. Newly available climate maps for key design parameters (wind-driven rain (section 6.2.3), maximum and minimum temperature (Volume 1, Chapter 3), rainfall intensities (Volume 1, Chapter 4) and overheating risks (section 6.2.2) are important for guiding design into the future. A significant amount of Ireland's urban and rural heritage is already at risk because of vacancy and dereliction and will be more vulnerable to changes in climate.
B.33	The role of planning and architectural design will be critical to adaptation in urban and rural settlements. Planning for an increasing and urbanising population demands coherence across spatial scales. It is crucial that exposure to flooding is not increased and that flood risk management guidelines are followed. There is abundant evidence for the value of nature-based approaches to reduce climate change impacts in urban areas. These include urban trees which can, with careful choice of species and planting, provide cooling, water retention, shading and some absorption of pollutants. The thoughtful siting of parks and green and blue spaces improves thermal comfort and general quality of life for inhabitants. Sustainable urban drainage systems offer potential for managing pluvial flooding. Planning based on local climate zones, which have already been developed for Dublin, can further aid spatial planning at the city scale by tailoring policies and guidelines to the typologies of local climate.
B.34	Ireland's long-sustained trend of dispersed rural settlement, highly dependent on transport-intensive and dispersed services, is a form of 'lock-in' that will present challenges for ensuring climate resilience. Ensuring that our goals for adaptation, rural development, housing, infrastructure, heritage protection and biodiversity are complementary rather than contradictory will require a greater degree of coordination and calibration of expectations than currently exists.

Critical infrastructure

B.36 Ireland depends on the resilience of its critical infrastructure for delivering public services, economic growth and a sustainable environment. Approaches to risk screening have been developed to examine vulnerabilities across four critical infrastructure sectors, namely transport, energy, water and communications infrastructure. Risk screening is useful for high-level assessment and identifying assets and locations for further analysis. This will need to be complemented with standardised quantitative approaches for stress testing critical infrastructure and identifying potential failure points, adaptation options and cascading risks.

B.37 Without effective adaptation, damage costs at the European scale to critical infrastructure from extreme events attributed to climate change are likely to increase from 2018 levels of €3.4 billion per year to triple that amount during the 2030s, six times by 2050 and 10 times by 2100. The main hazards causing these damages are expected to be heatwaves, droughts and coastal flooding, but also inland (fluvial, pluvial and groundwater) flooding, windstorms and wildfires.

B.38 For transport, sea level rise and flooding are key climate change risks. For energy, 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. Cascading of failures from the energy sector into other sectors is a key multi-sectoral risk. For water infrastructure, key climate change risks include flooding, wastewater treatment overflow and reductions in water quality related to extreme rainfall events, together with possible decreases in summer rainfall and droughts. For the ICT (information, communications and technology) sector, climate change risks related to extreme wind speeds are a key concern.

B.39 Some current infrastructural risks may reduce as the climate warms. For example, pipe bursts due to water freezing is a major weather-related operational issue for the water sector, but such bursts may become less frequent in a warmer future climate, as the number of frost and ice days is projected to decrease. However, gains could be offset by drought impacts through cracking and drying of the soil.

Health and wellbeing

B.40 Projected changes in extreme events are likely to have direct and indirect impacts for health and wellbeing. The number of people exposed and vulnerable to heatwaves will increase. To date, the number of flood-related deaths and rates of injury are not well recorded, but there is extensive evidence that floods have significant impacts on health and wellbeing, including mental health, across populations. Loss of and changes in valued places as a result of climate impacts have been related to the experience of solastalgia, a psychological grief experienced because of environmental loss. An ageing Irish population will pose additional challenges for public health in a changing climate. Without adaptation, projected changes in floods and droughts and associated impacts on water quality are likely to impact public health.

B.41 As a country with a high rate of excess cold-related deaths, warmer winters may have a positive effect in reducing this risk in Ireland. But climate change may also aggravate existing public health pressures on respiratory diseases such as asthma through increased circulation of aeroallergens in a longer growing season and changes in air quality. Shifting geographical ranges of vectors and associated pathogens, but also human behaviour, may have consequences for exposure to vectors and vector-borne diseases.

B.42 Responses to extreme events through emergency management and recovery affect direct and indirect health outcomes. The responses of governments and insurance companies have a significant impact on the wellbeing of populations following flood events, with information and financial support from public agencies contributing meaningfully to the wellbeing of affected populations.

B.43	Climate change is also likely to increase the exposure of critical health infrastructure. Overheating in hospitals and residential care settings has been identified as a public health concern in the UK during heatwaves, with hospitals reaching dangerous temperatures and a lack of capacity to cool older, less efficient buildings. There is evidence that similar conditions were experienced in Ireland during the heatwave of 2018. Flooding poses a significant risk to health care infrastructures both in direct damage and in preventing provision of care. Development of a register of at-risk infrastructure and services is needed to inform adaptation.
B.44	Systemic approaches to adaptation planning for public health are needed to develop effective strategies to reduce climate risks. The health and wellbeing outcomes of adaptation actions across all sectors should be monitored and used to evaluate the success of adaptation interventions. It cannot be assumed that interventions will do no harm or be equally successful across populations.

Business, industry and tourism

B.45	Climate change is likely to bring risks and costs to the Irish economy amounting to billions of euros per year by 2050. In 2020, Ireland experienced the third highest climate-related economic losses per inhabitant in Europe (Eurostat, 2022). Climate change adaptation in business and industry in Ireland is limited to date, and significant efforts are required to coordinate effective adaptation efforts with actors in the private sector.
B.46	As a highly globalised country, Ireland is vulnerable to shocks to supply chains, but these risks are yet to be sufficiently systematically assessed. Further research is needed to identify the vulnerabilities of business and industry to supply chain risks. In addition, important local direct and indirect risks for businesses, employees and customers emanate from flooding and storms, sea level rise, coastal erosion, heat extremes, water scarcity and drought.
B.47	Currently, the scale of climate change risks to the banking and financial sector in Ireland has yet to be quantified. Climate risks are not well reflected in the pricing of insurance, investment and lending. As these risks become more fully integrated into financial processes, they will affect access to capital and insurance.
B.48	Tourism, a key sector in the Irish economy, is highly exposed and vulnerable to climate risks and extreme events. While warmer summers are often held up as an opportunity for Irish tourism through increasing visitor numbers, without careful management this could create damaging and unsustainable pressures on sensitive heritage sites and environments. Careful and integrated adaptation planning that values heritage protection and ecosystem services is needed.

C. Realising the benefits of a climate-resilient Ireland

Following the assessment of climate change impacts and adaptation across sectors, this section reflects upon and presents the key steps necessary to build momentum on adaptation and to develop a pathway for realising a climate-resilient Ireland.

C.1 **Define objectives.** The success of adaptation is contingent on negotiating and defining goals around what success looks like and that account for competing values and worldviews. Without a clear definition of goals, it is difficult to monitor both the progress and the outcomes of adaptation. {Chapters 1, 10}

C.2 **Ensure just adaptation/resilience.** The decision-making process of selecting and implementing actions and their associated outcomes should reflect the principles of 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. {Chapter 1}

C.3 **Recognise adaptation as an iterative process.** In the context of climate change, risks emerge from the dynamic interactions between climate-related hazards (e.g. heatwaves, floods, droughts), exposure and vulnerability. Risk is dynamic and in constant evolution as the frequency and intensity of hazards change and as exposure and vulnerability change through many drivers. {Chapter 1}. Therefore, adaptation is a process that responds to the dynamics and evolution of risk. This is the idea of adaptation as iterative risk management, whereby emphasis is placed on adaptation pathways as ongoing cycles of assessment, prioritisation, action, monitoring and evaluation, reassessment and response. {Chapters 1, 10}

C.4 **Place greater focus on monitoring and evaluation.** In Ireland, and internationally, monitoring and evaluation of adaptation are limited as the focus is primarily on progress in implementation. Greater focus needs to be placed on process and outcomes, including elements of justice and wellbeing. An all-purpose and globally acceptable set of indicators that comprehensively measures adaptation does not exist. Learning requires knowledge of how and why adaptation has or has not happened, which cannot be accomplished by quantitative metrics alone. Opportunities for institutional feedback, peer learning and knowledge sharing, with adaptation built on a culture of learning, collaboration and sharing insights, need to be further developed. {Chapter 10}

Figure SPM.2 Climate-resilient development pathways consolidate climate action and adaptation towards long-term sustainable development – the adapting towards what question. Source: Werners et al. (2021). Reproduction licensed under the Creative Commons Attribution CC BY 4.0 licence (https://creativecommons.org/licenses/by/4.0/).

C.5	**Understand social dimensions.** Successful adaptation depends on reducing vulnerability. This necessitates a better understanding of the spatial, temporal and socioeconomic nature of vulnerability. Consideration should be given to how assessments of vulnerability can inform the development of adaptation plans and the evaluation of outcomes. {Chapters 1, 10}
C.6	**Work with people and nature.** Widening adaptation actions to include nature-based approaches opens opportunities for multiple co-benefits for people and nature. Implementation of nature-based approaches can have positive outcomes for environmental quality, biodiversity, health and wellbeing. A greater focus on non-structural measures and opportunities for better governance will help open pathways to transformation. {Chapters 1, 10}
C.7	**Increase participation and cooperation.** Successful adaptation requires collaborative planning efforts and co-production. Methods that facilitate adaptation across sectors need to be further developed and integrated into policy processes. The role of the private sector and individuals/communities in adaptation also needs to be further developed. Communities will need support for adaptation and need help to generate leadership in collaboration with local government. {Chapter 10}
C.8	**Minimise response risks.** Adaptation actions themselves can entail risks, termed 'response risks', which may result in maladaptation. These include the risk of adaptation actions being ineffective and/or unjust or resulting in unintended adverse effects. Feedback opportunities for those affected by adaptation need to be created to evaluate and learn from experience in order to avoid maladaptation. {Chapters 1, 10}
C.9	**Recognise cross-sectoral and cascading risks.** Ireland takes a sectoral approach to adaptation. Increased coordination across sectors is required to ensure that joined-up opportunities are not lost and that efficiencies of scale are achieved while minimising cross-sectoral risks and cascading impacts. Ireland's national climate change risk assessment, the new National Adaptation Framework and revised national sectoral adaptation guidelines can be important additions in this regard. {Chapters 1, 10}
C.10	**Tailor climate services to needs.** Effective climate services should be based on scientifically credible information and expertise, have appropriate engagement from and between users and providers, and have effective access mechanisms to meet user needs. Important for the development of effective climate services in Ireland is the opportunity to provide ongoing dialogue and learning about how climate research and model outputs can be best tailored to decision needs, contexts and decision-making frameworks. The National Framework for Climate Services is a beneficial mechanism to support adaptation planning and action. {Chapters 1, 10}
C.11	**Integrate 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. Numerous frameworks exist to support decision making under uncertainty but are under-deployed in Ireland. This is even more important where adaptation decisions concern critical infrastructure and/or where exposure and vulnerability are high. Frameworks for decision making under uncertainty and for evaluating adaptation actions are needed to support adaptation in Ireland. {Chapters 1, 10}
C.12	**Avoid lock-in and maintain flexibility.** Adaptation action taken today may lock us into resource allocations and decision pathways that limit future choices to adapt, increasing the risk of creating lock-in effects that limit future resilience. Climate resilience requires integrating flexibility and diversity into climate adaptation. {Chapter 1}
C.13	**Invest in adaptation.** Adaptation needs to be seen not as a cost but as a necessary investment. Adaptation is about placing Ireland in a position to prosper in the decades ahead. Resourcing of adaptation needs to move beyond the limits of traditional cost–benefit analysis. Aside from the material impacts, climate change threatens cultural heritage, sense of place, wellbeing and nature – all non-economic losses that are rarely captured in traditional economic assessments. {Chapter 10}

D. Knowledge gaps

In performing this assessment, a range of knowledge gaps have been identified. Specific gaps are detailed at the end of each chapter in the underlying report. Here, broad priorities are identified to improve the basis for future assessment activities and to enhance the knowledge base for adaptation.

D.1	**Address knowledge gaps on impacts for sectors.** A key challenge in compiling this assessment, and for adaptation more generally, is that there is a very uneven distribution of climate change impact assessments across different sectors. To date, there has been no programmatic funding of research to assess impacts across different sectors using a consistent set of climate model projections. This results in considerable gaps in our knowledge in key sectors. For coastal and flood risks, it is important that locally tailored sea level rise projections that extend beyond 2100 are developed for informing adaptation. Research is also needed on how to strategically integrate such long-term projections into spatial planning and the siting of critical infrastructure, for example.
D.2	**Increase capacity.** Adapting to climate change presents new challenges, and success will depend on capacity in research, training, upskilling and retention of existing and new professionals, together with engagement with and learning from communities. Irish research takes a leading role internationally. However, further investment is needed to grow the enduring human capacity, skills and infrastructure necessary to consolidate and sustain this contribution and address core gaps in knowledge. This will require investing in and leveraging knowledge from all disciplines and the local knowledge held by communities themselves. Developing capacity and leveraging the insight of the private sector into key vulnerabilities and exposures will be necessary to realising a climate-resilient Ireland.
D.3	**Understand adaptation processes and outcomes.** International research shows that barriers to adaptation emerge from neglect of place-based values, a lack of engagement with affected communities, shortcomings in, and failures of, governance and a lack of financial resources. Climate modelling and impact assessment needs to be supplemented with research into adaptation processes and outcomes. This has salience in informing adaptation that is just and equitable.
D.4	**Relocation and managed realignment.** Understanding the negative impacts of relocation and how to avoid or minimise them and the potential opportunities and trade-offs of managed realignment need be further understood. Consideration needs to be given to understanding the justice dimensions of relocation and the policy tools necessary to navigate such issues in the fairest way possible. Approaches to adaptation that consider managed realignment can reduce flood and erosion risk, reduce maintenance costs, mitigate coastal squeeze, and create new habitats and biodiversity benefits, while minimising relocation, depending on site-specific constraints. The potential opportunities and trade-offs of managed realignment need be further understood.
D.5	**Sustaining and enhancing monitoring networks.** Sustained and enhanced monitoring is essential for tracking emerging signals of change, the changing nature of risk and the attribution of impacts, and for tracking the success of adaptation outcomes. It is critical that monitoring across sectors is enhanced and supported, such as monitoring of invasive species, wildfires and coastal change. Collation of the impacts from extreme events is limited in Ireland presently. For evaluating the success of adaptation actions, further efforts at quantifying losses from extremes would be valuable.
D.6	**Ireland's islands.** A key gap in knowledge is how climate change is likely to affect Ireland's islands and their communities. Little research has been undertaken to examine climate change impacts and adaptation in these important locations. Ireland's islands face unique climate change pressures from land and ocean and often have unique challenges and cultural heritage, both tangible and intangible.

D.7	**Nature-based approaches.** Given their many potential co-benefits, the potential for nature-based approaches for climate action, including adaptation and mitigation, across all sectors needs to be more fully explored and assessed. This includes their potential effectiveness across local contexts, development of capacity for design and implementation, and opportunities to scale up successful interventions.
D.8	**Transboundary climate risks.** In an increasingly interconnected world, transboundary climate risks can flow through shared ecosystems and resources, trade links, financial interdependencies and people (through migration or forced displacement). Ireland's open economy and trade and finance links make it vulnerable to climate change impacts and adaptation responses in other parts of the world. Research is required to better understand transboundary risks.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An Roinn Iompair
Department of Transport


sfi
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ICCA
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